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The feasibility of the implementation of the Aquaponics system by low consumption LED diode technology with the help of renewable energies

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Abstract
Aquaponics is a system for the simultaneous development of aquatics and plants. In this article, the growth of plants in the Aquaponics system is indicated by artificial light for the growth of lettuce. As a result, the efficiency and benefits of using this system are investigated in proportion to conventional and old methods, such as economic justification, reduced energy, and fuel consumption, reduced cropping area, reduced water consumption significantly, reduced pests, and consequently, deletion of all fertilizers, medications, and pesticides can be included. One of the main reasons for economic justification and reduction of energy consumption can be mentioned due to the use of full-spectrum led modules along with the use of pure solar energy. In this article, the manufacturing of modules for lettuce growth is also mentioned with the aid of low power LED diodes producing by specifying the lighting parameters.

Keywords: LED, Full Spectrum, Simultaneous planting, Solar Panel**.**

Introduction
In recent years, artificial light sources have been widely used to stimulate the flowering and planting of crops. LED lights for plant growth help energy saving, high efficiency and growth process acceleration and make them an integral part of future agricultural production. Due to the type and condition of the plants, there are different requirements for the intensity of light, the spectrum of light and the phototroids, in which the plants clearly affected more by photosynthesis. The optimal light spectrum curve for plant growth is shown in Figure 1. The efficiency of photosynthesis can be increased by light radiation in this spectrum.

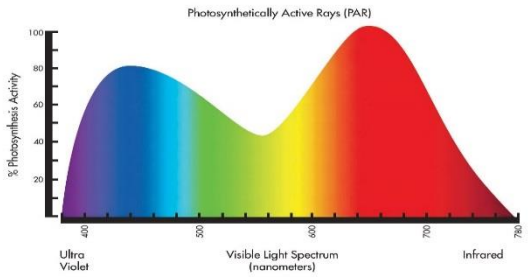

Figure 1 Optimal Light Spectrum Curve for Plant Growth [1]

As mentioned before, photosynthesis is a major photochemical reaction in plants that converts light energy into chemical energy, and chlorophylls are green pigments within the plants, especially in leaves and stems. There are two types of chlorophyll: “chlorophyll a” and “chlorophyll b”. The “chlorophyll a” and “chlorophyll b” absorption spectra are shown in Figure 2. For “chlorophyll a”, the absorption peak on a 430 NM (blue light) and 662 NM (red light) is observed. On the other hand, the absorption peak is 454 NM (blue light) and 643 NM (red light) for “chlorophyll b”. Some absorptions are also found in 500-540 NM (green light) for “chlorophyll b”.

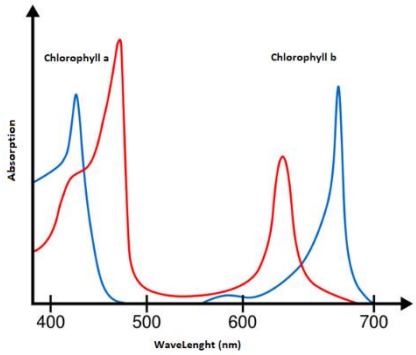

Figure 1 Absorption Spectrum Curve of “chlorophyll a” and “chlorophyll b” [2]

As a result, due to the different needs of the plants, one kind of diode cannot be used to grow all species.

Proper wavelength for plant growth

Lettuce cultivation in the traditional way has always been threatened by various pests. Mineral deficiency can cause malformations in the shape of lettuce or lack of growth. Many insects have a lot of interest in lettuce, such as the worms that cut the connection between the buds and the soil; wireworms and tubular worms, which cause the leaves to become yellow and crooked; crickets cause the leaves to dull and prevent the growth; thrips cause the leaves become greenish-gray or silver. Leaf worms create tunnel-like holes in the leaves; cockroaches and worm-cartilage also create large holes on the leaf, and mammals such as rabbits and palms, also eat the plant.

Lettuce may also suffer from several viral diseases, such as “black virus” that causes leaves to become yellow and crooked, and “mosaic virus” spread by aphids that can stop the growth and make the plant crooked. Fungal diseases such as “powdery mildew” and “downy mildew”, which cause plant corruption and base decay, “botrytis cinerea” that causes the whole plant to be corrupted and damaged.

The abundance of lettuce in one place causes pests and diseases to be absorbed. Weeds can also be problematic because the lettuce cannot compete with weeds, especially when spawned on the ground. In the commercial production of this product, herbicide poisons can put down these weeds. But this action has led to the development of some pesticide-resistant weeds and concerns about the environment and health.

Nowadays the due to the water scarcity in the world, planting in the soil and traditional irrigation has no economic justification. For this purpose, new methods of agriculture,

such as hydroponics and Aquaponics methods by replacing cultivars such as rock wool, LEKA (Lightweight expanded clay aggregate), rice bran, perlite, coco peat, and peat moss instead of soil, can prevent pests attack. In addition, in the Aquaponics method, in addition to the planting, fish can be cultivated in mostly waterless areas with a certain volume of circulating water.

Water or wastewater from pisciculture is an organic fertilizer source. Products produced in this system are known as a healthy and organic product, and they play an important role in the sale and marketing of fish and plants. Also, two types of products are produced from a single production unit, and in waterless and dry areas which faced the water scarcity, Aquaponics has an important role and is a model for sustainable agriculture.

Lettuce is a plant that has a high water intake. Lettuce is a long-day plant and a significant amount of water is needed for breeding it.

The required light for plant growth in this system can be artificially provided in greenhouses. In the out-of-date systems, greenhouses used CFL and HPS bulbs that have very high power consumption.

By replacing LED modules that are very low in energy consumption, in addition to supplying the plant needed light with specific wavelengths, it can save energy. Also, due to the adjustment ability of the amount of optical flux and the reduction of the heat generation compared with out-of-date bulbs, the length between the lamp and plant can be reduced. So in the current planned system, in addition to reducing the space, reducing water consumption, increasing production, (Production of two products simultaneously), and reducing the power consumption will increase the productivity.

Aquaponics is a combination of pisciculture and hydroponics in a system. In an Aquaponics unit, water flows from the fish source to the filters and the plant seedbed and then returns to the fish breeding tank. In the filtration, the wastewater of fish breeding tank is removed from the water.

The first step in filtration is passing the water through a mechanical filter that remove solid particles from circulating water and then water enter into a biological filter, in which water-soluble ammonia, that is a bacterial strain for an aquatic environment, is converted into absorbable nitrate for plants. This process is called nitrification. So, water with nutrients and nitrates goes to the seedbed of the plants, and once the food is absorbed by the plant, it returns to the breeding tank.

It is beneficial to the fish as the accumulation of the produced materials from the decomposition of plants can be as their required nutrients. Because microorganisms in the tank and the compounds of nitrogen and phosphorus, which are the result of fish, accumulate in water and is a limiting factor for the ecosystem.

The most important biological action in the Aquaponics is the Nitrification process. Nitrogen is one of the main elements in the animal body structure, and as a result of its decrease or increase, the growth process is disrupted. Nitrogen has an important role in amino acids, proteins, enzymes and energy transfer chains. Nitrogen is also the most important element in plant structure.

Nitrogen in gas mode constitutes 78% of the atmosphere, but it is a kind of nitrogen molecule (N_2) that is non-absorbable by plants. To become absorbable, they must be converted which is named nitrogen fixation process. In this process, in nature, nitrogen is combined with hydrogen or oxygen by bacteria, and a new chemical compound will be created in the form of non-absorbable ammonia (NH_3) and ammonium (NH_4) and nitrate (NO_3), which will be easily absorbed by the plants.

The waste from animal activity provides a huge source of ammonia. Other organic materials found in nature, like the remains of animals and plants, is broken down by fungi and bacteria and converted into nitrogen. This ammonia metabolism process and making it absorbable, which is done by a group of bacteria, is important to the Aquaponics system and these bacteria are

called nitrification bacteria. Initially, these bacteria convert ammonia to nitrite (NO2) and eventually to nitrate (NO3), and plants easily absorb nitrate by their roots.

Equilibrium of Aquaponics environmental conditions:

The word “equilibrium” describes all of the action that the Aquaponics ecosystem dynamics, including fish, plants, and bacteria which are dependent on it. In fact, it represents the balance between the amount of fish, the number of plants and the size of the bio filter (which means the amount of bacteria).

Feed ratio: Totally feed ratio depends on 3 important factors. The amount of daily food in grams, plant type (vegetative, millet) and area of cultivating area in square meters. This rate is expressed in terms of daily food intake at the cultivar level. In addition to the feed ratio, there are two complementary indicators to ensure the health of the system:

1.Health of fish and plant

Unhealthy plants and sick fish can be a warning sign of exiting the system from its balance, symptoms of nutritional deficiencies are observed in plants that the nutrients in the fish's waste cannot supply the plant's essential elements. In this case, the feed ratio or the amount of plants can be changed in the system.

2. Ammonia Test (N2)

If ammonia (NH3) or nitrite (NO2) be more than 1 mg/L, it indicates that the bio-filtration system or seedbed level is not sufficient and the surface area of the bio-filtration or seedbed should be increased. Aquatic animals can tolerate higher levels of nitrate (NO3), but if nitrate accumulation in the environment be higher than 150 mg/L in a few weeks, changing the water of the fish tank is necessary and the system should be corrected. According to these conditions, there should never be any leftover food in the breeding tank.All Aquaponics systems typically require several structures, including a fish tank, a mechanical filter, a bio-filter, and hydroponics seedbeds. Lighting for plant growth is also needed, which in this experiment a LED module with a specific wavelength has been designed. (Fig. 3).

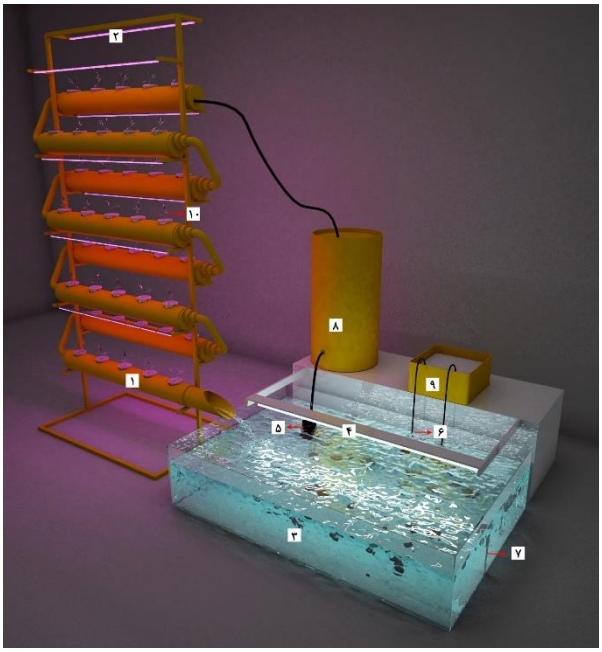

Figure 2 Schematic of the Aquaponics structure

No. 1: Structures for the placement of seedbeds, No. 2: Lettuce growth lamps, No. 3: Fish Tank, No. 4: Aquarium Lamp, No. 5: Water Pump, No. 6: Water Pump, No. 7: Air Pump, No. 8: A bio-filter with a water pump, No. 9: Mechanical Filter, No. 10: Lettuce

More than 150 different species of vegetables, herbaceous plants, flowers and small shrubs grow successfully in this system. Typically, leafy vegetables and some fruit vegetables such as tomatoes, cucumbers, etc. are used. Plants in terms of the need for food in the aquatic system are divided into two categories:

Leaf vegetables and herbaceous plants: Lettuce, Swiss lettuce, Basil, Mint, Parsley, Coriander, Onion, Shahi

Fruit Vegetables: This kind of vegetables requires more nutrients than leafy vegetables to produce flowers and fruits, including tomatoes, eggplants, cucumbers, watermelons, peppers, strawberries.

Other vegetables such as cauliflower, broccoli and cabbage require a moderate level of food.

The lettuce seed has been used in the implementation of the test, and the growth stages of the plant are shown in Figure 4.

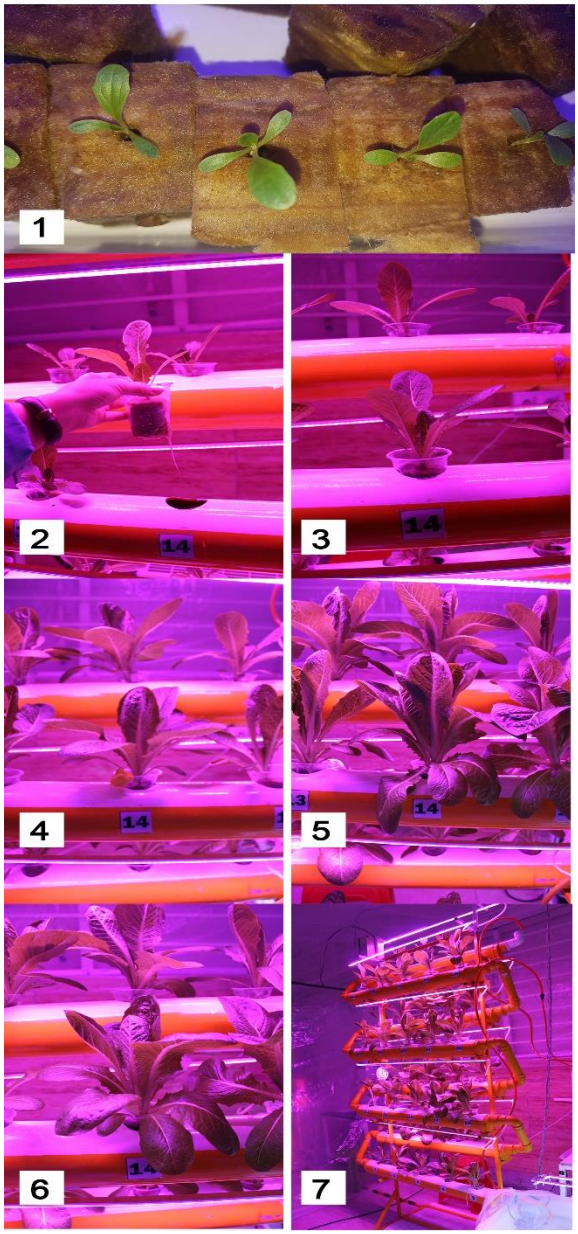

Figure 3 Growth stages of lettuce in Aquaponics system with LED light

Initially, the seeds are planted in a selected seedbed which is rock wool and after growth of 4 leaves, it will be placed in the main system (Fig. 1-4).
In order to choose the type of aquatic in the system, Tilapia fish, carp, alfalfa or ornamental fish such as redfish and guppy fish can be used. In this experiment, the carp has been used. Carp is a hot-water fish that has the best growth in water at 18-25°C. 35 fish with a weight of 50 grams, 1750 grams of carp totally were placed in the closed circuit system.

In order to accelerate and improve the growth of the lettuces, LED modules are used as shown in Figure 3 in which the LEDs with the observed ratio in Table 1 are located on the designed PCB and thus the lettuce plant growth lamp has been made (Fig. 5,6 and 7).

Table١ The LED ratio used in the plant growth module

UV (390 nm)	Blue (460 nm)	Herbal(520 nm)	Warm white(3100 K)	Wavelength(nm) color temperature(K)
0.8%	19.1%	78.3%	1.6%	percent

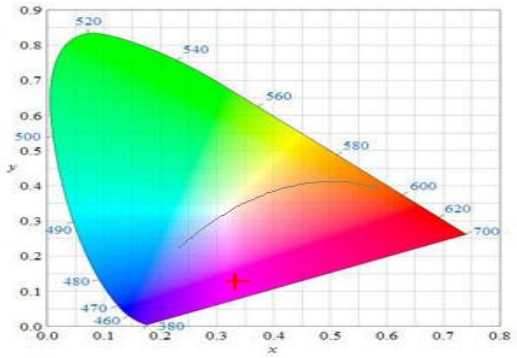

Figure 4 CIE 1931chart of Specific Light for Plant Growth

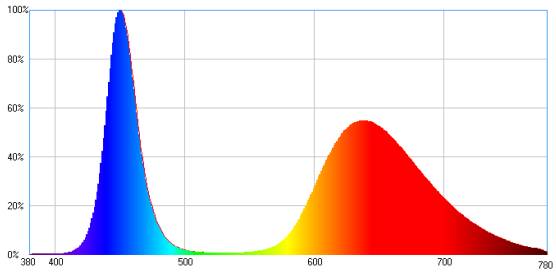

Figure 5 Specific Light Spectrum chart for plant growth

Figure 6 Enlarging the lamp used for lettuce growth

Comparison of LED lamps with other lamps

The CFL and HPS bulbs waste an average of 80% of their electrical energy and convert it to heat. Because of that, high power consumption is needed to provide more light, and this heat generated in greenhouses increases the cost of the cooling system in the warm seasons. But in LED lamps, the amount of heat dissipation is reduced to 10% and converts 90% of the used energy to light (Fig. 8).

In LED lamps, there is the possibility of creating the desired light color with desired wavelengths, without the use of color-coated filters, while the optical spectrum of the lamp is pure with uniform luminosity.

There is no way to adjust the light with the HPS and CFL lamps absolutely, but it's easy to do that by LED lamps using voltage level control by changing the pulse width.

Charts and Tables

Table٢ Test results of the characteristics of lettuce developed under the LED light-induced Aquaponics method

Laboratory	Acceptable range	Unit	Test method	Test results	characteristic
Testa Quality Control	١٥٠٠	mg/kg	Standard ٤١٠٦	٢٢١,٨	**Nitrate**
Testa Quality Control	-	mg/kg	Standard ٤١٠٦	٠,٠١>	**Nitrite**
Testa Quality Control	٠,٢	mg/kg	Standard ٣٩٠٩	٠,٠٦	**Lead**
Testa Quality Control	-	mg/kg	Standard ٥٣٤٦	٠,٠٠٠٢	**Mercury**

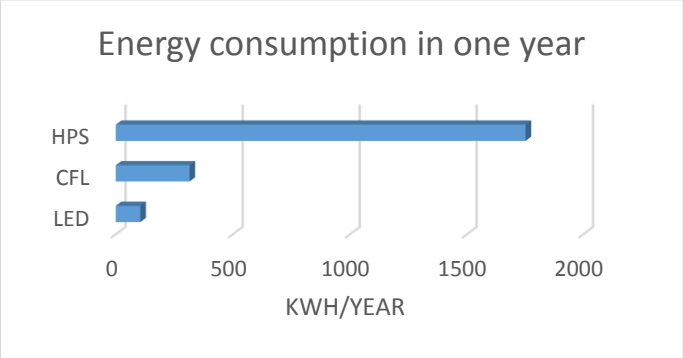

Figure 7 Energy consumption in one year

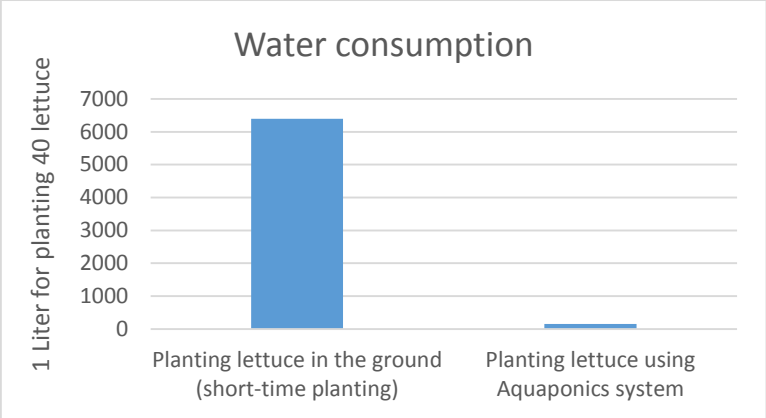

Figure 8 Comparison chart of water consumption for lettuce planting on land and Aquaponics system [3]

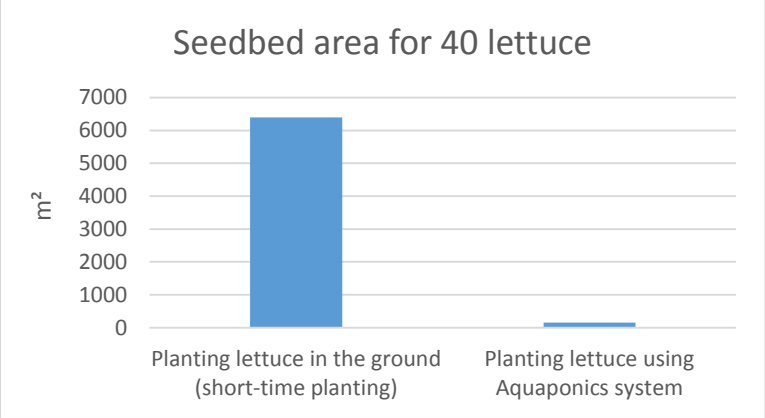

Figure 9 Comparison chart of the required planting area in the ground and the Aquaponics system

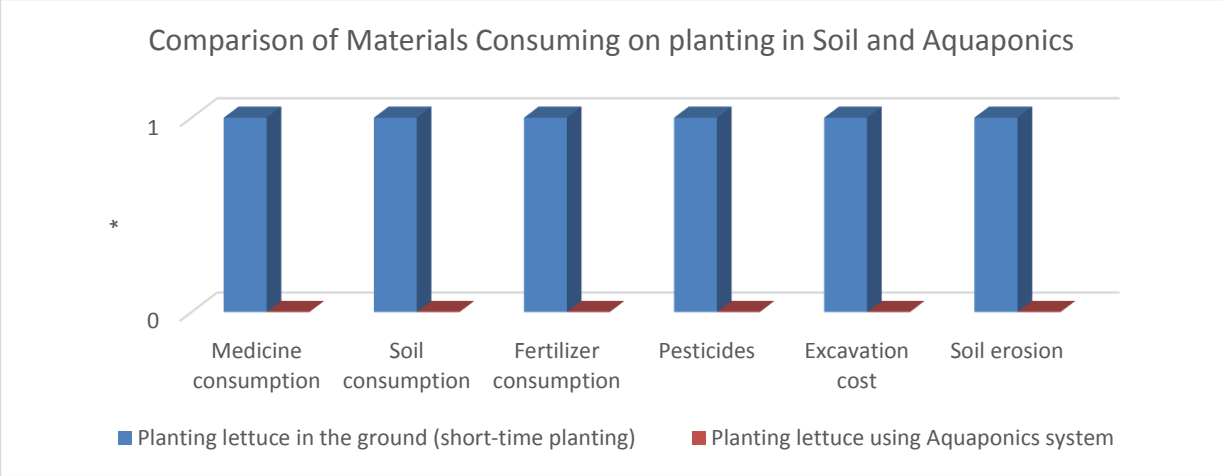

Figure 10 Comparison of Materials Consuming on planting in Soil and Aquaponics

Table۳ Calculation of power consumption in the Aquaponics system

Consumption type	Quantity	Power (w)	Hours used h/day	wh/day
Water pump	۲	۵۸	۲۴	2784
Water pump for filtration	۱	۱۲	۲۴	288
Large air pump	۱	۱۳	۲۴	312
Small air pump	۱	۵	۲۴	120
LED Brightness	1	۲۴۰	16	3840
Total	۶	۳۸۶	-	7344

Table۴ Calculating the implementation of a solar system unconnected tothe network

Required equipment	Requirements	Implementation suggestion
Battery	612 Ah	8 Batteries 100Ah
Solar panel	1950 W	6 Panels 235W
Inverter	1000 W	All sinusoidal inverter up to 1500W
Structure	2 KW	All galvanized structure
Charger control	80 A	2 Charger control, 40A, 24V
Connector	mc4-3*1	2 Pair Socket and Jack
Cable	1*4	Solar DC cable

Due to the amount of power consumed in the created system, solar energy can be used for the system according to Table 4.
A solar system unconnected to the network can relieve the dependence of consumer to the power grid, as the system generates all the electricity needed by the consumer. Therefore, a solar-powered system is larger than a solar power plant connected to a grid. For anunconnected solar system, such as a solar power plant, to be connected to a power grid, a solar panel with a storage capacity larger than the solar system connected to the grid should be selected and installed. However, if the justification of a solar power plant is suitable and appropriate, the solar system unconnected to the network is very affordable.
According to the average hours of sunlight in Mashhad, which is 5 hours, the system must be designed in such a way as to be able to supply the pump power when the power is off. Due to the fact that the power plant does not work in the most power generation time and sometimes less than installed

capacity, a number of backup panels and batteries has been used in the system design. As Tables 3 and 4 indicate, the power consumption of the system is 7000 W/H, which is generated by an unconnected solar system design of 10,000 W/H. Due to the forecast of maximum cloudy days and unfavorable conditions, power generation is about 1.4 times more than energy consumption.

Results Analysis

According to chart 9 and 10, it can befound that the ratio of water consumption and requiredseedbed for planting in the Aquaponics system was less than 2% in the soil.

As chart 11 indicates, many of the costly and harmful items, as well as the pollution have been completely eliminated in the Aquaponics system.

According to Table 3 and 4, solar panel with mentioned specifications can be used to eliminate environmental pollution and not use energy.

According to Table 2, the results of the test show four important characteristics to prove the absence of toxic substances in lettuce harvested from the system on March 28, 1397.

According to a report from the Testa Quality Control Laboratory, the tests are consistent with the 16596 and 12968 standards.

It should be noted that the average nitrate amount for lettuce harvested in the summer by international groups are less than 200 ppm. [4]

Conclusion

Products harvested from Aquaponics system are known as organic products, while two types of products are produced from a single production unit, and Aquaponics plays an important role in waterless areas, and is a model for sustainable agriculture. Plant cultivation with Fish breeding has several benefits, such as improving the taste and quality of agricultural products, improving the quality of water in fish breeding tanks, reducing environmental pollution, reducing water supply cost and saving fertilizer.

The Aquaponics system is not only an effective method for the recycling of aquatic breeding wastewater, but also generates high economic benefits. Aquatics breeding and LED lighting with specific wavelength in Aquaponics system will result in production increase, growth acceleration, while improving resource efficiency, resulting in increased revenue and lower operating costs. According to the analysis of the mentioned results in the case of power supply of the Aquaponics system, solar energy as renewable energy can be seen to have an impressive effect on modern agricultural development. The use of small solar power plants, as discussed in this article, is not economically feasible, but if it is needed in large industrial sizes it can bring economic justification and return on investment in the long time.

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