Design of a computerized aquaponic system harnessed with renewable energy.

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Abstract
Aquaponics is a combination of aquaculture (cultivating fish) and hydroponics (growing plants in water without soil). The eco-innovative technology behind the concept is a combination of the two production systems into one. This Computerized aquaponics powered by solar system employs engineering and computing principles. This integrates aquaculture, hydroponics an precision engineering intoasinglespecializedsystemtermedaquaponics for the production of local and high value non genetically modified plant (vegetable, fruits) and non- genetically modified animals (fishes, snails) for human consumption. The system is incorporated with a green house, a fish tank, a sump, a grow-bed and a submersible pump. It is embedded with some devices such as data logger, microcontroller, input sensors and solar subsystem. This aquaponics system will address some challenges confronting the efficiency of the traditional systems of agriculture. Sensors extensively employed are used for determining, analysing and controlling ambience with water quality in the system.

Keywords
aquaculture, hydroponics, data logger, microcontroller, simulation.

Introduction

The GMO crops may have several benefits such as increased yield and specific features. But, it poses significant risks to the health of living beings and environment[1]. The genetic modification of crops changes their natural behaviour towards various stimuli. The genetic simulation of crops can lead to the formation of toxic substances that can cause significant health hazards[2]. Some individuals are wary of GMO products because of potential negative impacts on the planet. GMO crops may require more herbicides than their traditional counterparts, which could increase environmental pollution. Researchers are concerned that any reductions in pesticide use will be erased over time as pests develop resistances[3].

The global demand for the production of healthier, non-Genetically Modified Organism [NGMO] and Non- Genetically Modified Plants (NGMOP) is on the increase. This is necessitated by the harmful effects of Genetically Modified Foods (GMF)[4]

In other to reduce cases of threat which genetically modified organic food po se to human health in Nigeria there is need to ensure the availability of high value and out of time foods especially for areas for like Damaturu in the north eastern part of Nigeria. This project is conceived because rainfall in Damaturu is less compare to other parts of Nigeria (lasting for just four months) and soul in poor. It is against this backdrop that this computerized aquaponics system which was powered by solar system was designed and developed. Solar energy was considered in preference to electricity in order to eliminate the effect of erratic supply and it is also cheaper. Aquaponics farming method is the systematic integration of two relatively well established systems of food production such as the aquaculture and the hydroponics in a reticulatory system under controlled conditions. This version of aqauponics titled "computerized aquaponics powered by solar systems" which is incorporated with a green house has some devices and some advanced computer software embedded in it. These components were employed using multidisciplinary principles in qualitative, quantitative and procedural manner to support the development of production of sustainable foods in a safer environment.

ISSN 2229-5518

Literature Review

The aquaponics method of farming often referred to as the merging of two relatively well established production technologies such as reticulatory aquaculture and hydroponics systems for the provision of sustainable foods in a symbiotic environment under controlled conditions is entirely not a new concept. It has been with us since the 1960s, but interest has increased rapidly in recent times due to need for local sustainable foods. The awareness generated by health, and developmental agencies that aquaponics which is a simple technology is capable of cultivating both vegetable, fishes and fruits in a water and soil rich deficient zone as obtainable in northeast region in Nigeria has been on the increase on daily basis[5]

Sneed et al. (1975) published the first description of an aquaponic system, which diverted aquaculture effluent through plant growing troughs. He employed the use of nutrients in aquaculture to nourish and grow plants; polluted fish water would be cleaned up before being released into the environment. Plants showed signs of nutrient deficiencies within a month, likely due to a couple of factors. In hindsight, fertilizer nitrate nitrogen was 150 times lower than it is today. Furthermore, the culture water was exposed to sunlight, which allowed microalgae to grow and further reduced the available nutrients. At around the same time, Dr. John Todd and Nancy Jack Todd led similar work at the New Alchemy Institute, which resulted in a natural wastewater treatment system marketed as a 'living machine'[5]. In 1978, Lewis et al. sought to address the dilute nutrient issue. They worked with the first recirculating aquaponic system, which was developed to operate with a high fish stocking density. While the idea was good, nitrate concentrations were too low at 6–10 mg/L, and producers were required to add a complete nutrient solution to support tomato growth. As a general rule of thumb, nitrate levels should be around 46 mg/L.

The low nitrate levels coupled with high amounts of fish feed suggested that massive denitrification, or conversion of fertilizer nitrate to nitrogen gas, was occurring and the nitrogen was being released into the atmosphere.[6], first started aquaponics farming on a small media bed and thereafter wrote a manual on aquaponics titled "How to do this" which later became a spring board for many scholars in the design of home based aquaponics all over the world today.

In 1986, Zweig developed a simple and productive aquaponic system by matching the feeding rate and biomass of the fish to the estimated nitrogen needs of the plants. Iron deficiency was addressed by replacing 20% of the fish feed with rabbit feed. While this work was an important step in the development of the technology, it went largely unnoticed.
Unfortunately, theunderstandingandpreventionofdenitrification was not well understood at the time. Salts that inhibit the growth of some plant specie accumulated in the system. Iron averaged 0.1 mg/L, which is less than the minimum of 1–2 mg/L suggested for hydroponic plant culture[7].Researchers Mark McMurtry, Douglas Nelson, and Paul Nelson of North Carolina State University also developed a recirculating aquaponics system. They placed their plants in a gravel bed creating an in situ biofilter. In 1993, Rakocy and Hargreaves reviewed aquaponics research and concluded that estimates of nutrient uptake and a deeper understanding of culture water nutrient dynamics are a necessity in the development of criteria for designing aquaponics systems8. attempted to track plant nutrient uptake in the UVI aquaponic systems operated with and without plants. Unfortunately, nutrients accumulated at equal rates in all systems and uptake by plants was not demonstrated. A follow up experiment was conducted to determine the optimal fishnumber-to-plant-growing-area ratio. In hindsight, we now believe that the nutrients produced by fish should have exceeded plant needs in all treatments. Lettuce head weights were about the

same in all treatments irrespective of the range of fish stocking densities tested. The plants grown in the aquaponics system were smaller than those produced hydroponically (172–248 g)[9], suggesting malnutrition. After refinement, the system produced lettuce heads of a comparable size.

A number of years later, it was demonstrated that the UVI system could be operated productively and continuously10. The final system consisted of four fish tanks, six plant troughs, a clarifier tank, screen filter tanks, degassing tanks, a sump tank, a base addition tank, a water pump, two air blowers, and over 200 air stones. A technically trained staff was used to operate it. Rakocy was effectively the first person to develop a fully-functional aquaponics system and thus, is often referred to as the 'grandfather of aquaponics.' Generally, plants were grown in water on floating polystyrene sheets called rafts(akocy 1989). Rafts require substantial aeration of the water to provide oxygen to plant roots and to support nitrification. Kratky used a system in which plant roots were held out of the water and exposed to moist air; this could be called a nutrient film technique11. Lennard and Leonard (2006) tested three kinds of systems, some of which have been subsequently used by others. They tested the following designs: gravel systems flooded with water, systems using the nutrient film technique in which plant roots were exposed to air and roots were bathed with a thin layer of fish water, and raft systems. They found that the gravel systems flooded with water were the best12. Ako (2013) tested trickling water under gravel, gravel ebb and flow, rafts with air gaps, and standard rafts. He found the first two to be best, but the former to be more maintenance free. It has been more than 20 years since Rakocy modified the technology, yet there are no known successful commercial systems based on his design. One purpose of the work highlighted in this publication is to remedy this. However, we can now see in hindsight that aquaponics is economically challenging. It cannot tolerate low prices for vegetables, low system biological performance, high capital expenses, or high operational expenses and remain profitable (Tokunaga et al.) In some Pacific Islands, vegetables are very expensive because they must be imported by airplane. Aquaponics has the advantage of producing vegetables that taste uniquely good and are grown organically, as fish and pesticides are incompatible. In particular, our objectives were to develop systems that require less capital investment and to develop operating instructions that are based on basic biology and chemistry. Systems should have clear chemical specifications, and remedies for chemical imbalances should be provided.

Nick Salvador [2003], after his research on aquaponics method for producing vegetables using plant science principle observed that the method of closing the loop between plant and animals is an effective way of improving water and nutrient efficiency thereby reducing waste13. Aquaponics gained more prominence recentlybecausemostcitiesarebecomingincreasing concerned with how food relates to the urban environment and are thus encouraging the development of sustainable food system that will contribute to high quality of life while promoting environmental sustainability [Brummett R.E 2003]. Aquaponics system have been used to produce high species of fishes such as mackerel, sadinella at an intensive indoor scale farms in the United Kingdom. Both professionals in the horticultural and agricultural industries have recommended that effective systems should be developed for utilization of renewable energy to reduce pollution and its effect on human health (Lennard et al, 2006). Savidov et al (2006) from their research on aquaponics opined that this system is also capable of increasing food yield compared to the soil based farming. A thorough study of these works by aforementioned scholars and other literatures not mentioned here gave the birth to the idea of developing this computerized aquaponics system that will be powered by solar energy systems for the provision of sustainable foods in regions having less rainfall and poor soil.

Design, Testing and Analysis

The Aquaponic system is divided into b four functional Parts;

i. Fish pond

ii. The grow bed

iii. Water Reticulation

iv. Solar subsystem

i. Fish pond

The fish pond design is dependent on the species of fish to be raised. Cat fish is used because of its viability, adaptability, availability, profitability in Nigeria. In theory, one gallon of water is needed for a pound of fish. However, it's better to plan for extra room ahead of time so that when your fish start to grow, the system doesn't fall out of balance. This model sized design is meant to cultivate 100 matured sizes. To know the storage capacity for a catfish, the stoking density must be known. Carriage capacity of a pond is a factor of water management technique. However, circulatory system of water management can accommodate higher number of fishes per square meter than a pond system.[12]Also the flow rate of ground water has a lot to do with number of fishes to be stocked.[13]

In designing this pond some many factors where considered**;** Feed Conversion Ratio, Depletion in the Dissolved Water Oxygen, Water Temperature variation, other water qualities.

Tank capacity

L= 1.19m=; h= 0.98m; b=0.90m

Volume= lbh=1.19 x 0.98 x0.90

$= 1.04958m^3$

$1m^3$=1000l

The total Tank capacity in litres is = 1000 x1.04958= 1049.58/ 3.8=276.5 litres;

With a gallon of water to matured fish size;

Total fish=276/1=250 max (tolerance).

Water quality for Damaturu;

SOLAR SUBSYSTEM

Water pump 55w on for 10 hours per day	= 550wh
Sensors aggregate @ 3w on for 10 hrs per day	= 30wh
Greenhouse Light 30w on for 5hrs per day	= 150wh
Total	= 730wh

Solar Panel required is;

730/ (6x0.85) = 143W

Solar panel of 150w is required

Effective charge

(150 W) x (6 hours of sunlight) x (70% direct sunlight x (85% eff. of the charge controller) =535.5WH

ISSN 2229-5518

Inverter battery requirement

The Amp Hours for the required battery = 730/12= 60.833333333333333 A

75AH was chosen (a unit 12v 200ah deep cycle batteries.

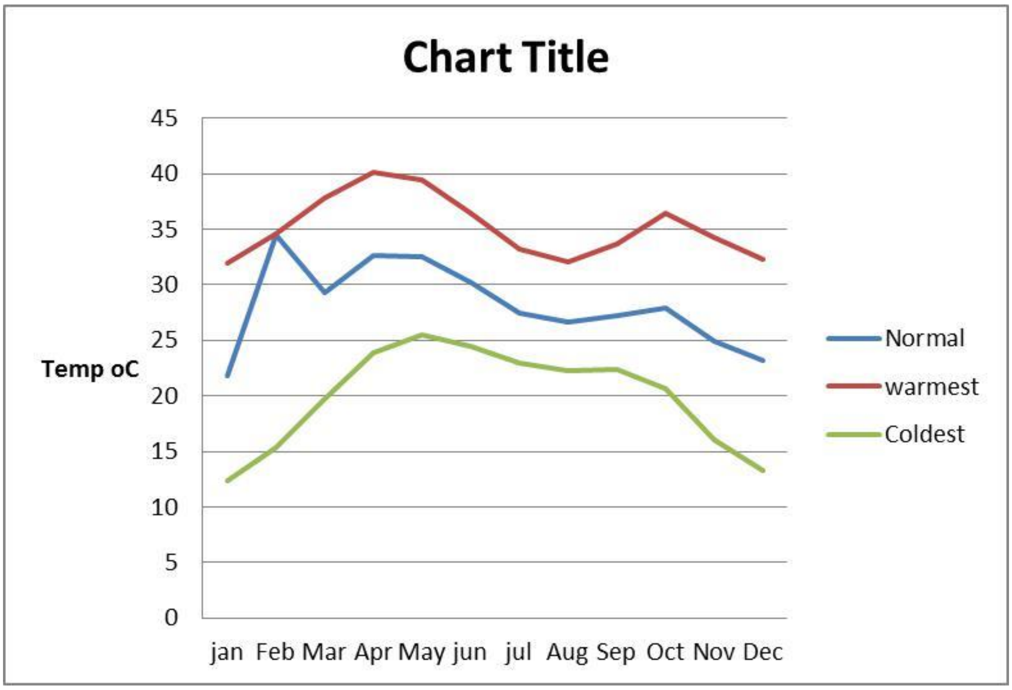
TESTING AND SENSORING

Variation in Water quality for PH, ammonium, Temperature was highly maintained at Minimal fish survival Temperature of 29^{o}c as shown on the data blogger graph below:

The monthly weather variations in Damaturu are shown below; the monthly weather variations in Damaturu are shown below;

S/N	month	Normal	Temperature		Precipitation
			warmest	coldest	Normal
1	January	21.8	31.9	12.4	0
2	February	34.5	34.6	15.3	0
3	March		29.337.819.7		0
4	April	32.6	40.1	23.9	1
5	May	32.5	39.4	25.5	4
6	June	30.2	36.4	24.5	7
7	July	27.5	33.2	22.9	10
8	August	26.6	32.0	22.3	10
9	September	27.2	33.7	22.4	6
10	October	27.9	36.4	20.7	1
11	November	24.9	34.2	16.0	0
12	December	23.2	32.3	13.3	0

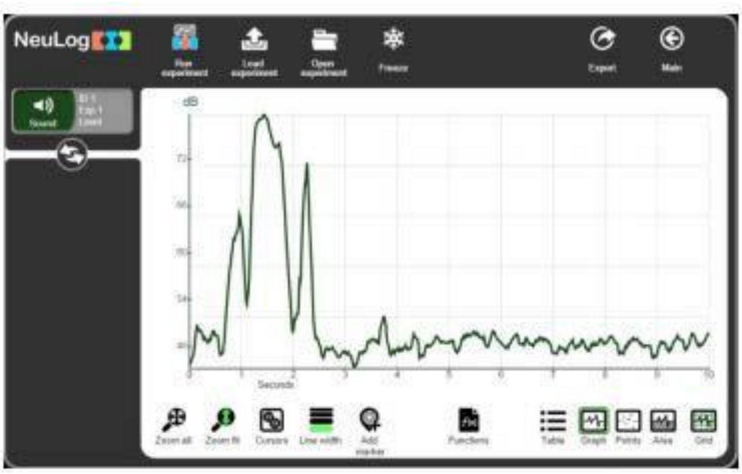
Table 1: yearly weather distribution in Damaturu [SOURCE: Maiduguri weather station]



Graph 1. Yearly temperature distribution in Damaturu.

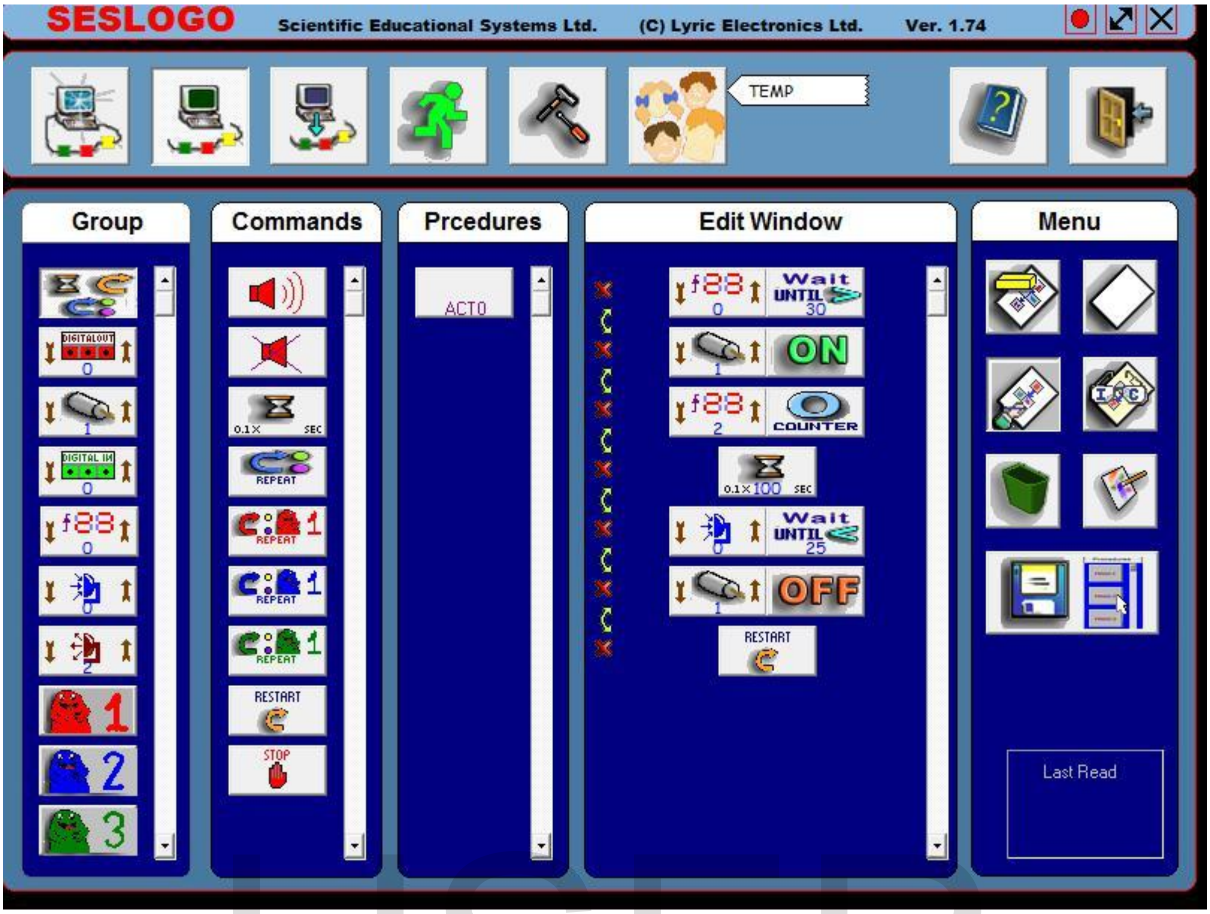
The temperature in Damaturu is highest between March and May as shown on graph 1. The temperature was detected on data logger shown below. A normal variation is plotted against warmest temperature and coldest temperature, a normal mean temperature was recorded and programmed in prog. 1 below

The temperature in Damaturu can be seen on data logger below



Temperature sensors program is shown below.

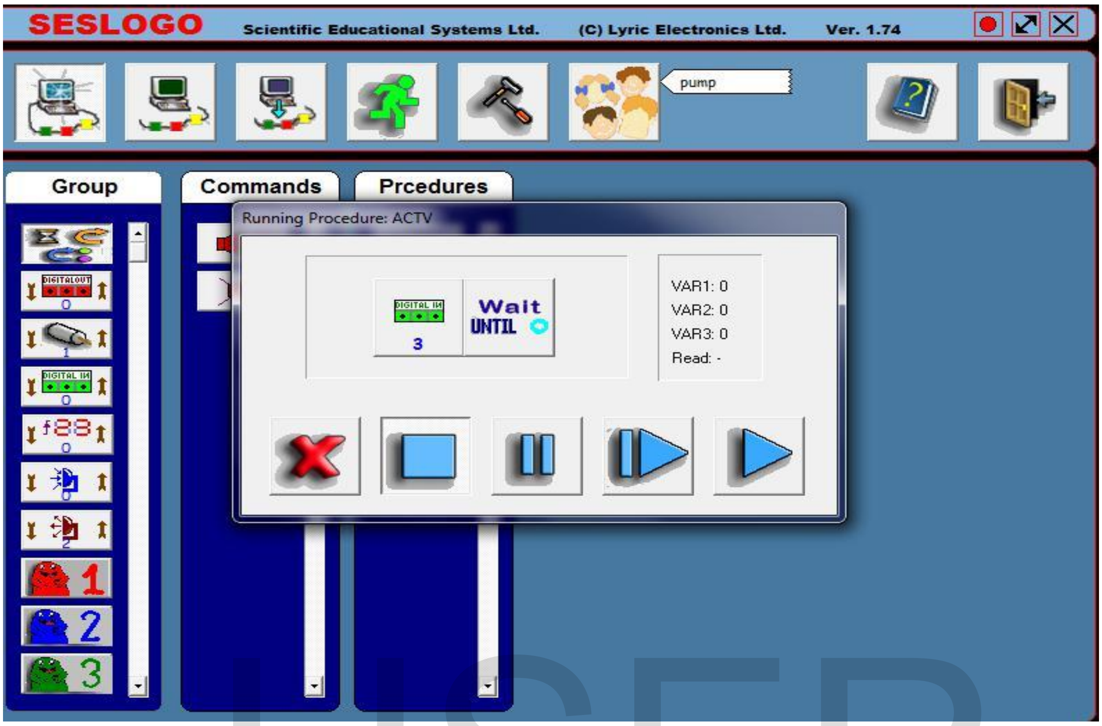
ISSN 2229-5518



Prog 1: temperature program for the pond Water quality was programmed

Prog 2. Pump and water quality program

SENSORING ANALYSIS AND SIMULATION



Prog 3. Simulation of the pump and sensor response.

CONCLUSION

Aquaponics is an integrated approach to efficient and sustainable intensification of agriculture that meets the needs of water scarcity initiatives. This improved agricultural practice is needed to alleviate rural poverty and enhance food security. Aquaponics is residue-free, and avoids the use of chemical fertilizers and pesticides. Aquaponics is a labour-saving technique, and can be inclusive of many gender and age categories. In the face of population growth, climate change and dwindling supplies of water and arable land worldwide, developing efficient and integrated agriculture techniques will support economic development.

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