Novel Approach to Urban Farming: A Case Study of a Solar-Powered Automated Mushroom Cultivation in a Plastic Box

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Abstract – A solar-powered, automated mushroom cultivation technique using a plastic box for urban place farming and ready-to-deploy to a disaster-hit-area is presented. The system is composed of a commercially-available plastic box where the mushrooms grow, and an automated monitor and control of air and soil humidity and air temperature for optimum mushroom growth. It is purposely designed to grow in a box to enable the easy stacking of boxes in a space-constrained urban place. The power can be sourced out from a commercial power or from the sun light using solar photovoltaic energy harvesting technology making it a standalone, ready-to-deploy food source in a disaster-hit area. Aside from organic substrate and mushroom seed, each box is equipped with low cost set of electronic components, small fan and a humidifier which facilitate the automated cultivation process. This system is not only useful for urban farming and disaster-hit-area deployment but also valuable for research purposes. It has an option to interface into a computer in a laboratory setting to precisely monitor, analyze and determine the factors that influences the optimum growth of mushroom. This approach of farming not only enabled the space-constraint farming but also improves the yield of harvest because of well-controlled growing environment. The proposed system is successfully designed, implemented and tested.

Index Terms – mushroom, urban farming, automated mushroom farming, solar-powered system.

I. INTRODUCTION

Urbanization is one of the indicators of a modernized, developed and progressed place or community. In the Philippines, high rise residential buildings in all cities in Metro Manila, as well as highly industrialized cities in Luzon, Visayas and Mindanao areas are living proof of a fast-growing urbanization. However, the fast urbanization of a place goes together with a rapid increase in urban poverty and urban food insecurity [1]. As buildings, malls and various infrastructures are erected like mushroom heads, growing number of homeless kids and families can be observed – most of them came from the provinces, a long back time. This is because they are really attracted by the opportunities which can be found only in urbanized cities.

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Food is linked to poverty. As there is no more place to do farming in the city as they usually do in the province, these people lived in streets or slums suffered from food insecurity. In addition, pollution is apparent in the urban due to lack of plants and trees that known sources of fresh air.

Another problem in urban is the higher cost of water and electricity. Many look at this as permanent burden or no solution at all. But with advancement of technology, this problem can be alleviated by the use of free and renewable energy sources such as solar photovoltaic (PV). The continuous decline on price of solar products together with the support of the government, the solar technology as a clean power source is very promising. With this, urban houses and buildings are highly feasible for PV installations. Under the Kyoto protocol, developing and already developed countries need to reduce their greenhouse gas emissions through projects including renewable energy [2].

In the Philippines, government is slowly getting involved in the Kyoto protocol regarding climate change. In fact, a law was formed and passed, the Republic Act No. 9513 – which is also known as "Renewable Energy Act of 2008" [3]. Solar as a clean source of energy is one of the topics under this law. And because of this, several solar companies were already started to invade this industry. Solar installations in residential, commercial and industrial structures are more visible nowadays than a decade ago.

Global climate change is not only the issue being solved by the use of solar photovoltaic technology, but as well as the food security in a disaster-hit area. Food supply is one of the major issues in disaster-hit area. This issue relates to the health and crime problems in the area. The usual food supplies are rice, noodles, canned goods and water – which have insufficient or lack of important nutrients. The inability of the people to plant and harvest at a short period of time complicates the problem on food. With this, approach of mushroom cultivation in a box will significantly aid them to grow and harvest good source of nutrients in just few weeks time.

It is agreeable that a novel approach in urban farming could help to reduce poverty, food security and pollution in the urbanized cities. Such approach does not require a lot of space, consumed less water and electricity and contributed minimal waste. This is highly possible by the use of technology in the advantage of farming. Such technology uses electronics controls and drivers to make the system clean and automatic.

A. What is Urban Farming?

Urban farming is not far different from conventional farming of plants. They both use soil, water and sunlight as food. They only differ by the way they are being grown. Conventional farming grows plants in the farm. A definition of farm is a vast portion of agricultural land suited for farming only. Urban farming on the other hand squeezes plants or vegetables in the little space on houses and buildings such as in rooftop, balcony and terrace such as shown in Figure 1. Sometimes plants are hanging on the building walls.

Figure 1. Conventional urban farming approach

Urban farming is very common in the cities and developed areas. This provides food and fresh air for the occupants. This brought innovation in the sense that the farmer should be creative enough in small space available. Also, the yield of urban farming is relatively better compare to the conventional farming as insects and weeds can be reduced, often attended, and automatically operated.

B. What is Mushroom?

Mushroom is a fungus that grows into a fruit on a fruiting body. There are many types of mushrooms – some are edible while other is poisonous. Edible mushroom are common in the Philippines and they are part of the long standing culture that they are being used as ingredients in many Filipino authentic dishes.

Figure 3. Mushroom cultivation in their natural environment

Mushrooms breed by spores. Under proper conditions, spores germinate into hyphae; then hyphae into mycelia. They get nutrients from the substrate until they colonized the whole fruiting body as shown in Figure 2. Temperatures, humidity and circulation of air should be controlled for the mycelia colony forms pins and grow into fruits [4].

Mushroom is ideal to grow in urban places. It requires no additional fertilizer (only substrate) and consumed less water. It also requires little space for several bags or boxes. It has little waste as its used fruity bodies/bags or substrates can be recycled into fertilizer. Additionally, mushroom is a good source of nutrients that are not usually found in other plants such as selenium, vitamin B2 and many others as shown in Figure 3.

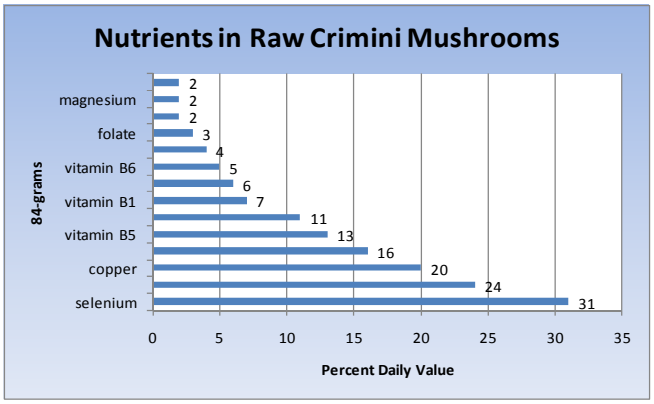

Figure 3. Nutrients in Crimini mushroom based on serving of 84 grams raw mushrooms [5].

II. PROBLEM OF TRADITIONAL URBAN FARMING AND FOOD SECURITY IN A DISASTER-HIT AREA

Although current urban farming is very promising, it has many problems that need to be addressed such as getting smaller spaces available, lack of time to take care the plants, and the impossible use of chemical when treating the diseases or infections. In a disaster-hit area, food source is a big problem coupled with lack of power source to be used in farming of mushroom.

A. Problems of Traditional Urban Farming

At present, Philippines urban cities are focus on housing and buildings with practically no available spaces for farming. For example, farming in terrace and balcony are prohibited in some prime condominium. With the use of box for farming mushroom, it can be stacked so that it will consume very minimal space.

Water source is another problem in traditional urban farming. The automation of giving water to the plant helps to optimize the amount of water for humidity inside the box. Fertile soil and fertilizer are another scarce in urban – thus selective plants should only be picked.

With mushroom, it does not require a lot of fertilizer. When plants are infected by diseases, the use of chemical in urban setting is highly illegal. With mushroom in a box, the possibility of infections is very minimal. Lastly, the waste from substrate and mushroom steam are just as decomposing leaves of tree which can be simply disposed as fertilizer.

B. Food Security in a Disaster-hit Area

The food supplies in a disaster-hit area are not only limited but lack of nutrients. Some supply foods are expired or spoiled. With the mushroom in a box powered by a solar source, it is easy to deploy several boxes to the area. This setting is very practical if power from grid is devastated and not yet restored. Based on the study, either eaten fresh or dried, the nutrients contains of a mushroom is almost the same.

C. Mushroom Farming

Mushroom farming is simple yet requires full attention in details at the start. From the preparation of spores to the pins and harvest, the steps are easy to follow. There are six steps outline in the guidelines and they are [6]: Phase I composting, Phase II composting, spawning, casing, pinning, and cropping.

Mushroom is also high yielding plant to the ratio of nutrients on the substrate. Since it is almost pest-free, it is also organic in nature. It is very healthy because of less trans-fat and other contains which directly related to the health problems. Lastly, it requires pretty little capital investment.

D. Renewable Energy Source

According to [7], "Oil, coal, hydropower, wind energy, biomass and solar energy are all directly or indirectly derived from the sun. Solar energy is the ultimate energy source and the time to establish the basis for a future society based on it is imminent". Solar energy is free and unlimited, clean, renewable, sustainable and reliable. This technology as well as other clean energy sources is the solution for about 1.6 billion people that have no access to electricity, and 2.4 billion rely on charcoal or wood as the primary source of energy for cooking and heating [7].

Though this technology is not new, the commercialization is just recently become affordable to the mere consumers. It only requires one time investment and it will result to a big savings. The lifetime of the latest solar photovoltaic is 25 - 40 years. The only maintenance required is the battery replacement which estimated to have a lifetime up to 6 years (when best battery in the market is used). Generally the return on investment is around 4-5 years. Solar is also environment friendly as its waste is non-toxic. However the manufacturing process produces waste.

Other uncommon benefits of solar energy are [8]:

- Solar systems are cost-effective in remote areas and for some residential and commercial applications.
- Solar systems are flexible and can be expanded to meet increasing electrical needs for homes and businesses.
- Solar systems can provide independence from the grid or backup during outages
- Harnessing solar energy spurs economic development.

Solar energy has possesses challenges as well. Namely they are [8]:

- PV systems are not well suited for energy-intensive uses such as heating.
- We cannot harness solar energy at night. To be used around the clock, solar systems require battery or thermal storage.
- Utility scale systems require a large amount of land.
- The highest solar concentration is found in areas far from population enter.
- Systems are affected by shading, cloudy weather, and dirt accumulation.
- Due to the cost per kilowatt-hour to generate electricity from PV, power companies often opt for cheaper sources for generation.

III. SOLAR-POWERED AUTOMATED MUSHROOM CULTIVATION IN A BOX

A solar-powered, automated mushroom cultivation technique using a plastic box for urban place farming and ready-to-deploy to a disaster-hit-area is presented. The system functional block diagram is shown in Figure 4. The system can source its power from either commercial outlet or solar harvester. There are advantages and disadvantages for one and another. The AC voltage from commercial or higher DC voltage from solar PV is regulated for the use of electronic circuits and controls. The current proto-type uses AC water sprinkler thus it can be directly connected to commercial source or to an inverter after the solar harvester. Process is controlled by Arduino Uno Microcontroller Unit (MCU) [9] and measurement data (humidity, temperature and time) [10] being display on the small LCD panel [11]. One of the important tasks of the MCU is to control when and how long the sprinkler and fan will be turned on.

Any size and color of plastic box can be used in the cultivation of mushroom. Each of the mechanisms necessary for the optimum mushroom growth is strategically placed in the box. Sprinkler is seated on top, fan and a small hole is placed opposite to each other, hygrometer and temperature sensors are dip into the substrate for accurate measuring results.

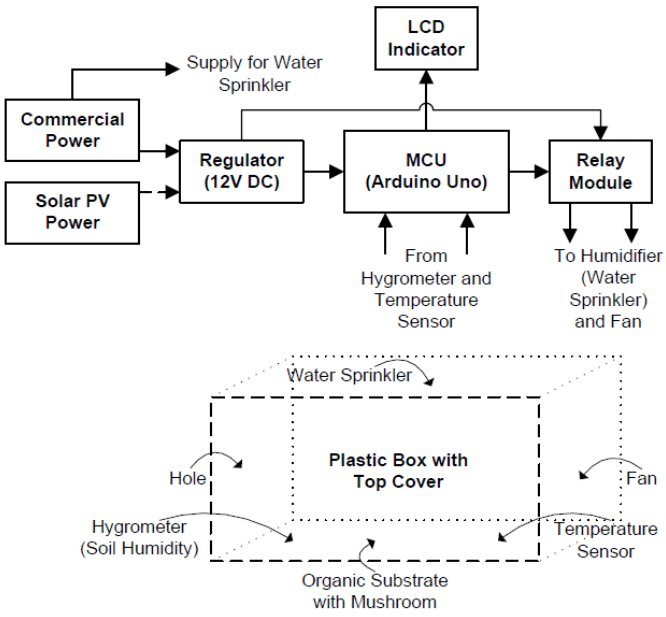

Figure 4. Functional block diagram of the system

The backbone of the system is the program or the code that runs the MCU, and its flow diagram is shown in Figure 5. The code is based on C programming of the Arduino's open-environment. As you can see, it is short, simple and straight forward program.

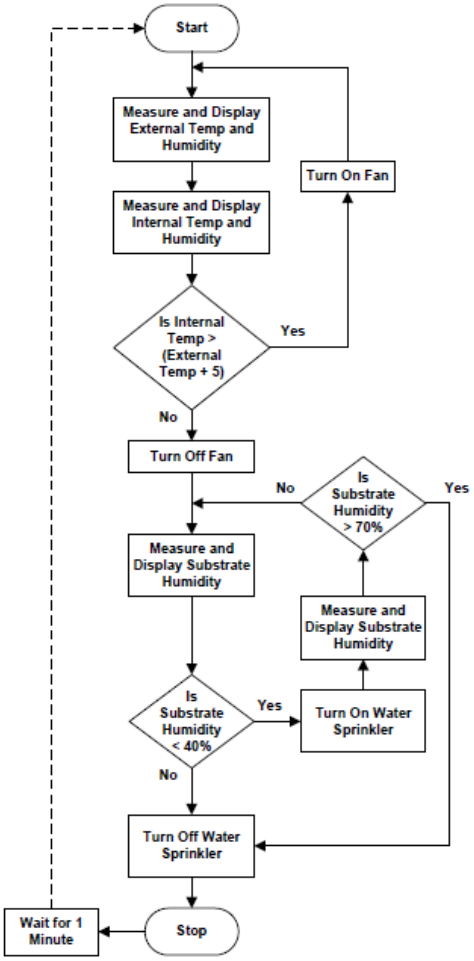

Figure 5. Flow chart of MCU program

A. Mushroom Cultivation in a Box

Oyster mushroom is chosen in this prototype. Substrate is taken from wood saw dust. Wood has more nutrients compare to the rice hull or grass compost. The actual picture of an automated mushroom cultivation in a box powered from commercial source is shown in Figure 6. In this size of box (20 x 13 x 14 inches), around 250 grams of oyster mushroom can be harvested every other day after the 4 weeks of maturity period.

Figure 6. Actual picture of an automated mushroom cultivation in a box powered from commercial source

B. Standalone Ecosystem

A solar-powered, automated mushroom cultivation technique using a plastic box is shown in Figure 7. The only difference is the power source which is solar in this case. A 100W Monocrystalline PV, 10A battery charge controller, 70Ah deep cycle battery, and a DC-AC inverter is used as power source. The quality and reliability of solar is proven to be high.

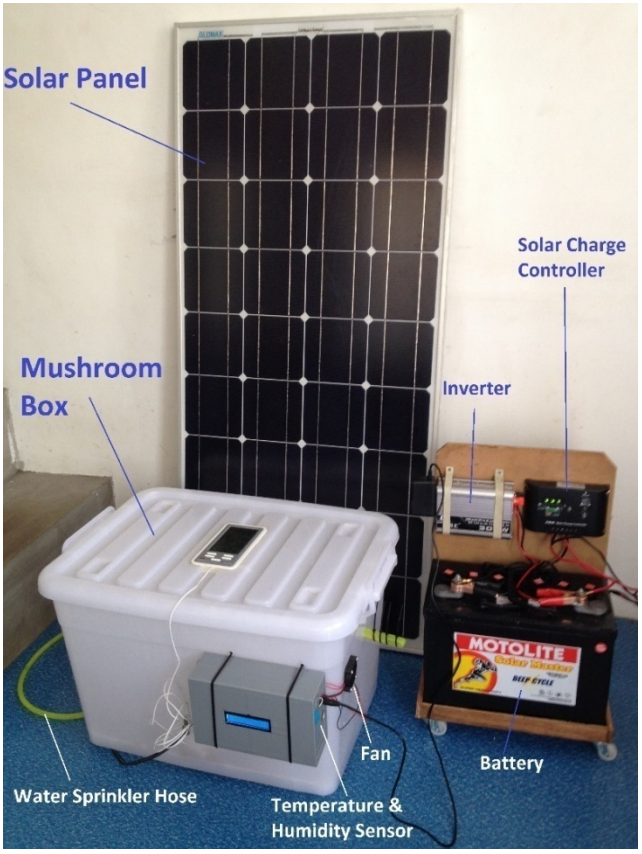

Figure 7. Actual picture of a solar-powered, automated mushroom cultivation in a box

C. Conduct Research on a Box

The same system can be used as an intuitive tool for mushroom farming development research. A precise and accurate humidity and temperature can be attained using this system. As a result, factors that can affect the optimal growth of mushroom can be studied and analyzed and the necessary corrections can be done. It only requires a computer to interface into the system to start the study.

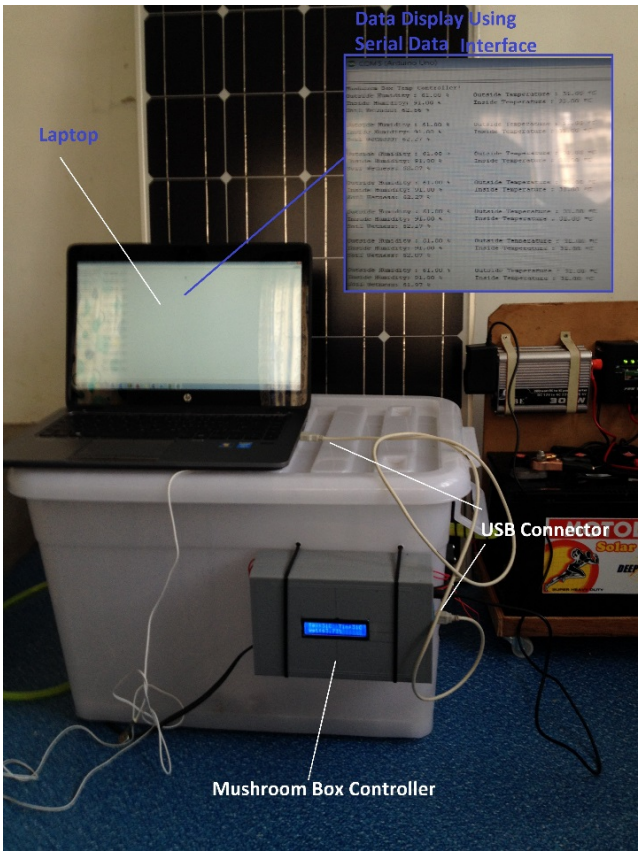

Figure 8. Actual picture of a setup for research purpose

IV. RESULT AND DISCUSSION

A solar-powered, automated mushroom cultivation technique using a plastic box for urban place farming and ready-to-deploy to a disaster-hit-area is successfully designed, proto-typed and tested. The temperature that the sensor can reach is around 10 - 50˚C. This is suited well for the intended purpose which is to measure a temperature of around 35˚C. The fan is DC model and it consumed around 1W when turned on. The hole opposite to the fan is 4cm in diameter. The measured humidity on the substrate or inside the box is around 70 - 90%. Mushroom substrate weighs around 3 kgs in a 20 x 13 x 14 inches box. Based on actual result, the oyster mushroom is matured after 4 weeks. Moreover, harvest can be made every other day which yields around 250 grams.

The bill of materials of the system and their estimated price is shown in Table 1. The total cost of the system is around Php. 3,000.00 excluding solar power source. The cost of the solar is a bit expensive in Php. 15,000.00 for a single system thus it should fall into an investment. But the solar PV can be used up to 6 years without running cost. The next expensive item is the sprinkler motor, followed by the MCU. Overall, depending on the system to choose, the cost can be optimized or lowered.

For much higher yield, based on the actual result, it is recommended to subject the box to ultraviolet light prior farming. This will ensure that the pre-exist bacteria will be killed.

Table 1. Bill of materials used in the system

Item Name	Quantity (pc)	Estimated price (Php.)
Arduino Uno MCU Development Board	1	1200
DHT11 Humidity and Temperature Sensor	2	600
Soil Hygrometer	1	300
HD44780LCD	1	500
Relay Module	2	300

V. CONCLUSION

A solar-powered, automated mushroom cultivation technique using a plastic box for urban place farming and ready-to-deploy to a disaster-hit-area is successfully designed, implemented and tested. The result shows that it is possible to cultivate mushroom in a plastic box either using a commercial or solar as power source. It requires less effort from the farmer because of the automation employs into it. A maximum of 250 grams of mushroom can be harvested every other day from a single box. Several boxes can be stacked to save space in an urban setting; while the same box can be deploy in a disaster-hit-area without so much work making it an alternative source of food. Mushroom can help to provides valuable nutrients that cannot provide by the usual relief foods. With the help of solar photovoltaic, the system is proven to work as a standalone system. The same system is also proven as an important tool for research and study because it can be interfaced into a computer in a laboratory setting. Finally, the cost of the whole system is practically cheaper compared to the traditional urban farming approach.

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