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Develop an automated monitoring system that allows the creation of an efficient hydroponic ecosystem, which increases the production of lettuce per square meter

Desarrollar un sistema de monitoreo automatizado que permita la creación de un ecosistema hidropónico eficiente, que eleve la producción de lechugas por metro cuadrado

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Abstract

The agricultural production methods of the last decades, have stood out for the use of the spaces, leaving aside even the land, mediating the greenhouses; in order to protect crops from climate variations, pests, raising their quality through better physicochemical characteristics and longer shelf life. The purpose of this work is to develop an automated system by means of materials such as sensors and microcontrollers capable of controlling physicochemical variables in a greenhouse, in order to provide the concentrations of nutrients, for the creation of an efficient hydroponic ecosystem, and standardized for an increase to production, in the cultivation of Romain variety lettuce. It is important to point out that within the hydroponic system, the Romain lettuce variety is harvested, obtaining larger products with an approximate weight of 1200 to 1500 g per piece, compared to those grown by the traditional method whose weights range between 1100 to 1300 g per piece, with a shelf life of 8 days in refrigeration.

Automated system, Microcontrollers, Hydroponic ecosystem

Resumen

Los métodos de producción agrícola de las últimas décadas, se han destacado por el aprovechamiento de los espacios, dejando de lado incluso la tierra, mediando los invernaderos; a fin de proteger los cultivos de las variaciones del clima, las plagas, elevando su calidad a través de mejores características fisicoquímicas y mayor vida de anaquel. El propósito del presente trabajo es desarrollar un sistema automatizado por medio de materiales como sensores y microcontroladores capaces de controlar variables fisicoquímicas en un invernadero, a fin de proporcionar las concentraciones de nutrientes, para la creación un ecosistema hidropónico eficiente, y estandarizado para un incremento a la producción, en el cultivo de lechuga variedad Romain. Los resultados obtenidos incluyen el diseño y las mejoras, hasta la optimización del invernadero para una producción máxima de 36 lechugas por metro cuadrado .Importante es demarcar que dentro del sistema hidropónico, se cosecha la variedad de lechuga Romain , obteniéndose productos más grandes con un peso aproximado 1200 a 1500 g por pieza, en comparación con aquellas cultivadas por método tradicional cuyos pesos oscilan entre 1100 y 1300g por pieza, con una vida de anaquel de 8 días en refrigeración.

Sistema automatizado, Microcontroladores, Ecosistema hidropónico

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Introduction

In recent decades, studies have shown a trend towards the development of new techniques, methodologies and technologies to optimise production processes, without neglecting the important interrelation between human beings and machines. The word hydroponics is derived from two Greek words, hydro, which means water and ponos which means labour, hence "work in water".

Hydroponic cultivation was used as far back as ancient Babylon, in the famous Hanging Gardens. The Aztecs with the so-called Chinampas, amazing islands of vegetables. (Tlacaelel, 2017)

Nicolas de Sausssure (1804) published that plants are composed of minerals and chemical elements obtained from water, earth and air. In 1842, he published a list of nine elements considered essential for plant growth (Mexicana, 2018).

Research on plant nutrition showed that normal growth can be achieved through a water solution containing salts of nitrogen (N), phosphorus (P), sulphur (S), potassium (K), calcium (Ca) and magnesium (Mg), which are now defined as macronutrients. Subsequently, seven elements required in relatively small amounts were discovered and are known as micronutrients, including iron (Fe), chlorine (Cl), manganese (Mn), boron (B), zinc (Zn), copper (Cu) and molybdenum (Mo). (Canovas, 1993; Benitez, 2011).

According to Díaz, García and Espinosa (2011), the inputs to be distributed in the greenhouses should be standardised recipes that allow for simple dosage.

The system developed was capable of producing, although there were problems in the fluctuation of growth proportions, presence of mould and fungi, so it was decided to address the environmental variables, controlling temperature, humidity and oxygenation.

The aim of the present work is to develop a new proposal for an automated hydroponic system, which by means of inert materials such as sensors and microcontrollers allows the generation of an efficient hydroponic ecosystem, focused on the creation of value and innovation.

The importance of this research is based on the fact that raising productivity, by requiring less space and resources; mediating automated systems, which evaluate the features and interactions that overcome environmental changes, awakens through literature and its significance a boost to the economic development of the country; in order to achieve the correct adjustment between environment and capabilities to promote entrepreneurial behaviour, so as to promote business innovation, through the generation of competitive advantages in MySMEs.

The second section of the paper presents the conceptual framework, as well as a review of the literature and empirical studies related to automated hydroponic crops. The third section describes the methodology employed, while the analysis and results are presented in the fourth section, to finally present and discuss the conclusions, limitations and implications for future research.

Theoretical Framework

There are many antecedents that are identified in the literature as ideas and determining factors that in conditions of opportunity, use automated systems, as well as their interactions and generate better productive processes, better products or services, better forms of organisation.

In Mexico, the Mexican industry has not been studied in depth, so it is interesting to start from automated systems and knowledge; associate it with the existing knowledge in the environment and consider those products generated in the interaction.

Hydroponics _Soil-less agriculture

Cultivation in an artificial medium consisting of a nutrient solution containing the essential elements needed by the plant for its growth and development.

Internal factors.

Extensive and growing literature has examined the importance of photosynthesis, cellular respiration and phytohormones.

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External factors

Climatic, biotic, abiotic, social and economic factors are known.

Advantages

Fewer and lighter working hours, no need for crop rotation, several harvests per year, no competition for nutrients, better root development, greater uniformity of crop pieces, minimal water loss, minimal or no weeds, reduced use of agrochemicals.

Disadvantages

High initial cost, knowledge of plant nutrition and physiology, good water quality, temperature and pH control required. In the last decade, innovative activities are displacing aspects of strategic behaviour of companies, innovative activities should be understood as those that lead to the development or introduction of technological innovations, which can be classified into:

- Research and technological development (R&D)
- Industrial design
- Industrial equipment and engineering
- New products
- Commercialisation of new products
- Technology acquisition
- Services with technological content

In previous works Peña (2017), found that the variable Adoption of new Product Processes for their Company but existing in the Sector accompanied by New forms of organisation, have the greatest discriminating potential to boost innovation in SMEs.

In recent decades, indoor crop research has been widely accepted in countries such as Mexico and Chile, where there are experts in the field, manipulating physico-chemical variables of particular species (Carrillo and Vásquez, 2008).

Methodology

The research refers to the theoretical support, it is of transversal type, in which the main factors of the processes were identified, as well as the relationships, and controlled experimentation & observation was chosen as the working method.

The scope of the research is of an exploratory nature, as it makes an approach to the problem of relatively unknown studies and at the same time suggests verifiable statements in order to generate knowledge that will contribute to research on the subject. The greenhouse is 5 m wide by 13 m long and 4.5 m high, it includes a double access customs to avoid the entrance of external agents to the greenhouse, built with galvanised profiles and greenhouse plastics. (See figure 1 and 2)

Electrical components

- Submersible water pump with 2 nozzles of 13 and 16 mm 400 GPH without noise.
- pH sensor
- Water quality sensor
- Electrical conductivity sensor
- Digital submersible temperature sensor DS18B20
- Atmospheric humidity sensor DHT 22
- BabyGroot Card V1.1
- Hydrometer
- 12 V 2nd power supply
- Arduino CCTV applications

Design

In the design phase, Autodesk Inventor 2017 software was used to create a top view, in order to understand the idea before building it. (Serrano, 2005).

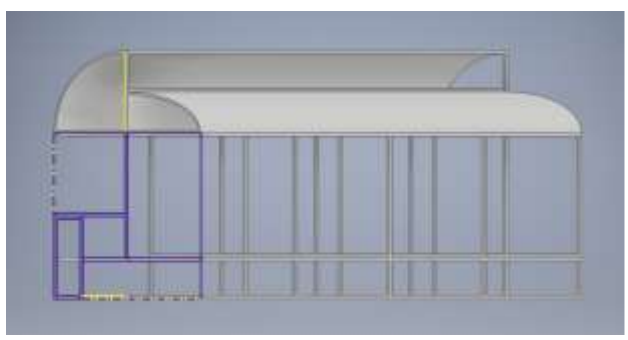

Figure 1 Greenhouse design side view Autodesk Inventor 2017

A DHT 22 environmental humidity sensor was installed, which sends a data packet to activate a relay that in turn activates a solenoid valve, which opens a water inlet directed to the anti-afrous mesh walls to control the humidity of the environment. The appropriate temperature should not exceed 40 degrees and should not drop below 40% humidity in the environment (Muñoz and Nuñez, 2012).

Figure 2 Customs-type double access door

Process

The first step is germination, by means of embryo until it becomes a plant; long-eared lettuce, Romain variety, was used.

Figure 3 Dry ice seedbed with seedling lettuce variety

To fill the cavities with substrate, a combination of 70 per cent Peat-moss and 30 per cent Perlite was used, three quarters of the cavity was filled, a hole was made 1 cm deep in the central part to place the lettuce seed and the remaining quarter was filled with substrate. (Anzorena, 1994; Guerrero et al., 2014; Flórez, 2012).

Second step, hydration of the seedbed, which was carried out in an ascending way, the seedbed was submerged in a tub until the water reached 50 per cent of the seedbed.

Third step, a wet napkin was placed on top of the seedbed and it was kept in a space where it had no contact with sunlight and its temperature was warm. It is left for 3 days until the sprout appears, after which it will be exposed to the sun for 21 days or until it reaches 10 cm of true leaf growth.

Fourth step, transplant the seedling, for which the root is cleaned using water to remove the substrate in which it was germinated.

Fifth step, the seedling is placed in a glass with indentations so that the root can support itself and obtain nourishment from the new substrate.

Figure 4 Slit vase plant

Sixth step, install the vessel in the pond to follow its growth. Holes were placed in a PVC pipe every 20 cm and with a perimeter of 10 cm.

Figure 5 Front view of hydroponic system

This alternative system can achieve up to 36 lettuces per square metre.

Figure 6 Hydraulic proportioning system with nutrient

Seventh step, feeding the seedlings, through an irrigation system that includes a pump placed inside a 100-litre tank of nutrient solution, conductivity and pH sensors, which are calibrated and checked daily.

Figure 7 Assembled hydroponic system

Indicators

The BabyGroot development board with analogue outputs, connected to the environmental humidity, pH, electrical conductivity and temperature sensors, was used for digital monitoring purposes, for hourly, daily monitoring or to check for any extra changes and can be interpreted via LCD or Bluetooth communication to a mobile application.

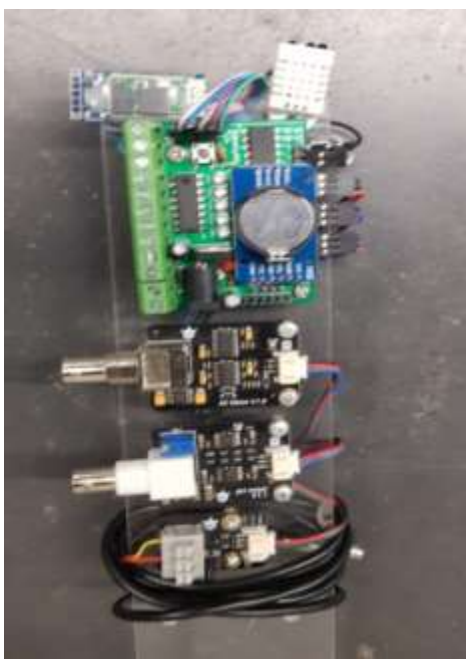

Figure 8 Automated system board

Results

According to what was expected after 3 days of germination, 21 days of seedling growth and 28 days of ripening in the hydroponic system, the Romain lettuce variety was harvested, obtaining larger products with an approximate weight of 1200 to 1500 g per piece, in comparison with those cultivated by traditional methods.

The lettuce obtained has a longer shelf life, reaching 8 days in a refrigerator, without losing its firmness, colour or flavour.

The yield per hectare in the traditional way is 70 to 80 days, for Romain lettuce with a large head, dark green colour and weights between 1100 to 1300 grams approximately, placing 3 plants per linear metre, with a planting density between 50 and 80 thousand plants per hectare, in comparison with the hydroponic system, which takes 56 days for dark green Romain lettuce with a weight between 1200 and 1500 g, without taking into account that the vegetable has less water and more fibre per lettuce, reaching 250,000 to 330,000 plants per hectare, in addition to the benefit of using 80% less water for irrigation during its growth.

Figure 9 Hydroponic lettuce for human consumption

Below is a sample of the code as an example, code that was used for the automation of the hydroponic automated system.

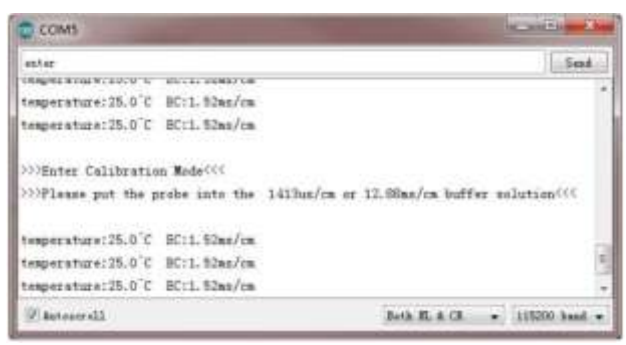

Figure 10 Arduino IDE terminal calibration of buffer solution

Calibration of the pH sensor within 25 °C to pH 7.0.

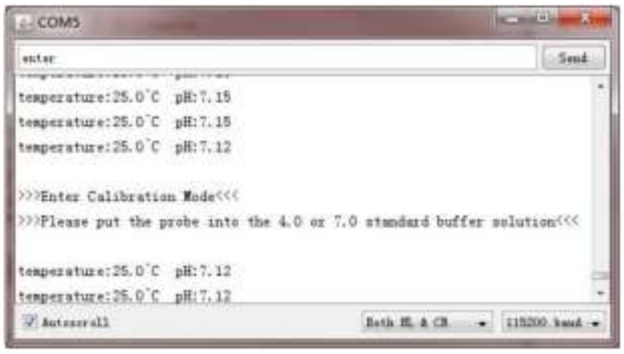

Figure 11 Arduino IDE terminal pH calibration

Conclusions

The study shows that automation in food procedures always results in benefits in terms of quality, precision, optimisation of the use of resources, including time, hygiene and productivity. In this case, it was possible to obtain up to 400 lettuces per week using 65 square metres.

Staff training is considered essential to control the variables, allowing the stability of the process.

Recognising that innovation projects are composed of more than one source of knowledge, type of organisation, geographical location, sector and market niche; thus, in the dynamics of innovation, organisation, technologies, sector dynamics and societal response are interwoven (Rip, 2012).

The optimisation of organisational performance is explained through the company's ability to constantly renew itself by identifying and exploiting new opportunities in response to customer demands and continuous improvement.

The present study is not without limitations, the complete coverage of all articles dealing with the topic of automated hydroponic system could not have been achieved, given the search procedure chosen. Therefore, there could have been papers that were addressed to automated hydroponic systems but used a different language. Consequently, the factors derived from the analysis need to be treated with caution.

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