QUALITY EVALUATION OF VEGETABLES CULTIVATED THROUGH AQUAPONICS

by

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(2018-16-004)

THESIS

**Submitted in partial fulfilment of the
requirements for the degree of**

MASTER OF SCIENCE IN COMMUNITY SCIENCE

(Food Science and Nutrition)

Faculty of Agriculture

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF COMMUNITY SCIENCE

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695 522

KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"Quality evaluation of vegetablescultivated through aquaponics"** is a bonafide record of research work done by me during the course of research and thethesishasnotpreviouslyformedthebasisfortheawardofanydegree,diploma, fellowship or other similar title, of any other University orSociety.

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ACKNOWLEDGEMENT

I am grateful to ***"Almighty God"*** *v* iii *ided me the strength to fulfill the task in a satisfactory manner*

*I wish to express my sincere gratitude and indebtedness to Dr.****Suma Divakar.****, Professor and Major Advisor, for her expert advice, valuble suggestions, inspiring guidance, enthusiastic approach, constructive criticisms, thought provoking discussions, unreserved help and kind concern during the conduct of this research work and preparation of thesis. I value her knowledge and wisdom which nurtured this research in the right direction without which fulfilment of this endeavour would not have been possible. She has been a support to me during each step of this venture and my obligation to her lasts forever. I really consider it as my greatest fortune in having her guidance for my research work*

I am indebted to ***Dr. Shalini Pillai. P,*** *Professor, Department of Agronomy, College of Agriculture, Vellayani, and member of Advisory Committee, for her valuable advice, extreme patience and whole hearted approach for the successful completion of the thesis.*

I am extremely thankful to ***Dr. Brigit Joseph,*** *Professor**,** Department of Statistics, College of Agriculture, Vellayani,and member of Advisory Committeea member of Advisory Committee for the support, constant criticism and valuable suggestions rendered throughout the period of research work and course of study.*

With great pleasure, I express my gratitude to ***Dr. Krishnaja. U****, Assistant Professor, Dept of Community Science**,** College of Agriculture, Vellayaniand a member of Advisory Committee for her encouragement, wholehearted help and support throughout the period of my research work.*

My heartfelt thanks to ***Biju Sir****, Fram Proprietor, Rose Gardens, Ulloor, Thiruvananthapuram for his keen interest, immense help, constructive suggestions and cooperation rendered throughout the course of research endeavor.*

I am truly and deeply grateful to other teachers of the department, Dr. Beela, GK. teacher And Anitha Chandran teacher for their utmost help and encouragement rendered during the study and also thankful to non-teaching staff of the department.

I would like to express my heartfelt gratitude to my beloved seniors, ***Anila chechi, Bency chechi, Soumya chechi, Kavitha chechi, Tharani chechi, Priya chechi, Gopika chechi****, for their valuble suggestions, constant encouragement, sincere help and support in times of need. No words can truly portray my indebtedness to my friends* ***Abhina,Geethanjali, Pravitha, Rajyalakshmi, Swathi, Pravalika, and Alekhya*** *for their immense love, help and support, without which I would not have been able to complete this venture.*

I am thankful to Kerala Agricultural University for the technical and financial assistance for conducting this work.
On a personal note I express my love and gratitude from my deep heart to my dearest nanna, amma, chechi and anna. The love, support, patience and constant encouragement given by them was a real source of inspiration without which I could not complete this research endeavor.

Bakam Himabindhu

Dedicated to My Family

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LIST OF ABBREVIATIONS

%	Per cent
^{0}C	Degree Celsius
et al.	And other co workers
PLW	Physiological loss of water
µg	Microgram
G	Gram
g/100g	Gram per 100g
e.g.	example
ROS	Reactive oxygen species
SCSs	soilless culture systems
viz.	Namely
Fig.	Figure
P^H	Negative logarithm of hydrocarbon ions
DW	dry weight
Yr	Year
$	dollar

Introduction

1.INTRODUCTION

Today's Indian farmer is exposed to many challenges owing to low agricultural growth, sustainability concerns and land degradation. Large areas of farmland have become fragmented and have also become infertile due to the overuse of fertilizers and pesticides. Extensive usage of fertilizers in the conventional methodofgrowingcropshasdegradedthequalityofthesoil,thathasincreasedthe nitrogenlevelinthelocalwater.Theincreaseofnitrogenlevelinwaterhasbecome harmful to the ecosystem. Along with this, the lack of rainfall has decreased the groundwater level, which has also affected the traditional farming system (Savci, 2012).

Having side lined agriculture, Kerala has become a state with high dependency on other states for day-to-day food necessities, as it is a big importer of crucial food items such as cereals, pulses, vegetables, milk and meat products.

In this context, advanced farming methods are needed to overcome these challenges. The technological and scientific advancements in the area ofagriculture have started a new regime of cultivation for the landless households, especially in urban areas. Integrating hydroponics, that is the method of raising plants without soil (Savvas, 2003) and aquaculture have assumed additional importance in the current agricultural scenario (Subasinghe *et al*., 2009).

"Aquaponics" farming is another option, which can prove to be feasible, if the farmers are able to manage the system through proper maintenance combined with technical support. There is rising attention given to Aquaponics, as it is a system of aquaculture that involves hydroponics to raise fish and edible plants and can be accomplished in non-traditional localities; for example,inside warehouses and also onmarginallands.Itcanalsomakeavailablelocallygrownproductswithoutusing synthetic pesticides, chemical fertilizers or antibiotics. The benefits of aquaponics system includes the proficient use of water, reduced waste, organic-like management,co-locationformaking“two”agriculturalproducts(i.e.,ediblefish and plants) and there is increased density of crop production, and it also supports the interest of “locally grown food products” (Somerville *et al.,* 2014).

Aquaponics is a combined method of growing fish besides crops in are- circulating system .In other words, it is an integrated system of hydroponics and recirculating aquaculture in one production system.The water from fish tank includes fish excreta, that become nutritious for the plants. Plants in turn purify the water emerging into the fish tank to keep the fish healthy (Diver and Rinehart,2006).

The key 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).

In areas where water is limited and land holdings are low, aquaponics farming is appropriate. Crops cultivated on aquaponics are capable to grow in denser climate and also have a smaller amount of damage. In Kerala, the land holdings that are available for agriculture are limited to less than 0.2 hectares (OECD, 2009). Therefore, the smallscale agriculturists target to maximizeproductionwithintheleastresourcesavailable.Increasingconsciousness of consumers on too much use of fertilizers and pesticides are forcing the farmers toamovementthatfavorsorganicfarming.Theattentionoftheyounggenerations to produce vegetables and also other local cultivations on a small scale in the existinglandareahasfurthermoreincreasedthescopeoforganicfarming(Ramesh *et al.*,2005).

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).

Aquaponicsallowsintensiveproductioninsmallareas,producingfresh 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).

It is an ideal way of raising food that helps to conserve sustainability, as it needs only 10 percent 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.

Aquaponics has got good acceptance in several districts of Kerala in recent times, as the system has several benefits, which includes the rise in productivity within a short time interval. State Fisheries Departments and MPEDA (Marine Products Export Development Authority) are encouraging Aquaponics through offering training programmes and also technical provision to the farmers (Biswas and Kumar, 2015).

Keralahouseholdshavestartedoffchoosingupaquacultureinsmallerta nks withvegetablesindistinctgrowbeds,inthevacantspacesthatcomprisesofterrace and balconies of apartments. The process of recycling wastewater and making that water accessible for more uses has improved its demand all over thistime.

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 makeuse of a great variety of vegetable crops in their aquaponics systems, in order to meet the increased consumer needs andpreferences.

India,beingconferredwithadiversityofnaturalsurroundingsandchang ing climatesandseasons,hasanumberofediblegreenleafyvegetables,mostofwhich 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).

Aquaponicsposesavariedandconstantpolyculturesystemthatletsfarm ers 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 lowcycle.

Since aquaponics has the potential to be a sustainable, approach for safe food production and studies on aquaponics operations and products are scarce,this study attempts to compare the quality of leafy vegetables grown in this system to the conventionally cultivated ones, to as to serve as a reference for prospective farmers and consumers.

Review of Literature

2. REVIEW OF LITERATURE

The literature reviewed for the present study entitled “Quality evaluation of vegetables cultivated through aquaponics” is organized under the following headings:

2.1 The Changing Phase of Urban and Peri Urban Agriculture

2.2 Soil less revolution in Agriculture

2.3 Aquaponics-The new farming approach

2.4 Under exploited Green leafy vegetables

2.5 Changing Food demands and Consumer preferences

2.1. The Changing Phase of Urban and Peri Urban Agriculture

Migration of individuals towards urban territories creates more pressure on food, shelter, water and fundamental necessities (Cohen, 2006). Uncontrolled urbanization can cause poverty, lack of healthy sustenance, social uncertainty, joblessness and decrease of environmental resources. In India the urban populace is imagined to develop by 404 million by 2050 and governments should face an enormous challenge of taking care of the population in a reasonable manner. Urban areas are significantly viewed as the reason for contaminating earth (cities contribute up to 70 percent of the worldwide CO_2emanations) resulting in climate change. Its evil impacts results in mental illnesses as well, due to overcrowding (World Urbanization Prospects, 2010).

This has necessitated the development of another form of environmentally and economically sound urban horticultural framework, specifically, Urban farming and Peri-urban agriculture (UPA), which includes waste and waste water management,needs to be made an indispensable part of the urban planning process (De Bon *et al.,* 2010).

"Urban agriculture" is used to characterize the developing of plants and the raising of animals for food and different uses inside and around urban areas and towns (Van Veenhuizen, 2006). Urban and peri-urban farming can be broadly characterized as the production, handling and supply of foodstuffs like cattle, fish, and ornamental flowers inside and around urban areas (Mougeot, 2000).

The Food and Agricultural Organization of the United Nations (FAO) has recognized Urban and Peri-urban agriculture as a cultivating system that can add to domestic food and dietary security and occupations, along with improving urban environment and sanitation, thus achieving poverty alleviation, food security and justifiable urban development. Food and Agriculture Organization, characterizes urban and peri-urban agriculture as an industry located inside (intra-urban) or on the periphery (peri-urban) of a town, a city or a metropolis, which develops and raises, processes and distributes a variety of farming agricultural products, utilizing to a great extent human, land and water assets, items and services found in and around that urban region.

In many developing nations, urban agriculture is picking up support from governments together with global organizations like the United Nations Centre for Human Settlements, the United Nations Conference on Environment and Development, the Food and Agricultural Organization and the Consultative Group on International Agricultural Research. Urban farming cuts over all income groups, however most of those attempting urban agriculture are the urban poor. Not every one of them are recent rural migrants; rather, many are nearby inhabitants with access to land, water and different assets. While practicing urban agriculture, individuals can seek different occupations simultaneously. This is likewise ideally appropriate for women who can consolidate urban agriculture events with their family work (Gupta and Gangopadhyay, 2013).

Decreasing urban poverty and protecting ecology was the underlying aim of urban and peri-urban agriculture (UPA) in the Millennium Development Goals (MGDs) (Vazhacharickal and Gangopadhyay, 2014).

The dumping grounds can be changed to produce vegetables (Gupta and Gangopadhyay, 2013). The commitment of UPA towards livelihood methodologies, waste reusing, decreasing urban poverty, increasing occupation, income generation and food security of the urban poor particularly in developing nations has frequently been focused on (Yasmeen, 2001; Cofie *et al.*, 2003; Obuobie *et al.*, 2006; Hill *et al.*, 2007; Graefe *et al.*, 2008; Sinha, 2009). There is a growing business sector for these items in urban communities especially for natural produce with the increasing purchasing power and nutritional consciousness amongst the inhabitants (Sahasranaman, 2016).

More than 800 million individuals over the world are related with urban cultivation (Birch, 2009). Urban and peri-urban agriculture (UPA) has been promoted as a way to bring food-centered production to urban regions (De Zeeuw *et al.*, 2011).

Urban heat islands (UHI) are created because of the absence of greenery besides the high compactness of buildings, which is the primary issue of numerous urban cities (De Zeeuw *et al.*, 2011). The heat island intensity can create an increase of up to10°C temperature difference, with regard to the rural areas and can economically increase energy use with manufacture of anthropogenic heat (Qiu *et al.*, 2013). Urban agriculture not only just adds to food independence and compelling survival approaches for future urban communities, in addition, it helps in decreasing urban heat island impact- which is projected as a significant issue soon, because of global warming and environmental changes (Specht *et al.*, 2014), lessening of urban energy impression (Oberndorfer *et al.*, 2007; De Zeeuw, 2011) and decreasing weight on agrarian land (Specht *et al.*, 2014).

Viswanath (2008) has expressed that terrace gardening is a healthy hobby, not just to keep one engaged for two or three hours in seven days, it also gives the joy of being amidst a developing garden. It gives a chance especially for housewives to slowly escape from the daily schedule of running the issues of household and being with flowers and fruits of their own making. Amaranthus, brinjal, tomato, green chilies, cowpea, lady's finger, bitter gourd, snake gourd, cucumber, pumpkin, capsicum, coriander, salad cucumber, ash gourd and clove beans are regular vegetables found in Kerala, developed on roof tops (Chandran, 2017).

Making the households self-sufficient with fresh vegetables is the main idea behind Terrace gardens. Any open spaces which is receiving sunlight, with access to organic wastes can be utilized for this. The added advantages are the need for minimal soil and water. Containers kept for discarding can be used for planting, besides decaying household wastes can be dumped into it (Vazhacharickal, 2014).This endeavour helps the family and community to become self sufficient.

Roof top vegetation often turns instrumental in strengthening family bonding. Further it generates a tremendous interest in teenagers which is vital to sustain a green and salubrious community for tomorrow. A vegetable garden serves as a perfect platform for family members to come collectively with specific team spirit for the sustainable needs of the community. Gardening is an outlet for creativity and also relaxes the frustrated minds (Green, 2004).

Greenery on roof tops, will bring down environmental heat, purify air, utilize solar energy and will bring back biodiversity (Getter and Rowe, 2006; Snodgrass and Snodgrass, 2006).

The practice of cultivating plants or rearing animal life in vertically inclined surfaces is called vertical farming (Despommier, 2010), Integrating feasible agriculture like hydroponics is referred to as Building Integrated Agriculture (BIA). If quantified, vertical garden will constitute up to 30,000 hectares as cited by Prakash in 2008, who was the pioneer of hydroponics and the one who presented Soilless Cultivation in India with his "*Pet Bharo*" project. Growing plants without soil, with using of nutrient rich liquid is referred to as Hydroponics. The plants are just placed in the air (Barbosa *et al*., 2015).

UV lights and a clouding system are used to grow plants in Aeroponics. The roots hang in the air and gain nutrients from the open surroundings (Lakhiar *et al.,* 2018). Aquaponics joins the two cultivation systems primarily aquaculture and hydroponics to cultivate fish and vegetables together in a built, re-circulating ecosystem using regular useful microscopic organisms, to change over fish wastes to plant supplements (Normala *et al*., 2010). The integration of fish and vegetables makes a perfect growing environment that is more gainful than conventional methods (Geoff, 2002).

Zeeuw (2004) concluded that Urban agriculture was effective in utilizing unused open spaces in cities for generating income and employment, along with purifying freshwater resources, providing greenery, reducing pollution and recycling of organic waste.

Mental wellbeing and mental prosperity of the society are the major positive outcomes of urban farming, as suggested by Ali and Srivastav (2017). It also helps to maintain our food culture and tradition along with being an avenue of relaxation, creativity, joy and social learning (Vazhacharickal, 2014).

With people's interest it can likewise end up being a functioning open space alongside upgrading food security in community. It brings about food sufficiency along with creating employment and raising income from agriculture (Bryld, 2003).

The main provisions of urban farming are its eco-effective engineering and urban landscapes; decreased food miles and transportation conservation of water assets; energy utilization and production; reusing of natural waste; new landscaping opportunities; improved community food security; provision for educational facilities; connecting of consumers to food production; motivation to designers and planners and financial benefits for urban territories with potential items and yields (Specht *et al.*, 2014). Urban farming will serve as a water management device and vertical cultivating as a potential substitution to conventional farming in future (Vazhacharickal and Gangopadhyay, 2014).

The challenges envisaged in promoting Aquaponics are the need for technical structures, the uncertainty in the new approach, in experience in the use wastewater, minimal stake holders and the extra finance needed (Specht *et al.*, 2014).

Sustainable development cannot be accomplished without natural sustainable urbanization. This is a new concept of "recreational agriculture" where in community level participation in agricultural activities with recreational motive is expected. It will need policymakers to identify newer approaches to implement it (Gupta and Gangopadhyay, 2013).

An entirely new ecosystem, like a microclimate for birds, butterflies, spiders and bees can be planned. It can involve the community with the motive of recreation. It will also help in reusing and recycling waste, establishing greenery, creating positive environmental changes and also providing acceptable ecosystem for the flora and fauna. Consumerism can also be brought down with respect to food products (Vazhacharickal, 2014).

In India Urban agriculture is being incorporated in numerous urban areas including Mumbai, Delhi, Kolkata, Bengaluru and Chennai under the initiative of government, private organizations or even individuals. There are various commercial Composting centres in Kolkata and Chennai, Dairy units in urban and peri-urban Bengaluru and Kolkata, Landscaping endeavours in Delhi, and agro-forestry service in Hyderabad city (Pothukuchi and Kaufman, 1999).

In urban communities like Delhi, Hyderabad, Chennai and Ahmedabad direct and indirect utilization of waste water in urban and peri-urban agriculture is wide spread. There are new activities to sell treated waste water to farmers in Noida, Hyderabad, Delhi, and Chennai. Treated sewage is sold in Chennai and there is expanding interest for the same. The Noida authority utilizes treated waste water for inundating some green belts and have plans to take on tertiary treatment to get waste water fit to drink. In Hyderabad, farmers lift local effluent from the Musi River for irrigation uses. The utilization of waste water in urban agriculture decreases interest for fresh water as well as helps shut the circle in urban water management. Wastewater utilization is considered safe for stopping environmental pollution. Natural waste from the city can be composted and utilized in urban agriculture with the additional advantage of diminishing waste that is dumped on land. FAO reports that extensive farming in Havana prompted the close elimination of nearby refuse dumps for household waste (Sahasranaman, 2016).

Agriculture in urban areas should include horticulture, animal husbandry and fisheries as a mandate. The planning should consider food and nutrient security, emphasizing entrepreneurship and environmental balance. The eventual fate of agriculture will exclusively rely on individuals who grasp present day innovations and have the passion to take it forward (Ali and Srivastava, 2017).

Kerala is a persistent ribbon of settlement with no division among urban and rural settlements. Urbanization is going on at a quick pace and Kerala is relied upon to turn into an all urban state sooner in the near future (Sharma, 2004).

2.2. Soil less revolution in Agriculture

The prime challenge in development is to end hunger and malnutrition through making agriculture and food distribution sustainable. Providing wholesome and fresh food for the future is our fundamental challenge, particularly for the developing worldwide populace (Alexandratrs and Bruinsma, 2012). Resource limitations for agricultural production have turned out to be more rigid than before, while the yields have reduced down. It is this main reason for the prevailing anxiety that food production would never be sufficient for the ever growing population.

Conventional agricultural (Geoponics) practices have caused extensive adverse effects on the environment. Conventional agriculture has degraded the soil by overuse of fertilizers, mismanaged water and utilized fertile land for nonagricultural purposes (Killebrew and Wolff, 2014 and Walls, 2014).

The fast growth of the total populace balances the high price of production of food. Simultaneously, worldwide environmental change is to be relied upon that raises the risk of frequent drought. Agriculture is in a period of significant change around the world and managing difficult issues. In future, it would be a troublesome undertaking to offer a fresh and wholesome food supply for the quickly developing populace utilizing traditional agriculture (Lakhiar *et al*., 2018).

Herein, the need to concentrate on judiciously using natural resources like land and water is needed. Nearly twenty five percent of land has become unusable due to faulty practices like poor soil and water management, atmospheric pollution, fast urbanization, continuous cropping, in addition to frequent droughts, and groundwater depletion. Newer techniques need to be developed to feed the whole population (Popp *et al.*, 2014).

Under such conditions, the soil-less cultivation is the elective innovation to adjust successfully to the changed circumstances. The idea of the soil less culture tries to offer a creative answer to ensure the ecological and financial sustainability of food supplies with high nourishing quality. This system is the solution for countries with lesser agriculture land, with food shortages and burgeoning population (Pual, 2000; Sardare and Admane, 2013).

In present day farming, proficient soilless cultivation methods are viable agro-systems that utilize energy and materials productively at the most significant level of sustainability, that is seen. Agriculture dependent on soilless culture remains as a significant achievement in present scenario. This current cultivation should meet the four mainstays of sustainable agriculture: Caring for the wellbeing of buyers; concerned about the wellbeing of farmers; attentive about the soundness of nature, along with agro-social advantages.

Hydroponics, aeroponics and aquaponics are current farming methods that use nutrient rich water preferably, than soil for plant sustenance (Bridgewood, 2003) and to be effective. These innovative modern farming methods need smaller amounts of water and space in comparison with the conventional farming methods. One more benefit of these innovations is the capacity to practice the vertical farming production which raises the yield of the unit area (Marginson, 2010). The advantages of the new present day agriculture methods are various. Besides higher yields and water proficiency, when performed in a controlled environment, those recent modern methods can be intended to help nonstop production all over the year (Brechner and Both, 2014).

The pattern of water and nutrient uptake of plants needs to be thoroughly comprehended, to provide them in the new systems for optimum crop growth and development (Klaring, 2001). The need of huge amounts and highquality vegetable products to fulfil the growing needs of the total populace justifies the advancement of technologies which synchronize the water and nutrient solution demand and supply to conservatory plants so as to accomplish crop yield optimization.

Hydroponics

Hydroponics is the craft of soilless cultivation where growth of plants happens in a soil less medium. It can be affirmed to be the best option for organic soilless cultivation. Plants can be cultivated in water medium enriched with nutrients. The possibility of growing food crops is also to be confirmed here. Mineral nutrient solutions are used to nourish the plants in this system (Song *et al*., 2004).

Hydroponic methods are exceptionally adaptable and can run from simple backyard structures to profoundly advanced business endeavors. Different commercial and specialty crops can be developed utilizing hydroponics, including tomatoes, cucumbers, peppers, eggplants, strawberries, and a lot more (Barbosa *et al*., 2015).

Singh and Singh (2012) have defined that hydroponics involves the growing of plants in soil-less condition with nutrients given through nutrient medium. This method assists in confronting the difficulties of environmental change and helps in production with effective use of natural resources and controlling malnutrition. PVC pipes are cut to suit the space available and water is directed through them with nutrients needed by the plants. The innovations in this line calls for automations and engineered structures. Organic cultivators, now are seeking feasible hydroponic systems. Solution culture and Medium culture are both practiced in the hydroponics system.

There is programmed control of nutrients through roots in Solution culture, But there is high risk of the plants to dry, if the flow of solution stops under any un foreseen circumstances. Hence, vigilant care is needed (Sengupta and Banerjee, 2012; Sardare and Admane, 2013). Black polythene film covered vessels are used for storing the solution, like the polythene beakers, pots and glass containers (Sengupta, and Banerjee, 2012). It is otherwise called “Liquid Hydroponics” technique. Roots are placed in most apt lengths into the solutions **(**Maharana and Koul, 2011).

In the media culture technique the media for the roots are more solid and sound and is named accordingly, viz., sand culture, gravel culture or rock wool culture. Sub-irrigation and top-irrigation are the two types of media irrigation. It can utilize -Hanging pack method or Trench or Trough method or Pot method (Sengupta and Banerjee, 2012).

Nutrient Film Technique (NFT) is a sensor driven hydroponic method. Here there are channels on the sides of the PVC tubes to grow plants upward from the outside. The nutrient rich water nourishes the plants. These plants grow in short durations. The sensors detect pH, solution conductivity and temperature of the unit (Velazquez *et al*., 2013).

Water utilization is found to be 20 times lesser than in conventional methods. They require less space and no pesticides as the medium is not contaminated. Moreover, there is no threat of weeds and harvesting is very simple (Mahesh *et al.,* 2016).

There are commercial models suiting home and institutions. Similarly, nutrient solutions, growth media, made to order fabricated systems, portable pH instruments are entering the agri bazaars. In this system the grower has complete control over nutrient transfers (Mahesh *et al*., 2016).

Aeroponics

This is another breakthrough in soilless cultivation technique. Here nutrient rich fog is used to nourish the medium. Plants are grown on cloth or equivalent firm media. The medium protects the plant from pathogens as well. Aeroponics succeeds more in vertical growing arrangements and in utilizing the space productively (Lakhiar *et al*., 2018).

In this system, the plant roots do not have soil to attach on, but nutrient enriched from air. Roots involuntarily choose the best location for oxygenation and moisture. The optimized condition for nutrient assimilation for quick development of the cultivated plants is designed. The aeroponic method is more easy to understand as the plants are completely isolated, they are totally hung up in the air and the roots of the plants are not joined to anything likes oil or water. Likewise, the harvesting of yields is easy. Numerous vegetable crops like tomato, potato, lettuce and a few of the leafy vegetables are being commercially cultivated in aeroponic system (Gopinath *et al*., 2017).

Controlled Environment High-Rise Farm (CEHRF) is a solution which is used in an aeroponic growing system, preferred for its 90 per cent decrease in water use, manure use to the tune of 60 per cent, 60 per cent decrease in nutrient use and pesticide use by100 per cent and stimulated crop growth, and higher density capacities when related with traditional farming. The growing routine is intended to give an all year constant harvest by counter balancing planting times, so that a consistent and dependable crop yield can be accomplished while giving full year round employment in a safe environment with benefits. These farms can be set close to the populaces they are expected to serve, keeping money in local economies (Gopinath *et al*., 2017).

Plants grown in the aeroponics methods have additionally been appeared to take-up more minerals and nutrients, making the plants more healthier beneficial and potentially more nutritious (AlShrouf, 2017).

Atomization nozzles provide the nutrients to the suspended plants. Plants are suspended in the plastic holders or foam. The nozzles make a fine spray mist intermittently or consistently. The method has proven some encouraging returns in different nations and is suggested as the most proficient, helpful, huge, practical and convenient plant growing method than soil and other soil-less techniques (Lakhiar *et al.*, 2018).

Aeroponics is more quick and efficient in yield compared to other systems. It requires very less water and nutrients. Water requirement is only 40 per cent of the requirement in hydroponics and 95 per cent less than in conventional methods. But the care needed is high, because of the sensitivity of the plants to pH and nutrient densities. Aeroponics methods are preferred over different systems of hydroponics, due to the better air circulation and nutrient solution transfers to plant roots, stimulating better growth and control of pests. They additionally record more faster plant growth, less space, flexibility, convenience to care and fewer pest attack (Mahesh *et al*., 2016).

Drawbacks have also been noted for the most part, being its extreme fragile condition. Moreover, grow this not reliable in this system. Small changes in pressure and water supply can kill the plants. Moreover they are extremely technical and costly (Buckseth *et al*., 2016).

Aquaponics

Aquaponics combines two systems: the RAS- Recirculation aquaculture systems and hydroponics (plant production in water, without soil) working in a synergistic fashion. This combination is a self- sustaining system that can be executed in individual homes just as in a large scale levels (Diver and Rinehart, 2010).

When in hydroponics, nutrients are manually provided with commercial formulas, in aquaponics the water is provided from an aquaculture tank or basement. This water is rich in nutrients for hydroponic culture. The plants are grown in specific grow beds averting the utilization of soil (Pattillo, 2017).

Domestic types for home and indoor culture are accessible with the aquarium- a current hydroponic method. The method is a self-manageable model. The water from aquaculture is best utilized as the nutrient rich fluid needed for the hydroponics. Various vegetables like spinach and tomato can be cultivated through aquaponics with the Gold fish aquarium (Saaid *et al*., 2013). Aquaponics possesses numerous advantages mainly with respect to cost in comparison to hydroponics as the expense of fertilizers applied in hydroponic system is costly as compared to the aquaponics system where fish food is used as source of nutrients. There is no need of frequently transferring the nutrient solutions in the aquaponics system, unlike in hydroponics where due to the precipitation of salts and chemicals, the levels become harmful to the plant (AlShrouf, 2017).

Several studies and researches have determined that the aquaponics farming commonly demonstrated quicker and progressively proficient outcomes in terms of plant growth, when compared with hydroponics. Aquaponics system is easier to maintain than hydroponics, since there is no need to monitor the electrical conductivity as in the latter approach. The natural ecosystem in aquaponics implies that components tend to balance one another, and there will be no compelling reason to monitor nitrate, ammonia and pH at frequent intervals. Moreover, hydroponics is comprised of an artificially made sterile environment while aquaponics is a natural ecosystem, thus making it totally organic (AlShrouf, 2017).

The advantages of aquaponics method is that it includes the skillful utilization of water, diminishes waste, has organic like management, co-location of two agricultural items (i.e.,edible fish and plants) and there is dense crop production, and it becomes more appealing as they are locally grown food products that are safe (Somerville *et al*., 2014).

Benefits of Aquaponics are accounted for as 90 per cent less water is required for the natural plant culture, compared to conventional gardening; They are extremely effective in the water reusing aspect; They are self- sustainable models, as the two sections feed each other. In addition, the indoor technique is achievable by using aquariums; less space is needed as the plants grow over the arrangements of aquarium. No weeding intercessions are required as they are additionally soilless. Not only organic vegetables, but also protein rich fish are the yield of this approach (Mahesh *et al*., 2016).

Such practices can make organic agriculture feasible at the home level. All these approaches have the scope for solving the food crises that would arise in the near future. A participant supervisory approach can make this system reach the common man **(**Mahesh *et al*., 2016). In addition, these methods also enables numerous socio-economic advantages with the scope to manage the expanding worldwide food challenges, environmental changes and effective usage of natural assets. Moreover, the soilless method can give enough new, clean and hygienic vegetables all through the year with no intervals. The system utilizes minimum input and enables variety output with higher yield (Palm *et al*., 2018).

Thus soil less cultivation is the remedy for nations in short of cultivable land, unpredictable climate,food insecurities and increasing populace. The concept behind promoting the soil less culture is to ensure nutritionally rich foods with environmental and economic sustainability (Pual, 2000; Sardare and Admane, 2013).

2.3. Aquaponics-The new farming approach

Expanding human populace has crept into agricultural lands for the need of residential areas, making large scale issues for agriculture produce, in India as well as in the whole world. Sharma *et al.* (2018) appropriately drew out that it is the need of hour to concentrate on alternative methods of farming which can guarantee better production in lesser area and in lesser time. In thiscircumstances, aquaponics is probably the best happening. This procedure has been effectively executed where the water accessibility is limited and soil quality is not up to the mark for agriculture. Aquaponics is modern, sustainable food production system combining aquaculture with hydroponic vegetable crops. Further, this method is helpful for both rural and also for urban regions, as in this method, there is no need of soil and additional land. It is advantageous to execute this method indoor along with outside terraces.

As a support for farm households, the nation has begun numerous projects and NMPS (National Mission for Protein Supplements) is one of these. This mission joins Hydroponics and Re-circulatory aquaculture system in such a way that nutrient requirements for both the systems are satisfied, viz., the nutrient rich fish waste from aquaculture unit becomes a nutrient media for the plant, simultaneously the plants free the water of obnoxious components that might be poisonous to fishes. Vegetable yield in hydroponic and aquaponic systems can be double the yield from the conventional horticulture systems. Economics of hydroponic systems has been evaluated by a numerous agencies and now is expected to be a mere 960 Rs/m2 for a grow bed of 34 m^2 system in Asia. Where the production site is far away from the business site, the aquaponics is a reasonable answer to produce the vegetables and fish at the same time on site (Sharma *et al.,* 2018).

This innovative approach utilises spaces and places that normally would not be utilized for growing food and has the capability to condense and compress production in small available areas (Goddek *et al.,* 2015 and Kloas *et al.,* 2015). Hence, it is suitable for urban areas especially flats, abandoned sites, housing estates, offices, schools etc. It has the attraction of being "locally produced food" to satisfy food safety concerns (Van Gorcum *et al*., 2019).

Types of Aquaponics and related Systems

(a) Floating raft method: Rafts made of Polystyrene boards are made to float on top of water, on which the plants grow (Fitzsimmons, 2012 and Danaher *et al.,* 2013). The process of nitrification goes on beneath the polystyrene sheets. Due to the greater surface area, exposure of roots is possible to a greater extent to the culture water, besides clogging of dirt does not occur. The low temperature beneath the raft is favourable for the system (Rakocy *et al*., 2004). The fish tank and this tank are kept separately. The water flows from fish tank to the raft tank and it flows back after filtration. Bacteria thrive in both tanks. This is the salient feature of this method (Tyson, 2007).

(b) Gravel system method: This is a common and low cost method, where in the grow bed is filled with gravel (Nelson, 2008). The beds are alternately flooded and drained to ensure air circulation (Rakocy *et al.*, 2004). The unit is easy to operate as there are only a few components and additional filtration is not required (Leonard and Lennard, 2007). The main disadvantage of gravel is that it will collect suspended impurities that can include un beneficial microbes. The containers for gravel should be strong enough as well (Lennard, 2005).

(c) Nutrient Film Technique (NFT): In this system long narrow troughs are used for planting, it is supplied with water flowing continuously in very small quantities, which ensures moisture, oxygen and nutrients (Lennard, 2010; Nelson and Pade, 2007). The containers used are light weight, cheap and easy to handle. To save space, the troughs can be mounted over the tanks (Junge *et al.,* 2014). The problem of this system is that it compulsorily needs bio filters, since all kinds of bacteria will survive in the favorable humidity and temperature.

Similarly the need for larger than normal PVC pipes is a difficulty in setting the unit, as the organic ecosystem can be created only then (Rakocy *et al.,* 2004). The water, oxygen and nutrients are absorbed by diffusion in this method, But heavy roots can block the flow (Graber *et al.,* 2011).

(d) Recirculating Aquaculture System (RAS): This is an unconventional method of growing fish in controlled conditions. The main highlight of this method is that water is treated in a sequence of steps, so as to purify and reuse it. It is also referred to as the "intensive fish production system" (Helfrich and Libey, 2003).

There are filters maintained to remove large particles like feed, faeces and bacterial debris (Couturier *et al.,* 2009). There are nitrifying bio filters to convert ammonia of fish faeces to nitrates (Gutierrez-Wing and Malone, 2006). Similarly, there are a few gas exchange devices to dispel dissolved carbon dioxide given out by fish and bacteria (Summerfelt, 2003; Moran, 2010). UV light is also needed to sterilize water periodically (Sharrer *et al.*, 2005; Summerfelt *et al.*, 2009). Ozonation and protein skimming is also essential for microbial control (Goncalves and Gagnon, 2011 and Attramadal *et al*., 2012). Denitrifying systems are also required to remove the nitrates formed (Van Rijn *et al*., 2006).

In this system, therefore plant biomass formation is inevitable, due to water treatment (Yoram *et al*., 2009). Seven kilogram of biomass is produced on an average for every kilogram of fish produced (Graber and Junge, 2009).

Aquaponics is the combination of RAS and hydroponics in a balanced environment. Reusing the waste discharged by fishes, to grow plants is the fundamental idea behind aquaponics. It is also conceived as a very environmentally sustainable endeavor. It uses 90-99 per cent less water than other conventional practices. Thus the release of waste is reduced, the requirement for antibiotics for fish diseases can also be avoided. Increase in suspended impurities is however a matter of concern. This can affect the water quality and lead to increase in levels of ammonia. Total Ammonia Nitrogen (Resley *et al.,* 2006; Lee *et al*., 2013; Hambrey Consulting Aquaponics Research Project, 2013).

These problems can be overcome in the changed RAS and aquaponic technology which includes growing plants for the filtration and nitrogen elimination (Nazar *et al*., 2013; Turcios and Papenbrock, 2014).

(e) Decoupled aquaponics systems (DAPS): This system utilizes water from the fish, but does not return the water to the fish from the plants. It adds on mineralization components and sludge bioreactors that can convert organic matter into bioavailable minerals, like phosphorus, magnesium, iron, manganese and sulphur, which are mostly deficient in normal fish effluent. The two components form parts of the loop, to detoxify or dilute the effluent. Besides sludge digesters if coupled in, can make it possible to reuse organic wastes from fish as nutrients for plant growth (Goddek, 2017 and Goddek *et al*., 2018).

Partition of the system is required for the conduct of various procedures. The faeces and un eaten feed wastes (fish sludge) has to be removed in the hydroponics system. Bioreactors are needed to convert this sludge into fertilizers or reuse organic wastes, likewise stems and roots from the plant production segments are fed into the biogas plant for heat and electricity generation. DAPS is required to recycle water, Water is made to move between segments in such a manner as to monitor levels of nutrients.

When there is deficit of phosphorous (P), the world over, by utilizing digesters in aquaponic systems, phosphorus in fish waste can be converted to orthophosphates that can be used by plants, on a large scale (Goddek *et al*., 2016). A system built into the aquaponics system, for this purpose can have this added advantage. Sludge digesters can also be built along with to process the solid waste (Monsees *et al.*, 2015; Emerenciano *et al.*, 2017and Goddek *et al.*,2018).

(f) Integrated Multi-Trophic Aquaculture (IMTA): In this method different species of plants are grown with wastes released from aquaculture (Kir, 2009 and Turcios and Papenbrock, 2014). It reuses resources like water and produces fertile biomass, that can be used to nourish plants outside the system. The most commonly used IMTA systems in open marine waters and landbased processes includes – fish, suspension feeders and grazers, for example, shellfish and seaweed, crustaceans such as sea cucumbers, sea urchins and polychaetas in bottom cages (Chopin *et al.*, 2010; Guerroro and Cremades, 2012). It can also incorporate marine aquaculture with various farming practices like mangrove planting with aquaculture, called aqua silviculture (Troell, 2009; Angel and Freeman, 2009).

So, IMTA includes, Aquaponics, Fractionated aquaculture, Integrated agriculture-aquaculture systems (IAAS), Integrated fisheries-aquaculture systems (IFAS) and Integrated peri urban aquaculture systems (IPUAS) (Biswas *et al.*, 2012). IMTA embraces the utilization of both freshwater and marine water with the adhering ecology, for environmental stability through stable food production; Bioremediation and bio mitigation along with balanced fish production are the star features of this method (Neori *et al.*, 2004; Troell, 2009 and Chopin *et al.*, 2010).

Inputs for the system

Mostly, leafy vegetables and herbs like lettuce are best for culture in an aquaponic system. Fruits, because of their long production cycle are not appropriate for this culture procedure. The suggested plants species are spring onion, basil, coriander, lettuce, fruit vegetables like cucumber, tomato, beets, blueberries and okra (Sharma *et al*., 2018).

Aquaponics systems similarly support different kinds of freshwater fish including trout, tilapia, carp, catfish, roost, goldfish, pacu, barramundi, roost, trout, mullet, oscars, grass carp, fresh water lobsters and ornamental fishes. Gold fish are the second easiest fish to grow due to their low cost. Goldfish too grow rapidly, flourish in different waters and produce a lot of waste for bacteria to change over into nitrates. Aquaponics supports koi fish, which individuals breed and sell for a benefit (Ramsundar, 2015). Fish to a great extent responds well to business fish feed. Their diets have to be well balanced in terms of all macro and micro nutrients (Surnar *et al*., 2015).

Potential of Aquaponics Production System (Fish and Vegetable)

In an effectively run tropical or sub-tropical system 20-40 kg of leafy vegetable production per m^2 every year can be anticipated (McMurty *et al.*,1997).

Studies reveal that spinach can be harvested 12 times each year and tomatoes 6 times each year through hydroponics and aquaponics (Surnar *et al*., 2015). If fish is harvested and restocked on a quarterly basis. For tropical/sub- tropical systems, the yield range might be 30-70kg/m^3/yr. The complete production from fish and vegetable has been observed to fluctuate between 3 to 160 kg/m^2/yr, however with most of values somewhere in the range of 30 and 80 kg/m^2/yr (Graber and Junge, 2009).

Since water is reutilized aquaponics systems are reported to use 90 per cent less water than conventional cultivation practice. This will suit the cultivation in water deficient regions. Besides, analyses reveal that with aquaponics, 6 times more food can be grown per square foot, compared to soil cultivated means, which is just what is needed for the space stressed urban areas. As far as food safety is concerned, the condition only favours organic practices, as chemicals and pesticides will put the fishes in danger (Somerville *et al*., 2014). The system is at the same time economic in that the inputs are minimum with respect to water and manures. It is also preferable in the ergonomics angle, as there is less of bending, lifting, even, deweeding is not needed here (Walker, 2016).

In Kerala, Ratnakaran's handy model (2015) is felt appropriate an urban user, with respect to size, cost and net connectivity. A 20 liters water tank cut into halves served as fish tank and grow bed.

Jacob (2017) introduced IOT technology, with Remote sensors and related components, even a camera was connected with a control button widget. The image is sent to Cloudinary, from where it is sent to the dashboard for exhibition.

An aquaponics system combining tomato plants was utilized reasonably effectively to reclaim and restore domestic wastewater (Rana *et al*., 2011).

For every kilogram of fish produced in feedlot aquaculture, the nutrients in the subsequent waste water permitted a vegetable biomass creation of 7kg (Wilson, 2005).

Level of potassium and dry matter was reported to be less in aquaponic tomatoes in comparison to hydroponic system (Schmautz *et al.,* 2016). Yield and sensory qualities of various tomato varieties were tested in the aquaponics and hydroponics setup. Yield was higher in aquaponics, which is presumed to be due to higher water temperature in aquaponics and thus the faster initial growth of the plants, favouring early ripening. A comparative sensory assessment of ripe fruits of the variety 'Grappella' revealed that 15 per cent of people preferred the taste of tomatoes grown in aquaponics, 21 per cent the hydroponic type, 47 per cent fruits cultivated in soil and 17 per cent could not detect any differences (n = 19) (Graber and Junge, 2009).

Lettuce grown in aquaponics produced 6.73 per cent higher yield than that cultivated in hydroponic system, and aquaponically grown lettuce had lower nitrate concentration (1079 mg kg-1 FW) than those grown hydroponically (1229 mg kg^{-1} FW). The antioxidant capacity by DPPH method for lettuce leaves was observed to be 181.5±43.9mgTE100g^{-1}fw in aquaponics and 132.7±21.39mgTE100g^{-1}in hydroponics (Alcarraz *et al*., 2016).

Yield of aquaponically grown basil (AqB)was higher than the hydroponic basil (HyB); extra nutrients, particularly N that was accessible to aquaponic basil, which resulted in their 14 percent greater plant height and 56 percent more fresh weight assessed with HyB. Comparable outcomes were reported by Savidov (2005); Lennard and Leonard (2006), too obtained similar results in tomato, cucumber, and lettuce grown under aquaponic and hydroponic systems.

Calcium content of Basil leaf grown on aquaponics was 2.93mg and hydroponics was 2.92mg. Iron content of Basil leaf developed on aquaponics was 96.1mg kg^{-1} and that through hydroponics was 99.1 mg kg^{-1} (Saha *et al*., 2016).

The management of aquaponics is easy and simple, as both the systems, hydroponics and re-circulatory aquaculture balance one another. In this way, the water quality is maintained by the hydroponic system and nutritional prerequisites are satisfied by the excretory material discharged by the fishes. It is a progressive method for growing plants, where the aquaculture effluent is intentionally averted through plant beds in a sustainable closed system. It is represented in a survey report led by Love *et al*. (2014) that, aquaponics has been getting growing concern since 2010, which indicates its expanding impact in society as an advanced response for food security.

Rajasthan is the largest state of India where water quality and amount both are variable and the soil quality is likewise not much favorable in some areas for the fish culture. The soil is sandy in the western part of state, consequently cannot be utilized for fish cultivating. Consequently, in such territories aquaponics can be embraced as an innovative practice for fish cultivating and upgrading efficiency of the locale for fish protein (Sharma *et al.*, 2018).

Aquaponics, vertical farming and living wall technologies will, make history in the annals of agriculture due to its decreased land requirement and high productivity.

From a customer's point of view, urban aquaponics thus has benefits as a result of its environmental advantages, short flexible chains and also because it answers the consumer demand for safe locally produced foods (Milicic *et al.*, 2017).

Aquaponics is one of the key food production innovations which could transform our lives (Vanwoensel *et al.*, 2015), as far as sustainable and proficient food production is concerned, it can be modernized and can turn out to be significantly and progressively efficient.

Aquaponics is coming into the forefront of Commercial agriculture with technical improvements in design and assurance of productivity (Bernstein, 2011).

2.4. Under exploited Green leafy vegetables

Plants are the cardinal blessing from God to man kind. Leaves of woody and short lived herbaceous plants were eaten as food by people since ancient days. Enormous knowledge on consumable plants has been acquired by man even before civilization due to their abundance in nutrients and minerals that are vital in maintaining optimal health.

India, being a tropical nation has a bounty of plant species that grow naturally, and in earlier days many of them were part of the conventional diets (Murugan *et al*., 2014). Greens are the leafy vegetables whose leaves and stem parts are consumable. Among different green leafy vegetables many are remaining underutilized and unexplored (Bhavithra *et al.,* 2019).

Leafy vegetables hold a significant place in well-balanced diets. Green leafy vegetables are the least expensive of the considerable number of vegetables being within the reach of the poor man, at the same time, being richest in nutritional value (Devi *et al*., 2006). A considerable lot of these plants are mainly rich in proteins, vitamins, minerals, phytonutrients mostly antioxidants (Randhawa *et al*., 2015). They play a significant role in providing variety to the diets heading to more balanced source of micronutrients. The major leafy vegetables likewise have important role in the Indian cuisine, because of their higher dietary fiber content and low calorific value (Gopalan *et al*., 2000).

Studies have reported that Indian green leafy vegetables, for example, basella (*Basella rubra*), fenugreek (*Trigonella foenumgraecum*), hibiscus (*Hibiscus cannabinus*), coriander (*Coriandrum sativum*), cabbage (*Brassica oleracea*) and spinach (*Spinacia oleracea*) are rich in dietary fiber. Adequate dietary fibre intake decreases the risk of cardiovascular diseases and colon cancer (Jenkins *et al*., 2001). Its role in preventing and controlling constipation, diabetes, diverticulosis and obesity are well established (Spiller, 2001). Plant varieties, agro-climatic conditions, stages of maturity and type and rate of manure applications affect the quality and quantity of fibres.

Green leafy vegetables (GLVs) are the most vital ingredients of a food basket, owing to the presence of bio active compounds along with vitamins and minerals (Nambiar *et al*., 2010). Consumption of leafy vegetables helps in the all physiological activities in the body antioxidants, therefore apart from being a source of nutrients, GLVs include anti-ageing components and many healing principles (Gupta and Prakash, 2009). The regular intake of these vegetables controls free radical damage and onset of degenerative diseases (Van Duyn and Pivonka, 2000; Oboh *et al.,* 2008).

Free radical scavenging property is achieved due to the presence of phytochemicals like flavonoids and phenolics (Murugan *et al.,* 2014). Many underutilized vegetables have more nutrients-Vitamin C and pro-vitamin A than widely accessible commercial species and varieties. Moreover, these underutilized vegetables have protection from a several biotic and abiotic stresses of the environment.

The ethno botanical reports offer data on the medicinal properties of green leafy vegetables which comprise details on their anti-carcinogenic and antibacterial (Khanna *et al.,* 2002), antidiabetic (Kesari *et al*., 2005) and anti-inflammatory activities (Garcia-Lafuente *et al.*, 2009).

Sree *et al*. (2013) reported that intake of green leafy foods improved nutritional status and reduced specific illnesses like diabetes, malignant growth and hepatotoxicity.

Green leafy vegetables (GLV) has been stated to cause bringing down the risk of age-related cataract (Gupta and Singh, 2012). This condition is responsible for more than 40 per cent of the world's blindness in developing countries. Forty-four per cent of visual deficiency is inferable from cataract too (Sree *et al*., 2013).

Retinol deficiencies in developing countries arecorrected byleafy vegetables, by being rich sources of lutein, provitamin A, β-carotene and not holding bioavailability issues.

Similarly, vitamin A deficiency is also controlled by these foods especially eye morbidity like xerophthalmia (Nambiar and Seshadri, 2001 and Nambiar *et al*., 2005).

The most prevalent morbidity namely anemia which causes numerous symptoms like vertigo, blurred vision or spots in the cornea (floaters), fatigue and lassitude, sleeping disorders, poor muscle tones, muscle tightness and cramping, numbness in the extremities, whiteness, dry skin and hair, pale tongue (likewise lips and nail beds), poor memory, PMS, scanty, difficult or no menstrual periods, a persistent feeling of cold, heart palpitations, and tension/nervousness, can be prevented and cured by regular intake of leafy vegetables (Sharma and Vijayvergia, 2013).

Lack of awareness of their importance is the main reason behind their low utilization.

Such common underutilized leafy vegetables are *Alternanthera sessilis, Alternenthera pholoxeriodes, Amaranthus cruentus, Amaranthus spinosus, Diplazium esculentum, Ipomoea indica, Kratava magna, Malva verticillata, Oxalis corniculata, Polygonum plabium, Portulaca oleracea, Trigonella balansae, Typhonium trilobatum,* and so on. These vegetables are commonly utilized as everyday vegetables. Though, some different plants like as *Bacopa monnieri, Boerhavia diffusa, Centella asiatica, Enhydra fluctuans, Hygrophila auriculata, Leucasaspera, Trianthema portulacastrum* etc. Are utilized as leafy vegetables with therapeutic objectives.

Vegetable amaranth act as an alternate source of nutrition for individuals in developing nations since they are a rich and cheap source of carotenoid, protein, nutrients and dietary fiber (Shukla and Singh,2003).

In traditional system of medicine, GLVs are utilized to treat different diseases. For example, the leaves of *Daucus carota* are used to relieve constipation. *Portulaca oleracea* can be utilized as an antiscorbutic and its paste has been applied for wound healing (Sultana and Rahman, 2013).

Purslane is famous as a traditional medication in China and Hong Kong for the treatment of hypotension and diabetes (Simopoulos, 2004; Uddin *et al.,* 2014).

Nitric acid a compound found in *Centella asiatica* which has a beneficial outcome on brain activity (Prasad *et al.,* 2017). Islam *et al.* (2002) further revealed *Ipomoea batatas* leaves as an incredible source of antioxidative polyphenolics which competed with other commercial vegetables.

Leaves of *M. oleifera* work as a valuable source of nutrients for all age groups. In certain parts of the world for instance Senegal and Haiti, health workers have been curing malnutrition in small children, pregnant and nursing women with

Moringa leaf powder. The leaves are known as incredible sources of vitamins and minerals being served crude, cooked or dried (Fahey, 2005). Fuglie (2005) reported that 8 g serving of dried leaf powder would fulfill a child within age group of 1- 3yrs with 14 per cent of the protein, 40 per cent of the calcium, 23 per cent of iron, and almost all the vitamin A that the youngster needs in a day. One 100 g portion of leaves could give a woman with over a third of her every day need of calcium and give her significant amounts of iron, protein, copper, sulfur, and B-nutrients.

Aqueous extract of *Ipomoea amphibian* has brought to light its anti-cancerous, anti diabetic and even antioxidant activity (Saxena *et al.,* 2017).

Major biological activities showed by Basella alba are androgenic, anti-diabetic, anti-inflammatory, anti-microbial, antioxidant, anti-cancerous, antiviral, CNS depressant, hepato defensive and wound healing properties because of the presence of B - sitosterol and lupeol in the plant (Saleem *et al.,* 2001).

Saha *et al.*(2015) examined the mineral content of different under utilised greens and reported that *Brassica nigra* had 241.20 mg/100 g of iron , which was followed by *Brassica juncea* (118.50 mg/100 g), *Amaranthus viridis* (118.13 mg/100 g), *Basella alba* (90.80 mg/100 g) and *Chenopodium collection* (85.46 mg/100 g).

*V. unguiculata*s showed high antioxidant capacity, which was in positive relationship with existence of high amounts of phenols, tannins and flavonoids (Aathira *et al*., 2017).

High carotene levels of leaves were confirmed by Jyotima and Alka, (2016); The highest β-carotene was found in Carrot leaves i.e., 5440±11.05µg/100g, next by *Moringa (Moringa oleifera*) leaves 4453 ±17.090 µg/100g, and Spinach (*Spinchacia oleracea*) least (2740 ±12.01µg/100g). β-carotene content of bengal gram leaves was11.8 mg/100 g and t in carrots, it was 2.2 mg/100 g, on fresh weight basis. Significant ($p < 0.05$) differences were seen in every single other vegetable and herbs with the exception of mint and spinach.

Thorat (2018), reported that the chloroform extract of *Celosia argentea L.* has been found to repress the growth of *Escherichia coli* and *Pseudomonas aeruginosa*. The methanol extracts inhibited the growth of *Micrococcus pyogenes*. The aqueous extract of the leaves and roots were found to hinder the development of rhizopus species. An ethanolic extract (50 per cent) of flowers and seeds were stated to restrain the development of several bacteria.

Similarly, leaves of *Coleus aromaticiis* revealed a pleasing aromatic odour and a pungent taste. It is generally utilized for flavoring meats and salads, the leaves and the seeds are utilized in indigenous medication. The bruised leaves are rubefacient and vesicant and are utilized as counter- irritants in headache, neuralgia, rheumatism and other local pains by being scrubbed on the part or applied as a poultice. The leaves of *Gynandropsis pentaphylla*, are bitter, however cooking expels the bitterness. They are eaten as a pother bandas flavorings insauces. They are mostly pickled. The flavor of the leaves is because of anacrid volatile oil similar to that present in garlic or mustard (Sogbohossou *et al.*, 2018).

The green leafy vegetable of *Beta vulgaris*, *L.* leaves were compared with the out comes of *Beta vulgaris*, *L.* roots. Here the leaves comprised a higher amount of Vitamin A, Calcium, Iron, Magnesium, Phosphorus and Potassium. So it is recommended that the diabetes patients can avoid beet root since it contains higher amount of carbohydrate, starch and protein, while the leaves contains less a mounts of macronutrients (Suganya *et al*., 2017).

Pan and Bhatt (2018), noted that amongst various leafy vegetables studied, *C. tora* revealed the highest DPPH free radical scavenging activity-142.5mgAEAC/100g) followed by *A. spinosus*, *H. spinosa*, *Moringa oleifera (leaves*).

Kavitha and Ramadas (2013) revealed that *Spinach oleracea* had a high potential health benefit for diabetes, cardiovascular disease, stoutness and osteoporosis.

Many ignored and underutilized vegetables are nutritionally rich and can be modified to low-input agriculture. The erosion of these species, regardless of whether wild, managed or cultivated, can have instant consequences on the food security and well-being of poor people. Their usage can be proved to overcome nutritional disorders, like micronutrient inadequacies, the so-called hidden hunger.

Therefore, underutilized vegetables are turning out to be all the more widely and efficiently utilized to address malnutrition, poverty and economic prosperity. They comprise essential biological assets of the rural poor and can add to improving the prosperity of millions of our populace. Underutilized vegetable crops can likewise provide nutrition to the poor by meeting the nutrient requirements of vulnerable groups too.

2.5. Changing Food demands and Consumer preferences

India is a quickly developing and dynamic economy, which is portrayed by increasing incomes and changing consumer preferences. During the previous decade there has been a 16 per cent expansion in the number of urban upper and middle class households, whose optional spending has ascended by as much as 20 per cent. With increased incomes and rapid urbanization, consumer likings are also changing, as consumers choose higher quality consumption goods, and they are happy to address greater expenses for these (Ernst and Young, 2006). As food products are common goods, it is expected that consumers insist for food attributes, such as food safety and quality, which will also increase with increasing incomes (Roy *et al.*, 2010).

Food habits have changed tremendously with this generation of humans. Social standards of food and quality demands have also changed. The concerns are mostly on health and environment like allergic responses, pesticide toxicity or herbicide tolerance of plants and inadvertent toxicity to wildlife. Demand for nutrient labeling is also on the increase. The percentage of consumers who attempt to purchase gluten free items is 10 percent, which is well above the less than 1 percent of Americans who have Coeliac disease.

Organic foods are increasing in demand, in the trend in healthy eating. Organic food certification is reflection of consumers concerns about both health and the environment. Certification of organics is not a simple procedure. Organic crops must be grown in safe soil, have no alterations, and must stay separate from regular items. Farmers are not permitted to utilize synthetic pesticides, bioengineered genes (GMOs), petroleum-based fertilizers and sewage sludge-based fertilizers. Organically raised animals are not given antibiotics, growth hormones, or fed animal by- products. Moreover, the animals are given more space to move around and have access to the outside environment, the two of which help to keep the animals healthy. Foods with regional and local origin labeling are gaining importance. Actually, recent studies have demonstrated a greater interest in locally produced than organic products. Many buyers are happy to pay a premium for local foods. There as on for these patterns involve supporting local farms and preserving farms, in general. Locavores need to support the local economy and know where their food originates from. There are similarly the environmental inspirations, including the possibility that decreasing "food miles" is better for nature. Though, net effect of the local food move mentis still under discussion. Local foods are usually perceived as more fresh or of higher quality (Ostrom, 2006).

There has long been a consumer movement to reject modern agricultural technology, such as genetic modification, synthetic fertilizers, and irradiation. In the course of recent years, GM foods have been a particularly argumentative issue. Despite the scientific consensus that, GM items are safe for human intake, there has been an absence of acceptance by a segment of consumers, which is well documented and has resulted in decreased or curbed demand for GM food items. Customer attitudes in Europe towards GM foods as detailed in numerous studies and publications seem to have been strongly negative (Bredahl, 2001; Grunert *et al*., 2001; Grimsrud *et al*., 2004). US consumers generally stayed unbiased toward GM foods until recently when research studies recommend their slight objection to such food sources (Huffman and McCluskey, 2014).

Another category of new innovation is the “functional foods”, which can be characterized as modified food items that have been engineered or designed to contain increased health benefits that stretch out past the normal benefits of the traditional food product. Consumer acceptance and interest for these new food items are driven by public perception of risks, advantages, and safety of these food items (Hossain and Onyango, 2004). Though functional food provide health benefits beyond basic nutrition, some consumers even reject them since they are considered as innovations (Labrecque *et al*., 2006).

Globally functional foods have taken a large share of purchase by consumers, as they are understood to be useful to maintain health, besides their nutrient value. They come in the form of processed foods like, cholesterol lowering spreads, xylitol sweetened chewing gum and dairy products fermented with specific lactic acid bacteria, are all natural functional foods including soy, oats and grains high in fibre. Functional foods exist in all category of foods and they are taking a larger share of market than organics. Over and above the health perspective functional foods are becoming an economic opportunity. The business sector of functional or health-enhancing foods has been energized in response to worldwide changes in health, research in food and health, along with globalization. With life longevity, elderly people are looking more into health foods (Kaur and Das, 2011).

Each individual has varying ethical standards like treatment of animals, fair dealings, low pesticides etc., hence the generalizing of consumer behavior. McCluskey *et al.* (2015) assessed consumer willingness to pay (WTP) for three food items with various socially responsible attributes: minimal pesticide strawberries, fair-trade bananas, and milk from pasture-fed cows. The factor representing the consumer’s level of "environmentalism" was the most significant in explaining readiness to pay over these three items.

Siegrist *et al.* (2009) reported that even nano technology products were considered with doubt by potential buyers, as they insisted on natural additives. Hence, it was suggested that outlets are to create positive reactions to nanotechnology foods or GMF foods before marketing.

Organic foods are gradually taking the center stage in the world food market and in worldwide consumption patterns (Hjelmar, 2011). Natural produce has appeared to have halo effects on quality perception, which shows that consumers see food marked as organic as more "healthy, natural, nutritious and sustainable" (Falguera *et al.*, 2012; Vega-Zamora *et al.*, 2013; Hsu and Chen, 2014).

Corresponding to the propensity towards more healthier food, a move towards more environmentally friendly or "green" food products has developed, which is known as "ethical consumption" or "sustainable" (Aschemann-Witzel *et al.,* 2013**)**. In this way, organic food purchases can be viewed as actions motivated by beliefs about healthiness, good taste and a positive effect on the environment (Vega-Zamora *et al*., 2013; Shafie and Rennie, 2012).

Consumers are progressively worried about what they eat, so it is foremost to understand the implications of natural food (Pugliese *et al*., 2013). Several studies have given proof that consumer perspectives towards organic food altogether impact their decision (Stolz *et al.,* 2011). Peruvian investigations have been fundamentally descriptive in nature and little empirical search has concentrated on estimating the principle factors behind why organic consumers decide to buy organic products. It is said that when consumers have a good understanding of organic foods, awareness and purchase intentions increase. The population reckoning environment and animals, are more leaning towards organics. Though all foodstuffs are considered, organic fruits and vegetables are more in focus. Though scientific contradictions exist regarding nutritional supremacy, organic foods are considered beneficial on the whole. The absence of chemicals is what makes them more preferred. Compared to earlier days, there is less hesitation to spend more on organics (Mohamad *et al.,* 2014).

Consumer consciousness has increased with regard to nutrition, health and quality of food (Gil *et al.,* 2000). This has increased the demand for organic food. Phuah *et al.* (2011) expressed that consumer's health awareness has increased the demand for functional foods, organic foods, green foods and natural foods. With increase in life style disorders like obesity, type 2 diabetes, and coronary heart diseases, consumers are getting more and more mindful of healthy eating (Shaw *et al*., 2000).

Kumar and MuthuKumar (2016) discovered that consumers in Nilgiri district gave more significance to factors like health, environmental safety, knowledge and culture where natural food was concerned. But, they were indifferent towards characteristics of organic foods like taste, color of the food etc.

Ergin and Ozsacmaci (2011) studied factors influencing demand of consumers for organic food in the city of Ankara, Cankaya district, Turkey. From their investigation they found that a large portion of the married, graduated purchasers without children were purchasing organic products. The study also indicated awareness about advantages of organic food in Turkey is more among educated and financially secure people.

The International Food Information Council (IFIC) surveyed American buyers to understand their perceptions, beliefs and behaviours around food and food buying choices. They saw that inspite of the significance of familiarity,7 out of 10 consumers were eager to give up a familiar favourite item for one that did not contain artificial ingredients. Of the individuals who would, 4 out of 10 would pay 50 per cent more and 1 of every 5 would pay 100 per cent for such products.

Overall, consumers are particularly worried about the potential damage that conventional foods would bring to their personal health and public health, for example the development of allergies in youth. Surely, families with children are bound to purchase organic. Parents worried about perceived effects of growth hormones and antibiotics start buying natural foods during pregnancy or when their infant changes to baby food. Consumers are no longer ignorant of marketing tactics and unhealthy foods (Yue *et al.,* 2010). The details of production are understood by majority of consumers; Premium prices are being tolerated by a significant group (Yue *et al*., 2009). Eco friendliness is acceptable to decent percentage of the population (Basu *et al*., 2004). Organically food products are being preferred more and more. Sale of organic food items have increased at a pace of more than $5 billion per year (Willer *et al.,* 2008). Health consciousness, environmental friendliness, taste, freshness, quality; and desire to avoid genetically modified foods are the main rationale to prefer organic foods (Demeritt, 2002 and Yue *et al.,* 2009). Locally grown food items are preferred for their freshness, taste and lower costs. Besides they feel they are supporting the local economy (Yue and Tong, 2009).

Aquaponics is thus seen to be a young entrant in the field of Agriculture, which needs promotion as a means to maintain ecological balance. Leafy vegetables are reported to grow faster in this system. Though initial input expense is high, maintenance is easier than other systems. In the years ahead, scope of setting up such units to make families food secure will have to be studied.

Materials and Methods

3. MATERIALS AND MEHODS

The experiment entitled 'Quality evaluation of vegetables cultivated through aquaponics' was carried out to study and compare the quality characteristics of green leafy vegetables cultivated through aquaponics and conventional methods.

The methodology is discussed under the following heads:

3.1Locale of thestudy

3.2 Selection ofvegetables

3.3 Selection oftreatments

3.4 Selection of qualityparameters

3.5Statisticalanalysis

3.1 Locale of the study

The experimental site was selected at a farmer's field at Ulloor, Thiruvananthapuram, where there was a wellestablished 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.

3.2 Selection of vegetables

1. tuberless colocasia – *Colocasiaesculenta*
2. water spinach –*Ipomoeaaquatica*
3. malabar spinach – *Basella alba*

1.*Colocasia esculenta* leaves are reported to possess vital nutritive and nonnutritive components in significant amounts, but are underutilized, and lesser explored. Their chemical composition varies significantly depending upon climatic conditions and other agronomical factors of the location of cultivation andvariety(Gupta*etal*.,2019).Thebotanicalprofileofthevegetableispresented in Table1.

Table 1. Botanical characters of the vegetables selected for the study

Character	Vegetable		
Common name	tuberless colocasia	water spinach	malabar spinach
Scientific name	*Colocasiaesculenta*	*Ipomoea aquatica*	*Basella alba*
Family	Araceae	Convolvulaceae	Basellaceae
Habit	Herbaceous perennial	Semi-aquatic annual/perennialvine	Herbaceous perennial vine
Propagation	Seeds,Vegetative propagules	Seeds,Vegetative propagules	Seeds,Vegetative propagules
Nutritional importance	High protein and phytochemicals	Rich source of K, Mg, Mn and Fe	Richinantioxidantslike Beta carotene, lutein,zeaxanthin

3.3. Selection of treatments

T1- Plants cultivated through aquaponics

T2- Plants cultivated through conventional practices (OrganicPOP)

Same variety of the three vegetables were selected.

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

3.4 Quality parameters ascertained in the selected vegetables were:

Physicalqualities

SensoryParameters

Nutrientcomposition

Nutraceuticalcomposition

Shelflife

3.4.1 Physical qualities

3.4.1.1 Number ofharvests

The leaves were harvested for two months when they attained an edible size. The observations were recorded.

3.4.1.2 Total dry matter production

Mature plants of all three varieties 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.

3.4.2 Sensory parameters

Quality of any food is determined by sensory assets of the food. Sensory assetshelpinjudgingthequalityoffoodbymeansofusinghumansensoryorgans such as eyes, nose and mouth. The sensory qualities/assets were measured by means of using a score card which was proposed by Swaminathan(1995).Selected green leafy vegetables of both treatments were cooked with minimum embellishments (salt and oil) and were rated for their sensory qualities by a panel of 10 members.

The major attributes of sensory qualities are included below:

a) Appearance

b) Color

c) Flavor

d) Texture

e) Taste

Each of the abovementioned qualities were assessed on a nine point rating scale ranging from 1 to 9 as furnished in the Appendix 1. The evaluation was done by a semi trained panel of 10 members.

3.4.2.1 Appearance (Rawvegetable)

Quality of green leafy vegetables can be ascertained to a great extent by its appearance. Appearance of selected leaf samples of both aquaponics and conventional method were rated by direct observation using a 9point scale and analysis was done by calculating the ranked mean. Sensory evaluation was done by the judges using score cards.

3.4.2.2 Color (Rawvegetable)

Color is an important characteristic of food. It is one of the first criteria for selection of vegetables. Color of the green leafy vegetables cultivated through aquaponics and conventional methods were compared. The ratings were recorded in the score card.

3.4.2.3 Flavor (Raw and Cookedvegetable)

Flavor is the perceptual impression of food or other substances, and is determined primarily by the chemical senses of the gustatory and olfactorysystem. Flavor was also assessed by using the score card, by the members of sensory panel.

3.4.2.4 Texture (Raw and cookedvegetable)

TextureisalsoanindexoffoodqualityNotonlydoestexturehaveacasting vote over a food’s acceptability, it is also essential in identifying it. Texture of raw and cooked samples were evaluated by the Sensory panel. Raw samples were evaluated by hand feel and cooked samples through mouthfeel.

3.4.2.5 Taste (Cookedvegetable)

One of the most important factors considered for acceptability of food isits tasteandmostofthefoodswerevaluedfortheirtaste.Comparisonoftastewasalso done by using the scorecard.

3.4.3 Nutrient Composition

Nutritionanalysisreferstotheprocessofdeterminingthenutritionalcontent of foods and food products. The process can be performed through a variety of certifiedmethods.

3.4.3.1 Moisture(g)

Each sample’s moisture content was determined by using the method defined by A.O.A.C(1990).The analysis was conducted on the same day of harvest.

3.4.3.2 Fibre(g)

Fiber content of samples were assessed by acid and alkali digestion method (Sadasivam and Manikam, 1992).

3.4.3.3 Total minerals(g)

Total minerals were estimated for each sample by the method which was outlined by A.O.A.C (1995).

3.4.3.4 Acidity(%)

Acidity was estimated as per the procedure reported by A.O.A.C (1984) for each of the samples.

3.4.3.5 Soluble sugars(mg)

The soluble sugar content was estimated by the method of Dey (1990).

3.4.3.6 Vitamin C (mg)

Vitamin C content was assessed by titrating the samples against the dye 2,6, dichlorophenol indophenol method (Sadasivam and Manikam,1992).

3.4.3.7 Beta carotene(µg)

Carotene content of green leafy vegetables was assessed according to the method proposed by Srivastava and Kumar (1998).

3.4.3.8 Calcium (mg)

Calcium content of green leafy vegetables of aquaponics and control treatments were estimated after the digestion of the sample with triple acid. The triple acid digest was titrated by EDTA method (Jackson, 1973).

3.4.3.9 Iron (mg)

Iron content was determined by using the method recommended by Jackson (1973).

3.4.4 Nutraceutical composition

This section envisaged the analysis of bioactive compounds having antioxidant/ cardio-protective / anti-inflammatory properties and assessment of certain bioactive properties by in standard vitro methods.

3.4.4.1 Total Phenols

Phenol content was estimated by the procedure defined by Sharma (2001).

3.4.4.2 Phyticacid

Phyticacidcontentwasdeterminedbythemethodwhichwasrecommended by Wheeler and Ferrel (1971).

3.4.4.3 Tannins

Tannins were determined as per the procedure defined by Ranganna (2001).

3.4.4.4 Oxalates

Oxalate content of green leafy vegetables was estimated by the procedure which was suggested by Day and Underwood (1986).

3.4.4.5 Antioxidants

The radical scavenging activity of the samples was determined by 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay (Lim *et al*., 2007).

3.4.5 Shelf life

Shelf life of the vegetables were ascertained through checking of visible signs of deterioration and quantitative assessment of water loss.

3.4.5.1 Duration with respect to onset of visiblemarks

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

3.4.5.2 Physiological loss of water (PLW)

Underambient and refrigeratedconditionstheweightoftheGLVwastakenonadailybasisand 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 werenoted

PLW of vegetables was determined by using the followingformula:

Percentage PLW= (Initial weight – Final weight / Initialweight) ^{x}100 The results of the study are presented in the next chapter.

3.5 Statistical Analysis

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

Results

4. RESULTS

The study entitled ‘Quality evaluation of vegetables cultivated through aquaponics’ was conducted to compare the quality of green leafy vegetables cultivated through conventional methods and through aquaponics. The results of the study are discussed under the following heads:

4.1 Physical qualities

4.2 Sensory parameters

4.3 Nutrient composition

4.4 Nutraceutical composition

4.5 Shelf life

4.1 Physical qualities

Physical qualities of leafy vegetables were assessed with respect to number of harvests and total dry matter production.

4.1.1 Number of harvests

The number of harvests is an important physical characteristic, as optimizing yield is a major aim of crop production.

Table 2. Details of harvest of tuberless colocasia

Sequence of harvest	Yield (g/plant)	
	T1	T2
1st	25	20
2nd	30	28
3rd	22	25
4th	18	15
5th	26	21
6th	20	24
7th	24	22

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

Seven harvests were conducted in two months for the tuberless colocasia plants. From table 1, it is observed that the yield of T1 was higher than T2, the yield of each harvest was however comparable. Yield of T1 ranged from 18-30g, while that of T2 ranged from 15-28g.

Table 3. 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 intwo months. From table 2, 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.

Table 4. Details of harvest of malabar spinach

Sequence of harvest	Yield(g/plant)	
	T1	T2
1st	10	15
2nd	18	23
3rd	22	19

4th	25	28
5th	21	19
6th	26	22
7th	30	33

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

Seven harvests were conducted in two months. From table 3, it is observed that the yield of T2 was higher initially, but later plants in aquaponics gained pace, finally at the end of two months, their yields were comparable. Highest yield was obtained in the seventh harvest for both T1& T2 (30 g and 33g respectively), which was slightly on the higher side for T2.

4.1.2 Total dry matter production

This refers to the expression of plant productivity in terms of the dry weight of material produced per unit area during a specified time period. In this study, the dry matter production per plant was determined, as this was a controlled study.

Table 5. Total dry matter production of the selected leafy vegetables (g/plant)

Vegetable type	**T1**	**T2**
tuberless colocasia	119.5	45.25
water spinach	36.52	6.98
malabar spinach	85.99	110

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

Total dry matter production of tuberless colocasia was higher for T1(119.5g/plant), than T2 (45.25 g/plant). As for water spinach, it was higher for aquaponics samples T1(36.52 g/plant) than conventional ones T2 (6.98g/plant). Total dry matter production of malabar spinach was higher for T2, being 110 g/plant (that for T1being 85.99 g/plant).

4.2 Sensory parameters

Sensory quality contributes a significant part in the quality of any food. Sensory analysis is exercised to describe and quantify sensory qualities of products.

The five human senses give a whole impression of quality. Sensory evaluation can be characterized as a scientific discipline used to encounter, measure, analyze and infer characteristicsof food materials, as they are recognized by the senses of sight, smell, taste, contact and hearing. Sensory evaluation helps with estimating the eating characteristics of any food.

For consumers to choose a food commodity, the principle quality traits are appearance, color, flavor, texture and taste. All these qualities are determined by sensory evaluation. At the point when done appropriately, sensory information can give immense understanding into the food. Consumers finally prefer foods which are palatable and enjoyable.

Appearance

Appearance is the most significant criteria for the desirability of any foods. Color and appearance features of products would not be disregarded because these features may render the item acceptable/unacceptable.The appearance is a characteristic on which a choice is taken to purchase or consume (Meilgaard *et al*., 2006).

Color

Color is a principal quality of food and assumes a significant role in the acceptability of foods. Consumers judge the quality of a food product by looking at its color. Color includes both physical and psychological components: it is the perception by the visual system of light of wavelengths 400 to 500 nm (blue), 500 to 600 nm (green and yellow), and 600 to 800 nm (red), usually expressed in terms of the hue, value, and chroma of the Munsell color system. Deterioration of food is often accompanied by a color change (Meilgaard *et al*., 2006).

Flavor

Flavor refers to olfactory perceptions caused by volatile substances from product in the mouth by means of the posterior nostrils. It is the property of foods, beverages and seasonings, which has been characterized as the sum of perceptions resulting from stimulation of the sense ends that are grouped together at the entrance of the alimentary and respiratory tracts.

In some of the products, especially frozen foods where volatile compounds are not seen by feeling of smell at low temperatures, the sense of taste plays a deciding role for evaluating the flavour (Stone *et al*., 2012).

Taste

Taste, refers to gustatory perceptions (salty, sweet, harsh, severe) caused by soluble substances in the mouth. It also implies to the sensation of flavor perceived in the mouth and throat on contact with a substance. Taste receptors in the mouth sense the five taste modalities: sweetness, sourness, saltiness, bitterness and savouriness (Amerine *et al.*, 2013).

Texture

Texture is a much more complex parameter, that can be characterized as the sensory manifestation of the structure or inner makeup of products in terms of their reaction to stress, measured as mechanical properties (such as hardness/firmness, adhesiveness, cohesiveness, gumminess, springiness/resilience, viscosity), by the kinesthetic sense in the muscles of the hand, fingers, tongue, jaw, or lips (Lawless and Heymann, 2010).

Table 6. Sensory evaluation of tuberless colocasia

Sensory parameters	**T1**		**T2**		
	Sum of ranks	**U-value**	**Sum of ranks**	**U-value**	**Z value**
Appearance(raw vegetable)	114.5	40.5	95.5	59.5	0.68
Color (raw vegetable)	113.0	97.0	42.0	58.0	0.56
Flavor (raw vegetable)	116.5	38.5	93.5	61.5	0.83

Flavor (cooked vegetable)	133.0	22.0	77.0	78.0	2.07*
Texture (raw vegetable)	117.5	37.5	92.5	62.5	0.90
Texture (cooked vegetable)	76.5	78.5	133.5	21.5	-2.11*
Taste (cooked vegetable)	112	43	98	57	0.49

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

The appearance and color of products in the raw vegetables were rated by the sensory panel, as the cooked forms would not manifest difference in this quality. Flavor and texture of both cooked and raw forms were evaluated. Taste of cooked vegetable was rated, as they were otherwise inedible.

From the table 6, it is observed that sum of ranks for all parameters of tuberless colocasia grown on aquaponics -T1- scored more than T2. Scores of flavor and texture of the cooked vegetable showed significant difference among the two treatments (Z = 2.078 and -2.116 respectively).

Table 7. 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	126.5	28.5	83.5	71.5	1.587

vegetable)					
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 7, it is revealed that there was significant difference in the scores for appearance and color of raw water spinach of both the treatments (Z value = 3.023 and 2.305 respectively). Scores for texture, taste and flavor were higher in the case of T1treatment, but they did not show significant difference statistically.

Table 8. Sensory evaluation of malabar spinach

Sensory parameters	**T1**		**T2**		
	Sum of ranks	**U-value**	**Sum of ranks**	**U-value**	**Z value**
Appearance (raw vegetable)	115.0	40.0	95.0	60.0	0.718
Color (raw vegetable)	116.0	39.0	94.0	61.0	0.793
Flavor (raw vegetable)	86.5	68.5	123.5	31.5	-1.360
Flavor (cooked vegetable)	82.5	72.5	127.5	27.5	-1.663
Texture (raw vegetable)	101.5	53.5	108.5	46.5	-0.226
Texture (cooked vegetable)	113.0	42.0	97.0	58.0	0.566
Taste (cooked vegetable)	82.0	73.0	128.0	27.0	-1.700

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

As revealed in table 8, the sum of rank values of T1treatments showed higher values, but there was no significant difference among the treatments of malabar spinach for sensory qualities in both raw and cooked forms.

4.3 Nutrient Composition

Nutrients analyzed in this experiment are moisture (g), Fibre (g), Total minerals (g), Acidity (%), Soluble sugars (mg), Vitamin C (mg), Beta carotene (µg), Calcium(mg) and Iron (mg). The results are presented in the following tables.

4.3.1 Moisture

Moisture content influences the taste, texture, weight, appearance, and shelf life of foodstuffs, hence it is an essential parameter to be assessed. The mean moisture content of tuberless colocasia for T1 was 88.0g and that for T2 was 86.8g. Mean value of water spinach for T1 was 71.6g, which was higher than T2 (70.2g). Mean value of malabar spinach for T1 was 92.8g, which was higher than T2 (82.2g). Statistical analysis revealed there was significant difference in the moisture content of malabar spinach among the treatments. The results are depicted in the table 9.

Table 9. Moisture content of the selected green leafy vegetables

Sl no	Vegetable Type	Moisture content (g/100g)		P value
		T1	**T2**	
1.	tuberless colocasia	88.00	86.80	0.06
2.	water spinach	71.60	70.20	0.46
3.	malabar spinach	92.80	82.20	3.33E

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

4.3.2 Fibre

Mean fibre content of tuberless colocasia grown under aquaponics (T1) was and of those cultivated under conventional conditions (T2) was 0.79g. Mean fibre content of water spinach was 0.57g for both T1 and T2. Mean fibre content of malabar spinach was 0.41g for T1which was higher than T2 0.27g. Statistical analysis revealed that there was significant difference among both the treatments in the case of malabar spinach.

Table 10. Fibre content of the selected vegetables

Sl no	Vegetable type	Fibre content (g/100g)		P value
		T1	**T2**	
1.	tuberless colocasia	0.79	0.79	0.96
2.	water spinach	0.57	0.57	0.91
3.	malabar spinach	0.27	0.41	2.24E

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

4.3.3 Total Minerals

Ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals within a food.

Mean total mineral content of tuberless colocasia of treatment T1 was 11.1g, which was slightly higher than treatment T2(8.7g). The mean total mineral content of water spinach under aquaponics cultivation (T1) was 13.8g and for treatment T2 i.e., water spinach grown in soil was 12.8g. Mean total mineral content of malabar spinach was higher for T1-14.2g, which was more than T2 being 9.8g. Statistical analysis as depicted in table 11, indicate significant differences in values of tuberlesscolocasia and malabar spinach.

Table 11. Total mineral content of selected leafy vegetables

Sl no	Vegetable type	Total mineral content (g/100g)		P value
		T1	**T2**	
1.	tuberless colocasia	11.1	8.7	0.018
2.	water spinach	13.8	12.8	0.538
3.	malabar spinach	14.2	9.8	0.010

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

4.3.4 Acidity (%)

Table 12. Acidity content of the selected leafy vegetables

Sl no	Vegetable type	Acidity (%)		P value
		T1	T2	
1.	tuberless colocasia	1.56	1.10	0.000
2.	water spinach	1.00	1.01	0.946
3.	malabar spinach	1.54	1.15	0.001

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

Mean acidity of tuberless colocasia for treatment T1 was 1.56%, which was higher than T2 (1.10 %), while mean acidity of water spinach of both treatments were on par. In the case of malabar spinach, acidity was higher for T1- (1.54%) than T2 (1.15%). Statistical analysis revealed significant difference among the treatmentscultivated in aquaponics and conventional systems for tuberless colocasia and malabar spinach.

4.3.5 Soluble sugars

Table 13. Soluble sugar content of selected leafy vegetables

Sl no	Vegetable type	Soluble sugars content (mg/100g)		P value
		T1	T2	
1.	tuberless colocasia	6.67	4.88	9.171
2.	water spinach	9.30	8.54	3.02E
3.	malabar spinach	7.68	5.94	4.65E

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

In general, soluble sugar content of green leafy vegetables was found to be higher for plants grown in aquaponics than the conventional ones (T2). Mean soluble sugar content of tuberless colocasia cultivated under T1 was 6.67 mg and those for conventional (T2) ones was 4.88mg. The content in water spinach for T1 was 9.30 mg which was higher than T2 (8.54 mg). Mean soluble sugar content of malabar spinach for T1 was 7.68 mg and for T2, it was 5.94mg. Statistical analysis revealed that there was significant difference among the treatments.

4.3.6 Vitamin C

Table 14. Vitamin C content of selected leafy vegetables

Sl no	Type	Vitamin C content (mg/100g)		P value
		T1	T2	
1	tuberless colocasia	31.79	14.55	1.221E-15
2	water spinach	32.43	27.52	9.47702E-05
3	malabar spinach	13.97	17.88	0.002

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

Mean Vitamin C content of tuberless colocasia under T1 was 31.79mg which was higher than T2 (14.55mg). Mean Vitamin C content of water spinach of T1which was grown on aquaponics was 32.43mg and T2 which was grown in soil was 27.52mg. But, mean Vitamin C content of malabar spinach of T2 (17.88mg) was higher than T1 (13.97mg). Statistical analysis revealed there was significant difference in the vitamin C content among the treatments. The results are depicted in the table 14.

4.3.5 Beta carotene

Table 15. Beta carotene content of the selected leafy vegetables

Sl no	Type	Beta carotene(µg/100mg)		P value
		T1	T2	
1	tuberless colocasia	7.66	6.56	7.45E
2	water spinach	12.46	9.33	3.57E
3	malabar spinach	4.63	1.66	4.93E

(Values indicated are mean of 10 replications) Tvalue-2.10 T1- Aquaponics treatment; T2 - Conventional treatment β-Carotene is the primary provitamin A carotenoid that occurs together with the three main xanthophylls: lutein, violaxanthin and neoxanthin, which are called the ‘‘chloroplast carotenoids,’’ and the chlorophylls a and b as well as smaller amounts of their cis-forms in the chloroplast of leafy vegetables (Kidmose *et al*., 2006).

Mean beta carotene content of tuberless colocasia grown under aquaponics (T1) was 7.66 µg/100mg and that for conventional one (T2) was 6.56 µg/100mg. The content of water spinach was higher for T1, which was 12.46µg/100mg, while T2 had only 9.33µg/100mg. Mean beta carotene content of malabar spinach for T1 was 4.63µg/100mg and that for T2 was 1.66µg/100mg. On the whole, the observation was that beta carotene content of green leafy vegetables cultivated under aquaponics was higher than leaves cultivated under conventional ones. Statistical analysis revealed that there was significant difference in Beta carotene content among the treatments. The results are depicted in the table 15.

4.3.8 Calcium

Table 16. Calcium content in the selected leafy vegetables

Sl no	Type	Calcium content(mg/100g)		P value
		T1	T2	
1	tuberless colocasia	215.92	187.62	1.63E
2	water spinach	457.29	422.57	9.16E
3	malabar spinach	752.09	731.61	0.00

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

Calcium has earned the title of “super nutrient” because of its role in reducing the risk for osteoporosis, hypertension and possibly colon cancer, as well as other disorders (Miller *et al*., 2001). In this study, mean calcium content of tuberless colocasia cultivated under aquaponics (T1) was 215.92 mg and that of T2 (Conventionally cultivated) was 187.62mg.

The content of the same mineral in water spinach was higher in T1-457.29mg, which was higher than T2- 422.57mg/100g. Mean calcium content of malabar spinach was higher for crops cultivated under aquaponics (T1) i.e.,752.09 mg, than crops cultivated by conventional practices (T2)-731.61mg. Statistical analysis revealed that there was significant difference among the treatments.

4.3.9 Iron

Table 17. Iron content of the selected leafy vegetables

Sl no	Type	Iron content (mg/100g)		P value
		T1	T2	
1	tuberless colocasia	56.13	33.53	1.94E
2	water spinach	273.60	246.39	0.00
3	malabar spinach	98.68	73.94	2.70E

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

The mean iron content of tuberless colocasia cultivated under aquaponics (T1) was 56.13mg /100 g and that of conventional one (T2) was 33.53mg /100 g. Mean iron content of water spinach for treatment (T1) was 273.60 mg /100 g which was higher than the conventional one (T2) 246.39 mg/100 g. Mean iron content of malabar spinach for (T1) was 98.68 mg /100 g and for (T2) was 73.94 mg /100 g. Statistical analysis revealed that there was significant difference among both the treatments.

4.4 Nutraceutical composition

Nutraceutical components analyzed were total phenols, phytic acid, tannins, oxalates, antioxidants.

4.4.1 Total Phenols

Table 18. Total phenol content of selected leafy vegetables

Sl no	Vegetable type	Phenol content (mg/100g)		P value
		T1	T2	
1	tuberless colocasia	37.46	45.78	2.08E
2	water spinach	82.07	32.93	5.96E
3	malabar spinach	33.22	12.25	2.65E

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

Phenolic substances are responsible for the antioxidant activity of plant materials which is gaining much interest these days because of their known health benefits. The antioxidant activity of phenolic compounds is mainly due to their redox properties, which can play an important role in adsorbing and neutralizing free radicals, quenching singlet and triplet oxygen, or decomposing peroxides (Osawa,1994).

Mean total phenol content of tuberless colocasia of T2 was higher (45.78mg) than treatment T1 (37.46). Mean total phenol content of water spinach and malabar spinach was higher for crops cultivated on aquaponics than cultivated on conventional ones. The differences were statistically significant.

4.4.2 Phytic acid

Table 19. Phytic acid content of the selected vegetables

Sl no	Vegetable Type	Phytic acid content (g/100g)		P value
		T1	T2	
1.	tuberless colocasia	5.17	9.09	6.20E
2.	water spinach	2.44	3.24	0.00
3.	malabar spinach	2.81	4.19	5.86E

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

Mean phytic acid content of tuberless colocasia under T1 was 5.17 g and for T2 was 9.09g. While, mean phytic acid content of water spinach cultivated under aquaponics (T1) was 2.44 g and that of T2 was 3.24 g. Mean phytic acid content of malabar spinach for T2 was 4.19g which was higher than T1 (2.81g). The values were significantly different.

4.4.3 Tannins

Table 20. Tannins content of selected leafy vegetables

Sl no	Vegetable type	Tannin content (mg/100g)		P value
		T1	**T2**	
1.	tuberless colocasia	96.04	90.01	0.00

2.	water spinach	81.32	76.04	0.00
3.	malabar spinach	58.11	52.58	7.2E

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

Tannins are phenolic compounds that are composed of a very diverse group of oligomers and polymers. Mean tannin content of tuberless colocasia for T1 was 96.04mg which was higher than T2 (90.01mg). Mean tannin content of water spinach cultivated under aquaponics (T1) was also seen to be higher (81.32mg) in comparison to conventionally cultivated ones (T2)- 76.04mg. Mean tannin content of malabar spinach for T1 was 58.11mg which was higher than T2 (52.28). Statistical analysis also revealed that there was significant difference among the treatments.

4.4.4 Oxalates

Table 21. Oxalate content of the selected leafy vegetables

Sl no	Vegetable type	Oxalates content (mg/100g)		P value
		T1	**T2**	
1.	tuberless colocasia	74.8	83.6	0.13
2.	water spinach	44.0	44.0	-
3.	Malabar Spinach	66.0	66.0	-

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

Mean oxalates content of tuberless colocasia in aquaponics unit (T1) was 74.8 mg which was lower than treatment T2 (83.6mg), the conventionally cultivated ones. But with regard to water spinach and malabar spinach there was no change in the oxalates content of both the treatments. Statistical analysis revealed that there is no significant difference among both the treatments.

4.4.5 Antioxidants

Table 22. Level of Antioxidants in the selected leafy vegetables

Sl no	Vegetable type	Antioxidants content (mg/100g)		P value
		T1	T2	
1.	tuberless colocasia	95.90	89.56	1.11E
2.	water spinach	95.59	89.45	5.03E
3.	Malabar Spinach	96.58	76.12	7.81E

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

Mean antioxidants content of tuberless colocasia of T1 was 95.90 mg/100g, which was higher than T2- 89.56 mg/100g, mean antioxidant content of water spinach grown in aquaponics unit was 95.59 mg/100g, which is again higher than those grown conventionally (T2) - 89.45 mg/100g, Mean antioxidants content of malabar spinach of T1 was found to be 96. mg/100g, which was much higher than T2 (76.12 mg/100g). The values were significantly different.

4.5 Shelf life

Greater shelf life of vegetables is needed for the farmer to avoid economic loss. Shelf life of the vegetables was determined with respect to two parameters namely, duration with respect to onset of visible marks of deterioration and physiological loss of water (PLW).

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

4.5.1 Duration with respect to onset of visible marks of deterioration.

Table 23. Shelf life of selected leafy vegetables in ambient temperature(days)

	Shelf life(days)		
Vegetabletype and treatment	Control	PP covers	News paper
tuberless colocasia			
T1	6	6	7
T2	5	5	6
water spinach			

T1	3	3	4
T2	2	3	3
malabar spinach			
T1	6	4	6
T2	5	4	6

Table 23 shows that shelf life of 7 days was observed for tuberless colocasia when leaves are packed in newspaper. For water spinach there was no significant difference for both the treatments. For malabar spinach shelf life of 6 days was observed when they were packed in newspaper and PP covers.

Table 24. Shelf life of selected leafy vegetables in Refrigerated temperature(days)

	Shelf life(days)		
Vegetable type and Treatment	**Control**	**PP covers**	**Newspaper**
tuberless colocasia			
T1	8	7	8
T2	8	6	8
water spinach			
T1	4	5	6
T2	4	5	6
malabar spinach			
T1	8	4	6
T2	7	4	6

T1 - Aquaponics treatment; T2 - Conventional treatment

Table 24 shows that tuberless colocasia had a shelf life of 8 days when the leaves were packed in newspapers and control. For water spinach there was no significant difference for both the treatments. For malabar spinach shelf life of 8 days was observed when they were kept in control

4.5.2 Physiological loss of water (PLW)

Table 25. Physiological loss of water during storage of tuberless colocasia (0-6 days)

Storage in Ambient Conditions (%)		
Packing material	T1	T2
PP covers	25.42	24.60
Newspaper	60.12	59.07
Nil	52.82	53.84
Storage in Refrigerated Conditions (%)		
PP covers	10.99	10.91
Newspaper	16.77	15.76
Nil	33.98	33.77

T1- Aquaponics treatment; T2 - Conventional treatment

Table 25 – reveals no significant changes in the extent of physiological loss of water among both the treatments, when stored in ambient conditions and refrigerated conditions in PP covers. The moisture loss was higher when they were packed in newspaper and control when compared with PP covers. This loss was to a greater extent in ambient conditions.

Table 26. 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 26 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.

Table 27. Physiological loss of water during storage of malabar spinach (0-6 days)

Storage in Ambient Conditions (%)		
Packing material	T1	T2
PP covers	+11.85	+11.79
Newspaper	23.19	21.57
Nil	6.29	5.18
Storage in Refrigerated Conditions (%)		
PP covers	+12.51	+11.61
Newspaper	16.09	15.63
Nil	39.07	38.04

T1- Aquaponics treatment; T2 - Conventional treatment

Table 27 shows that vegetables packed in PP covers showed increased moisture content on storage in ambient and refrigerated conditions. But control and newspaper packing resulted in increase PLW, being higher for T1.

The difference in weight of leaves with respect to length of storage, packing conditions and temperature were analysed for each crop. The details are presented in the following tables.

Table 28. Effect of packaging material on weight of tuberless colocasia-T1

	Weight difference (%)					
Period	**Ambient conditions**			**Refrigerated conditions**		
	PPcovers	**Newspaper**	**Nil**	**PP covers**	**Newspaper**	**Nil**
2nd day	-10.11	-17.45	-32.67	+5.90	-8.89	-20.57
4th day	-14.89	-36.80	-45.56	+4.56	-10.82	-29.34
6th day	-25.42	-60.12	-52.82	+10.99	-16.77	-33.98

In ambient conditions, moisture loss was seen in PP covers and paperpackings as in control, while in refrigerated conditions, leaves packed in PP covers showed gain in moisture of nearly 11 per cent.

Table 29. Effect of packaging material on weight of tuberless colocasia -T2

	Weight difference (%)					
Period	Ambient condition			Refrigerated condition		
	PPcovers	Newspaper	Nil	PPcovers	Paper	Nil
2nd day	-10.45	-36.67	-33.89	+8.89	-6.80	-22.45
4th day	-22.25	-50.12	-43.30	+7.06	-9.56	-31.90
6th day	-24.60	-59.07	-53.80	+10.91	-15.76	-33.77

The trend in weight changes were comparable to T1, with regard to packing, duration and surrounding temperature. Leaves in refrigerated conditions gained weight when packed in PP covers.

Table 30. Effect of packaging material on weight of water spinach-T1

	Weight difference (%)					
Period	Ambient condition			Refrigerated condition		
	PP covers	Newspaper	Nil	PP covers	Newspaper	Nil
2nd day	-10.11	-40.45	-20.67	+15.90	-24.89	-20.57
4th day	-14.89	-46.80	-39.56	+19.56	-41.82	-37.34
6th day	-26.62	-67.82	-62.18	+12.01	-58.25	-56.20

Leaves packed in newspaper showed extreme weight loss to the tune of 68% in ambient conditions and 58 per cent in refrigerated conditions. Leaves in PP covers gained weight in refrigerated conditions (12%).

Table 31. Effect of packaging material on weight of water spinach-T2

	Weight difference (%)					
Period	Ambient condition		Refrigerated condition			
	PPcovers	Newspaper	Nil	PP covers	Newspaper	Nil
2nd day	-9.45	-46.67	-21.89	+10.89	-26.80	-22.45
4th day	-13.25	-50.12	-39.30	+15.06	-43.56	-36.90
6th day	-25.57	-70.00	-64.80	+11.76	-60.6	-57.23

Weight loss was greater in ambient conditions than refrigerated conditions, newspaper packing revealed greater weight loss to the tune of 70% in ambient and 60 per cent in refrigerated conditions.

Table 32. Effect of packaging material on weight of malabar spinach-T1

Period	Weight difference (%)					
	Ambient condition			Refrigerated condition		
	PPcovers	Newspaper	Nil	PP covers	Newspaper	Nil
2nd day	+10.11	-17.45	-2.67	+15.90	-14.89	-40.57
4th day	+14.89	-16.80	-5.56	+14.56	-18.82	-39.34
6th day	+11.85	-23.19	-6.29	+12.51	-16.09	-39.07

Gain in weight of leaves packed in PP covers was to the tune of 11% in ambient conditions and 13 per cent in refrigerated conditions. Weight loss was higher in paper packed leaves in ambient conditions than refrigerated conditions; while without packing, weight loss was higher in refrigerated conditions.

Table 33. Effect of packaging material on weight of malabar spinach-T2

Period	Weight difference (%)					
	Ambient condition			Refrigerated condition		
	PP covers	Newspaper	Nil	PP covers	Newspaper	Nil
2nd day	+10.45	-20.67	-3.89	+8.89	-16.80	-2.45
4th day	+12.25	-21.12	-5.30	+7.06	-19.56	-4.19
6th day	+11.79	-23.19	-6.29	+11.61	-21.57	-5.18

Weight gain of leaves was comparable, when packed in PP covers in ambient and refrigerated conditions; newspaper packing also revealed comparable weight loss in the range of 21-23% in ambient and refrigerated conditions. Lesser weight loss was observed in leaves without any packing.

Shelf life of leaves were not seen to show differences among the treatments. Packing in PP covers were generally seen to be ideal for all the three leaf varieties.

The results of the study are discussed in the following chapter.

Discussion

5. DISCUSSION

This chapter encompasses a critical appraisal of the salient findings of the study'Quality evaluation of vegetables cultivated through aquaponics' and the discussion is presented herewith under the following subheads.

5.1 Physical qualities

5.2 Sensory Parameters

5.3 Nutrient composition

5.4 Nutraceutical composition

5.5 Shelf life

5.1 Physical qualities

In the present study physical characteristics studied for green leafy vegetables were the number of harvests and total dry matter production.

5.1.1 Number of harvests

The study revealed comparable results for T1 and T2 in the case of tuberless colocasia and malabar spinach, while for water spinach T2 showed poor growth. Saha *et al*. (2016) observed higher yield in aquaponic and hydroponic systems than conventional system. When aquaponic basil produced 1.8 kg m^{-2}, field basil produced 0.6 kg m^{-2} (Rakocy *et al*., 2004).

Nitrogen has the major role in plant growth (Evert and Eichhorn, 2013), and it is referred to as the vital nutrient for crop yield (Blumenthal *et al.*, 2008).Therefore the more available N helped the aquaponic basil, to achieve 14 per cent greater plant height and 56 per cent more fresh weight. Savidov (2005) and Lennard and Leonard (2006), too observed similar results in tomato, cucumber, and lettuce grown under aquaponic systems compared to hydroponicsystems. Both nitrogen and phosphorous were available in optimum amounts to favour growth of the plants in the aquaponics unit.

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).

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).

The yield of lettuce cultivated in aquaponic system was 6.73 per cent higher than that grown in hydroponic system. LikewiseLettuce yields were higher in aquaponic systems which is suggested to be due to the consistent flow of nutrients into the roots, that were totally immersed with wastewater. The higher contact time of roots with the nutrient effluent gave more chances for plants to acquire nutrients, indicating that crop production was affected by type of cultivation (Lennard and Leonard, 2004 and 2006).

5.1.2 Total dry matter production

Seginer *et al*. (2004) reported that nitrogen stress led to increased dry matter production that was 3-4 times higher than the normal. Nozzi *et al.* (2018), 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 present study tuberless colocasia and water spinach grown in aquaponics had higher dry matter content, probably due to the unavailable nitrogen.

5.2 Sensory parameters

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). All T1 plants were observed to have better sensory qualities in this study.

Firmness is an important quality parameter of fruits that decides the time of harvest, transport, storage or market. Lopez *et al.* (2013) in their study on tomatoes observed that the main physical parameter influenced by the soilless system was firmness, which showed higher values than those achieved in soil.

This was in contrast to what Thybo *et al*. (2005) reported that the major variation in tomatoes cultivated in different systems was due to differences in variety, maturity, harvest time and electric conductivity (EC), and that the type of media had no impact on this.

Gruda (2009) 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), observed that the cropping system did not affect color, it was the harvesting time that was more pronounced.

Gruda (2005) observed that sensory ingredients such as sugars, acids, flavor substances as well as vitamins and secondary plant compounds were affected by changing the climate conditions in the greenhouse. Ho (2004), 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.

Khandaker and Kotzen (2018) indicated that the aquaponically grown bitter gourd was preferred and better in taste than the traditionally grown and imported bitter gourd.

5.3 Nutrient Composition

The importance and awareness of nutrition in public health has resulted in increased demands for knowledge of nutrient content of foods. The nutrients analysed in this study were moisture, fibre, total minerals, acidity, soluble sugars, vitamins and minerals.

5.3.1 Moisture

Moisture affects the activity of enzymes and co enzymes needed for maintaining the metabolism of the leaves. Badau *et al.* (2013) 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), being 72.83 per cent. The moisture content of green leafy vegetables cultivated through aquaponics was higher than cultivated through soil. Vincente *et al*. (2014) had pointed out the cultivation conditions impact structural differentiation which will have a marked effect on moisture content.

5.3.2 Fiber

The dietary fiber has become significant due to its beneficial effects in human nutrition viz., management and diabetes, heart diseases, obesity and gut health (Dhingra *et al.*, 2012). Crude fibre was higher in organically produced fruits compared to conventionally cultivated or control fruits (Abu Zahra *et al.*, 2006).

This study however showed on par results for fibre content between conventionally grown and experimental treatments.Yirankinyuki *et al*. (2013) observed that the crude fiber content of tuberless colocasia leaves was 1.00 per cent. Crude fiber content of water spinach was accounted for to be 1.76 ± 0.35 per cent (Umar *et al*., 2007). Whereas, crude fiber content of malabar spinach was 7.23 ± 0.17 per cent (Tongco *et al*., 2015). Fiber content of malabar spinach leaves was accounted for as 0.9 g/100g of edible portion (Oloyede *et al.*, 2013). Being organic and enriched with fibre increases its health value (Anderson *et al.*,1994).

5.3.3 Total Mineral

Ash is formed when oxidation of plant material in fire has progressed beyond charring, to the point where the carbon, hydrogen and oxygen components are to a great extent vaporized. The small amounts of mineral constituents in the plant then become the main component left behind as ash (Canti and Brochier, 2017). High ash content signifies that the leaves are rich in minerals (Alinnor and Akalezi, 2010). Umar *et al.* (2007) reported that the ash content of water spinach was 10.83±0.80 per cent. The ash content for malabar spinach (*Basella alba)* was reported to be 12.93 ± 0.10 per cent (Akanfe, 2013).

Results of this study reveals higher ash content of the various leaves cultivated through aquaponics. In contrast to this observation, the ash content was higher for conventionally cultivated vegetables in comparison with organically cultivated ones, as reported by Lombardo *et al*. (2012). Colla *et al.* (2002) and Rembialkowska (2007) also have similar findings, and attribute it to the changed physico chemical and microbial quality of the soil. Yirankinyuki *et al.* (2013) reported that the ash content of tuberless colocasia leaves was 10.00 per cent. Total mineral content is depicted in figure 1.

5.3.4 Acidity

Most green leafy vegetables are reported to have an alkaline effect. Variation in organic acids probably explains the interspecific variation in acidity of foods. Liao *et al.* (2019) observed that accumulation of metabolites like organic acids was closely related to nitrogen concentration; nitrogen has a role in limiting glucose, required for synthesis of ascorbic acid. The higher values of acidity in tuberless colocassia leaves and malabar spinach of the aquaponic unit could be due to slower nitrogen discharge in the aquaponics system. However, the results are not seen to be significantly different.

5.3.5 Soluble sugars

Soluble sugars together with organic acids are essential components of taste, this in combination with aromas, that have an impact on the overall organoleptic quality of fruits and vegetables. Fruit taste depends on the content and type of soluble sugars and organic acids (Bordonaba and Terry, 2010).

Soluble sugar is the primary product of photosynthesis (Voskresenskaya, 2003). The information on soluble sugar levels are important in deciding glycemic control for diabetic patients (Bavec *et al*., 2010).

Soluble sugar level was affected more by the time of harvest of green peppers ($P < 0.001$). Glucose and fructose concentrations relied upon the cropping system. They were seen to reduce by the end of the growing period, when level of sucrose increased. Higher sugar concentrations were reported in 2006 than in 2005 ($P <0.001$). Even the cropping system was significantly dependent on harvesting time.

Soluble sugar content was higher in T1treatment of this study. In comparison to green fruits, glucose and fructose concentrations were 1.8- fold higher than ripe fruits, while the sucrose concentration was lower. Compared to soil less cultivation, the concentrations of glucose and fructose was lower in organically cultivated one (Flores *et al.*, 2009).

Yoon *et al*. (2017) 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. Higher sugar, phenols, ascorbic acid and halo acetic acids levels were observed in plants cultivated in soil less media (Flores *et al*., 2009).

5.3.6 Vitamin C

Oluwakemi *et al*. (2017) stated in his study that the vitamin C content of malabar spinach was 19.38 mg/100g. The levels of Vitamin C are in line with the observations of T2 in this study. Vitamin C content was higher in T1 of the three types of leafy vegetables.

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).

An approximately 6 per cent higher vitamin C content in organic crops was reported by Brandt *et al*. (2011). It has been hypothesised that a high availability of plant nutrients, specifically nitrogen, through fertilisers may shift plant metabolism towards more pronounced growth and less pronounced defence. This has served as a rationale for hypothesising a higher content of antioxidant compounds, in crops from organic production (like aquaponics), compared to crops from conventional production. Vitamin C content is depicted in figure 2.

5.3.5 Beta carotene

Apart from being an accessory pigment, beta carotene is involved in non-photochemical quenching (dissipating excess energy from the photosystems as heat) and is also a potent ROS scavenger (Becker *et al*., 2015). Carotenoids are perceived as powerful natural antioxidants that help prevent a broad range of cancers and cardiovascular diseases (Rao, 2002).

The results of this study show significantly higher levels of beta carotene in aquaponically cultivated plants. The enhancement of water and soil nutrient uptake through water could have enhanced photosynthetic performance which in turn triggers an increase in synthesis of carotenoid pigments (Schopfer and Brennicke, 2006).

Carotene and its associated compounds were lower in content of hydroponically grown lettuce than conventionally grown ones. Lower carotenogenesis was attributedto lower sunshine, in the polythene covered units that even resulted in lower temperature (Kimura and Rodriguez -Amaya, 2003).Kidmose *et al*. (2006), identifies the factors affecting carotene synthesis as genetics, site conditions, climate and maturity. Since both the treatments of this study were placed under poly house conditions, this difference is not applicable here.

5.3.6 Calcium

Calcium is a known antidote for osteoporosis, hypertension and many types of cancers. It is physiologically essential for functioning of nerves, muscles, bones and blood coagulation (Miller *et al.*, 2006). Researches report the probable beneficial role of calcium, in particular, calcium-rich lowfat dairy foods, in weight management (Zemel, 2000).

Yirankinyuki *et al.* (2013) observed the level of calcium in tuberless colocasia to be 2.15mg/100g. The leaves of *Xanthosomas agittifolium* grown on aquaponics, revealed higher levels of minerals -iron (Fe), potassium (K), calcium (Ca) and manganese (Mn) (Cardoso *et al.*, 2019). Calcium content of water spinach leaves was 419.70 mg/100g, in the analysis report of Umar *et al.* (2007), which is in line with the T2 water spinach samples of this study.

However, Akanfe (2013), reported calcium content of 964mg/kg in malabar spinach samples; while, Oloyede *et al*. (2013) reported calcium levels to be 14.3 mg/100g in the same variety, which did not compare favorably with the T2 samples of this study.

In this study, overall analysis revealed higher amounts in T1 samples. Cassman *et al*.(2002) observed that, plant nutrient availability and uptake ability can be improved by the overall N balance and on the amount of nitrogen reserves. Probably the higher nitrogen accessible in aquaponic plants improved uptake of minerals like calcium.

5.3.7 Iron

Various studies on conventionally cultivated tuberless colocasia, malabar spinach and water spinach have been reported from various parts of the world. Umar *et al.* (2007), stated the iron content of water spinach as 210.30 mg/100g dry matter. Yirankinyuki *et al*. (2013) reported iron content of tuberless colocasia as 4mg/100g, While Gupta*et al.* (2019) reported the same to be in the range of 3.4-11.7 mg 100 g^{-1}. Iron content of 177.5 mg/100g was reported for malabar spinach by Oloyede *et al.* (2013). The variability in cultural practices, climate and variety could be the reason for the variable results.

Roosta and Hamidpour (2013) reported that the concentrations of Mg, Na, Fe and Zn were higher in aquaponic plants in comparison to those of hydroponicsThis is presumed to be because of the dissolved organic matter formed due to microbial decomposition of fish food and faces, which complexes with Fe and Zn, that increases availability.

The pH of aquaponic media is seen to range between 6-9 (Zou *et al.*, 2016), this suits the requirement of nitrifying bacteria; 7-8.5 (Tyson, 2004; Goddek *et al*., 2015), but for nutrient availability the pH needed is 5.5 to 7.2 (Tyson *et al*., 2008; Da Silva Cerozi and Fitzsimmons, 2016), so precipitation of Fe, Mn, P, Ca, and Mg do not take place (Tyson, 2011). Maintaining a pH of 7 caters to both these requirements (Rakocy, 2012).

The higher levels of nitrogen and phosphorous, is seen to positively influence yield, but not the nutrient content of the leaves. Both plants of hydroponics and aquaponics reveal on par nutrient values. Saha *et al*. (2016) reported that the boron (B), copper (Cu), iron (Fe), manganese (Mn), sodium (Na), and zinc (Zn) content of aquaponic and hydroponic basil were not significantly different. This explains the higher content of iron in T1of all plants in this study. Iron content is depicted in figure 3.

5.4 Nutraceutical composition

Nutraceuticals play a major role in the maintenance of health and treatment of diseases, without any side effects. The nutraceutical property of a food is decided by the bio active compounds present in that food. Nutraceutical components analyzed in this study were total phenols, phytic acid, tannins, oxalates, antioxidants.

5.4.1 Total Phenols

Phenols along with fibers vitamins, minerals, essential amino acids and phytochemicals such flavonoids, sterols, carotenoids and tannins responsible for the high antioxidant property of plant foods. Phenolics form a heterogenous group of compounds. They are produced in response to stressed conditions Various reports on conventionally cultivated leaves of the same species have been reported. The study revealed higher phenol content in T1 of water spinach and malabar spinach. Maisuthisakul *et al*. (2008) reported total phenolic content of malabar spinach was 15.5 mg GAE/g. Oluwakemi *et al*. (2017), reported that total phenolic content of malabar spinach was 61.00 and 90.52 mg/100g fresh weight for the green and red cultivars respectively. The total phenolic contents of malabar spinach were found to be 93.89 and 85.13 mg gallic acid equivalents (GAE)/g extract for ethanol and aqueous extracts, respectively (Tongco *et al*., 2015). Mariani *et al*. (2019) observed that the total phenolic content of water spinach extract was 76.96 ± 2.245 mg / g GAE.

Ibrahim *et al*. (2018) observed that phenols decreased with higher nitrogen fertilization levels.

Naguib *et al*. (2012), also reported similar findings in his study on broccoli. Another result obtained by Stewart *et al*. (2001) 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 *etal*., 2018; Ru *etal*., 2017; Wongkiew *etal*., 2017; Yavuzcan Yildiz *etal*., 2017). Hence the uncertain nitrogen levels could be reason for the higher phenol content.

According to Orphanides *et al*. (2013), Nitrogen based compounds are not synthesized in N deficiency, whereas carbon-based secondary compounds will be synthesized, thus decreasing the synthesis of nitrogen-based secondary compounds. Ibrahim *et al*. (2011), stated that the increase in total phenolics production under low N level can also be attributed to increase of total carbon- based secondary metabolites.

5.4.2 Phytic acid

Phytic acid is the main storage form of phosphorus (P), which has many metabolic functions like the storage of mineral elements like K, Mg or Ca; RNA transport, DNA metabolism etc., (Raboy, 2003). 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). The amounts of phytic acid in leaves are mostly lower than those of storage organs (Lott *et al*., 2000; Raboy, 2003).

Plants grown in aquaponics showed lower levels of phytic acid in this study. Thomas and Oyediran (2008) reported that phytate content of tuberless colocasia leaves was 0.47± 0.02 mg/100 g fresh samples. Raghuvanshi *et al.* (2001) reported that the phytic acid content of the analysed GLVs was found to be in the range of 0.92–13.06 mg/100 g fresh vegetable.

Gartmann *et al*. (2019) pointed out that higher phytate content could be due to the high Phosphorous content of the media; high pH favoured its accumulation along with Ca.

5.4.3 Tannins

Tannins are a class of phenols that act as free radical scavengers. They also are responsible for protein (Bhat *et al*., 2013). The molecular weight, number of aromatic rings, and the nature of hydroxyl group substitution, are factors affecting their bio activity. Through HCl method, deep blue spinach was visibly recognizable as high in tannin content - Condensed tannin being- 0.293 per cent (Gupta and Verma, 2011).Tannins content is depicted in figure 4.

The presence of tannins in the seeds of cereals and legumes has been thought to be of the factors involved in decreased protein digestibility. Most berries, for example, cranberries and blueberries contain hydrolysable and condensed tannins (Gupta and Verma, 2011).

Chabeli *et al*. (2008) reported that condensed and hydrolysable tannins increased in a quadratic fashion in response to N nutrition, perhaps representing the higher tannin content in aquaponically cultivated leaves in this study. Tannin content of leaf extract of conventionally cultivated water spinach was reported to be 0.24 + 0.02 % (Omale *et al*., 2009).

5.4.4 Oxalates

Calcium oxalate is a vital compound found abundantly in higher plants. They are responsible for maintaining calcium balance and protection from herbivores (Molano-Flores, 2001); detoxifying action (Franceschi and Nakata, 2005), imparting tissue strength and processing sunlight (Kuo-Huang *et al*., 2007). They infact precipitate out when calcium levels go abnormally high (Faheed *et al*., 2013).

Oxalate levels vary with plant parts, being highest in leaves and lowest in stems. Seeds have them on a moderate level. Its content is seen to increase with maturity. Oxalic acid formed 15 per cent of the dry weight of mature leaves of goose foot family, indicating that end products of metabolism.

Oxalate is an end product of glycolate metabolism (Franceschi and Nakata, 2005). Excess calcium and nitrates in the media are buffered by more oxalate that implies better nitrogen absorption and also cation–anion imbalance (Rinallo and Modi, 2002). Sheela *et al.* (2004), reported that the oxalic acid content of malabar spinach ranged from 60 to 84mg per 100g of edible portion. Zhang *et al.* (2009) reports that nitrogen and calcium nutrition affected oxalate levels probably this is reflected in the case of tuberless colocasia of this study.

5.4.5 Antioxidants

Hassimotto *et al.* (2005) observed that, that antioxidant activity is a combination of synergistic and hostile action of various compounds; they did not find any relationship between total phenolics content, vitamin C and antioxidant activity. Ren *et al*. (2017) had observed higher flavonoid and phenol contents in organic treatments, which eventually affects anti-oxidant activity. This is likely to be the cause for plants in aquaponics showing higher antioxidant activity, in this study also. Huang *et al*. (2005) reported 63.90 per cent of antioxidant activity in conventionally cultivated water spinach samples. Oloyede *et al.* (2013) in their study reported that antioxidant content of malabar spinach cultivated conventionally was 89 per cent.

5.5 Shelf life

5.5.1 Duration with respect to onset of visible marks

The shelf life of a food can be defined as the time period within which the food is safe to consume and/or has an acceptable quality to consumers. Shelf life assessment helps to have a knowledge of the commercial life of a product, without spoilage and with maximum appeal (Riva *et al*., 2001).

Roof top farming reduces transportation time, thereby producing fresher and longer shelf-life vegetables (Hartogs, 2013). Both harvest maturity and postharvest handling techniques are frequently geared toward extending the shelf-life of fresh produce after harvest (Baldwin *et al.*, 2007).

Vegetables remained fresh below 8^oC and above that temperature, tissue breakdown with discharge of bound electrolytes, yellowing and decay with off odours results. Temperature abuse in early stages did less harm than later stages (Kou *et al*., 2014).

Physiological state and shelf life of a fruit or vegetable reflects its response to the environment (Arora *et al.*, 2002; Zhou *et al.*, 2004; Pandrangi and Laborde, 2004; Francis and O'Beirne, 2001). This study did not show variations among the treatments with respect to shelf life.

Shelf life in harvested fruits and vegetables are mostly evaluated by the analysing the extent of electrolytes leaking out (Kou *et al*., 2012; Luo *et al.*, 2004).

Pandrangi and LaBorde (2006) reported higher loss of carotenoids with increase in temperature from 4^oC to 10^oC and 20^oC.

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).

The postharvest behaviour of Atemoya a semi-deciduous, exotic subtropical fruit was studied. Packing individual fruits was seen to give the best results. Fruits packed in PD -955 had a shelf life of 17 days at 15°C, while uncovered atemoyas had a shelf life of 13 days. PD -955 was preferred because of the low permeability of carbon dioxide and oxygen (Yamashita *et al*., 2002).

5.5.2. Physiological loss of water (PLW)

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).

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).

The results of the storage and packaging conditions on water loss from leaves of amaranth and fenugreek showed that water content of leaves decreased in all temperature regimes. Low temperature and high humidity conserves the freshness of the leaves, which is enhanced further by covering with polyethylene films. The maximum storage life achieved was 4 days in all the packaged samples of amaranth, and 6 days in fenugreek packaged samples stored at cool chamber and walk-in cooler conditions (Negi and Roy, 2003).

The results of this study had showed least shelf life for water spinach, as it is an aquatic plant that cannot survive outside its habitat. High moisture content becomes favourable for microbes to thrive and cause spoilage in the vegetables (Santos and Silva, 2008). Weight loss during storage has been seen to vary with the packaging conditions and storage temperature of spinach (Pandrangi and Laborde, 2004).

An analysis of change in moisture contents of the leafy vegetables during storage (0-6 days) with and without packing are depicted in the figures (5-8)

The study affirms the high or on par quality of tuberless colocasia, water spinach and malabar spinach grown in aquaponics. There is great scope for producing these vegetables at the homesteads and even at the community level.

Summary

6. SUMMARY

The present study entitled, 'Quality evaluation of vegetables cultivated through aquaponics' was conducted to compare the quality characteristics of selected green leafy vegetables cultivated through aquaponics (T1) and conventional methods (T2). The vegetables selected for the study were tuberless colocasia, water spinachand malabar spinach. Therefore, the two treatments in the study were –T1- Plants cultivated through aquaponics and T2- Plants cultivated through conventional practices (Organic POP).

The capacity of the grow bed of the aquaponics unit selected was 400 L and that of the fish tank was 500 L. Hundred tilapia fishes were grown along with the plants.The quality parameters assessed in the study were physical characteristics, sensory qualities, nutrient composition, nutraceutical composition and shelf lifequalities.

Physical characteristics were assessed with respect to number of harvests and total dry matter production. The yield of tuberless colocasia and malabar spinach were comparable among the two treatments. The yield of water spinach was higher for aquaponics samples (T1) than the conventional ones. Except for malabar spinach,the total dry matter production of tuberless colocasia and water spinach was higher for plants cultivated in aquaponics than conventional ones.

Sensory qualities evaluated for the study were; appearance (raw vegetable), colour (raw vegetable), flavor (raw and cooked vegetable), flavor (raw and cooked vegetable) and taste(cooked vegetable).All parameters of T1were found to be higher than T2,Analysis of scores revealed that flavor and texture of cooked tuberless colocasiawere significantly higher in comparison to T2. In the case of water spinach, significantly higher scores were offered for appearance and color of fresh leaves of T1, (z value-3.023 and 2.305 respectively).

Nutrients analysed in the experiment were moisture, fibre, total minerals, acidity,soluble sugars,vitamin C, beta carotene, calcium and Iron.Significant difference was found in the moisture content and fibre content of malabar spinach among the treatments. Statistical analysis revealed significant difference among the treatments cultivated in aquaponics and conventional systems for tuberless colocasia and malabar spinach, in total minerals and acidity content. Nutrient analysis revealed significant differences for soluble sugars, vitamin C, beta carotene, calcium and Iron between the parameters. T1 treatments revealed higher values.

Nutraceutical components analyzed weretotal phenols, phytic acid, tannins,oxalates and antioxidants. Phenol content was significantly higher in T1 of water spinach and malabar spinach (P value – 5.96707 E-22 and 2.65 E respectively). When phytates were higher in T_2, tannin content was significantly higher in T1. Antioxidant content was higher in T1 (in the range of 95.59 to 96.58 mg/100 g).

Shelf life studies revealed that tuberless colocasia (T1) remained fresh for 7 days when packed in newspaper, while T2 tuberless colocasia, kept only for 6 days in similar packing.water spinach had the least shelf life in ambient conditions-T1 had 4 days and T2 had 3 days, when packed in newspaper. Physiological loss of water was not found to be significantly different among both the treatments of any ofthe vegetables.

In the case of tuberless colocasia, PLW was higher in paper packing, placed in ambient conditions, being slightly higher in T1. water spinach packed in PP covers showed weight gain of up to 12 per cent. But the difference among the treatments was not significant.

Shelf life of leaves were not seen to show differences among the treatments. Packing in PP covers were generally seen to be ideal for all the three leaf varieties.

Overall analysis of the results revealed that, physical characteristics, sensory qualities, nutrient composition, nutraceutical composition and shelf life parameters of T1 were on par with T2, infact higher in most cases,indicating the scope of raising these vegetables successfully in households for Food and Nutrient security.

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QUALITY EVALUATION OF VEGETABLES CULTIVATED THROUGH AQUAPONICS

by

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(2018-16-004)

ABSTRACT

Submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN COMMUNITY SCIENCE

(Food Science and Nutrition)

Faculty of Agriculture

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF COMMUNITY SCIENCE

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2020

ABSTRACT

The project entitled "Quality evaluation of vegetables cultivated through aquaponics" was carried out at the Department of Community Science, during 2018-2020. The objective of the study was to compare the quality characteristics of selected green leafy vegetables cultivated through aquaponics (T1) and conventional methods (T2).

The capacity of the grow bed of the aquaponics unit selected was 400 L and that of the fish tank was 500 L.tuberless colocasia, water spinach and malabar spinach were the selected green leafy vegetables.Hundred tilapia fishes were grown with the plants. After the plants attained maturity, the physical characteristics, sensory qualities, nutrient composition, nutraceutical composition and shelf life of the two treatments of these leafy vegetables were studied.

Except for water spinach, yield of malabar spinach and tuberless colocasia were comparable in both the treatments. Dry matter production of T1tuberless colocasia(119.5g/plant) was higher than T2 (45.25g/plant).

Higher values for sensory qualities in both fresh and cooked samples of T1were obtained with respect to colour, appearance, texture, taste and flavor. In the case of water spinach, the higher scores obtained for appearance and colour of fresh leaves were significantly different (z value-3.023 and 2.305 respectively).

Nutrient analysis revealed significant differences in the moisture content and fibre content of malabar spinach among the treatments. Statistical analysis revealed significant difference among the treatments cultivated in aquaponics and conventional systems for tuberless colocasia and malabar spinachwith respect to total minerals and acidity content. Nutrient analysis revealed significantly highervalues for soluble sugars, vitamin C, beta carotene, calcium and Iron for T1.

In nutraceutical profile analysis, except for oxalate content, there was significant differences among the treatments.

Shelf life studies revealed that tuberless colocasia (T_1) remained fresh for 7 days when packed in newspaper, while T_2tuberless colocasia, kept only for 6 days in similar packing. water spinach had the least shelf life in ambient conditions -T1 had 4 days and T_2 had 3 days, when packed in news paper. Physiological loss of water was not found to be significantly different in any of the treatments of these vegetables.

Shelf life of leaves were not seen to show differences among the treatments. Packing in PP covers were generally seen to be ideal for all the three leaf varieties.

Overall analysis of the results revealed that, physical characteristics, sensory qualities, nutrient composition, nutraceutical composition and shelf life parameters of T_1were on par with T_2, or even higher in most cases, indicating the scope of raising these vegetables successfully in households for Food and Nutrient security.

APPENDIX-I

Score card for the organoleptic evaluation of leafy vegetables

Sensory Characteristics	**Treatments**	
	Control (Polybag)	**Aquaponics**
Color and appearance		
Flavor		
Texture		
Taste		
Overall acceptability		

1 - Dislike extremely
2 - Dislike very much
3-Dislike moderately
4 - Dislike slightly
5 - Neither like
6 - Like slightly
7 - Like moderately
8 - Like very much
9 - Like extremely

Remarks:

Signature: