EDIBLE CITIES OF POST-ANTHROPOCENE: A BIO-TECH HOUSEHOLD

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INTRODUCTION

The current global Covid -19 pandemic has brought into sharp focus the need for a global re-examination of agro-economics, production, distribution, and consumption of food. We have seen how long and convoluted our food chains are and how susceptible to severe disruption by a global emergency that pays no attention to cultures, economies, or borders. It has also highlighted how consumer behaviour, conditioned by many years of a perceived need for instant availability of a wide range of products with all year round availability, can rapidly descend into chaos which exacerbates the situation eg panic buying of food and hygiene products. In a recent article Cappelli & Cini [1] discuss the disruption to food chain caused by the Covid-19 pandemic and suggest the answer would be to shorten the food chains so that production and consumption are both as local as possible. Such arrangements can be an effective lifeline to communities exposed to food shortages, be they rural or urban. It is also argued that quality of life within communities will improve as the micro economies create employment opportunities and circulate money locally. This paper examines and describes a small-scale energy efficient food production model which addresses the concerns noted above. It also offers some practical steps to address these challenges. The fully developed commercial prototype is described as is the production process, highlighting recent research into the energy efficiency of it. The discussion is framed around four issues of global significance; **Sustainable Food Production**, issues of **Food Security** and the concepts **Circular** and **Foundational Economies** which are discussed below**,** with definitions cited from a number of sources.

Sustainable Food Production

There are many definitions of what constitutes a sustainable food system. However, they all share common threads relating to local issues such as security, efficiency of production, health and wellbeing of consumers. Central to the concept of sustainable food production is that it is built on principles ecological, social, and economic values of a community and region.

Pothukuchi and Kaufufman in their definition place more emphasis on efficiency of production and use of energy and processes that are in tune with local ecological and environmental conditions and the recyclability of waste. They also note that sustainability should take into account the balance between food imports into the community and local capacity. This mirrors the principles of the Foundational Economy discussed below i.e. production within a community should be driven by the needs of a community and not by the pressures of external corporations' view of what the community *wants.*

In the case of the system described in this paper the sustainability elements are the basis of the process. i.e. the growing substrate (wood chip) comes from sustainable sources such as managed woodlands and production requires sustainable low energy and labour input.

Food Security

Food security is a measure of the availability of food and individuals' ability to access it. Affordability is only one factor. The issues of supply and demand have role to play as do local and global geopolitical situations and environmental changes. Food security incorporates a measure of resilience to future disruption or unavailability of critical food supply due to various risk factors including droughts, shipping disruptions, fuel shortages, economic instability, and wars. In an increasingly unstable world (from the global to the local) small scale solutions can help to inform large scale challenges. Producing food as close as possible to where it is consumed builds resilience and reduces the chances of disruption and interruption of supply. It maintains control over the food chain within the community.

In the recent publication Food Bigger than the Plate the editors discuss the disconnect between farming ie the way we use resources and labour to create food, and urban life[2]. In essence, the rural has become the location of food production and the urban it's consumption. The projects covered by the publication's accompanying exhibition speculate on ways to reverse this trend and to integrate food production with urban living, utilizing small areas be they privately owned or communal. The Mushroom Garden Growing system discussed in this paper seems to be ideally suited to achieve this aim.

The Circular Economy

A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life. The Ellen McArthur Foundation in its publication "Cities and The Circular Economy for food" describes three elements which contributes to the circular economy for food in an urban situation all of which are elements of the Mushroom Garden growing system and products. These are summarized as follows:

'SOURCE FOOD GROWN REGENERATIVELY, AND LOCALLY WHERE APPROPRIATE- the growing substrate for the mushrooms can be sourced locally or at best regionally, and is the waste product of tree surgery for Shiitake mushrooms and waste organic matter eg straw or sawdust for Wood Oyster production, and when used it is returned to the land or garden as mulch or compost.

DESIGN AND MARKET HEALTHIER FOOD PRODUCTS- The Mushrooms grown in the system have a proven provenance for nutrition and taste.

MAKE THE MOST OF FOOD - the system and the produce produces very little waste all of which can be composted. [3]

The Foundational Economy

The Foundational Economy is a classic "bottom up" model. As opposed to the" top down" approach of many government institutions on local, regional, and national levels, it is a community led economic model based on community's real needs and rights. It does not blindly follow the perceived needs as laid out by dogmatic policies or the market. Bentham et al take a broader view on the matter in the Centre for Research on Social and Cultural Change publication "Manifesto for the Foundational Economy". They identify three major players that influence the Foundational Economy namely the state, the privatised utilities and supermarkets [4] This demonstrates how food production, distribution and consumption is such an important component of people's lives which can be addressed through the Foundational Economy. The Mushroom Garden's growing system is developed with the immediate

needs of the community the primary consideration, and, as the Mushroom Garden system is a Wales based project, it is a perfect fit for this important message from Welsh Government.

THE PROTOTYPE FOR GROWING HIGH VOLUMES OF QUALITY NUTRITIOUS FOOD

The paper discusses a prototype of a system for growing mushrooms called the Mushroom Garden System based on converted shipping containers. In essence, the shipping containers are insulated boxes where the environment can be manipulated to encourage growth of Shiitake and Wood Oyster mushrooms. The System is based on two units, one for sterilizing, inoculating, and incubating the growing substrate, which is wood chip and straw. The second unit is the growing or fruiting unit where the mushrooms emerge from the substrate and grow. For the precise steps and conditions for successful growing see section The Process.

Fungi are becoming increasingly important in the western world and developing countries as a valuable food source. A recent report from Fortune Business Insight [5] show an estimated increase of global mushroom consumption from 12.74 million tons in 2018 to 20.18 million tons in 2026. with an increasing canon of evidence of health improvement properties especially in immune system boosting properties and antioxidant properties.

The analysis below shows how both Shiitake and Wood Oyster mushrooms are rich in essential nutrients, which are enhanced and concentrated when the mushrooms are dried. The Vitamin D content is highlighted as the Mushroom Garden System generates three times more of the vitamin in Shiitake mushrooms than current commercial growers, as demonstrated by the data by USDA National Nutrient Data base.[6] below (see Table 4, Table 5 ,Table 3 and Table 7). The nutritional values as a percentage of the weight increases dramatically when the mushrooms are dried (weight loss 90% when dried so concentration increases). Particular attention should be placed on the protein values of the dried mushrooms which are higher than some processed meats eg bacon.

Nutrients	Amount
Basic Components	**100g Contains**
Protein	2.10g
Carbohydrates	5.20g
Water	86.69g
Ash	0.81g
Calories	
Total Calories	36.46Kj
Carbohydrates	
Dietary Fiber	1.00g
Sugar	1.00g
Other Carbs	3.10g
Vitamins	
Vitamin C	2.50mg
Minerals	
Iron	2.60mg
Sodium	21.98mg

Table 4: Fresh Shiitake Mushrooms source USDA National Nutrient Data base [7].

Typical Values	100g Contains
Energy	1492kJ/ 353kcal
Fat	1.0g
of which Saturates	0.2g
Carbohydrate	63.9g
of which Sugars	0.g
Fibre	11.5g
Protein	16.3g
Salt	0.03g

Table 5: Dried Shiitake Mushrooms source [8]

Basic Components	100g Contains
Protein	3.31 g
Carbohydrates	6.09g
Water	82.0 g
Calories	
Total Calories	217 KJ
Carbohydrates	
Dietary Fiber	2.30 g
Sugar	1.08 g
Other Carbs	2.71 g
Vitamins	
Vitamin A	30.00 mg
Minerals	
Iron	1.33 mg
Sodium	18.00 mg

Table 6: Fresh Oyster Mushroom source USDA National Nutrient Data base [9]

Typical Values	100g Contains
Energy	660kJ/ 160kcal
Fat	2.0g
of which Saturates	0.2g
Carbohydrate	0g
of which Sugars	0.g
Fibre	24g
Protein	23g
Salt	0.03g

Table 7 Dried Oyster Mushrooms source [10]

Most cultures would dry mushrooms before use not only to concentrate the nutrients but also to increase shelf life from 7 days to 12 months. The Mushroom Garden has had a confidential report commissioned through Coleg Menai Food Technology Centre with an UKAS certified laboratory in –2018 that shows the Vitamin D content of Fresh Shiitake mushrooms grown in our system increases x3 under LED compared to Fluorescent light of the same strength and quality in the same environment. Vitamin D has several important functions. Perhaps the most vital are regulating the absorption of calcium and phosphorus and facilitating normal immune system function. Getting a sufficient amount of vitamin D is important for normal growth and development of bones and teeth, as well as improved resistance against certain diseases. Mushrooms have long been known as a good source of vitamin D; however, our work has shown how the vitamin content can be greatly increased with LED light at lower cost. The system yields approximately 200kg /week of mushrooms when in full production.

The Process

The Mushroom Garden's growing system is an energy efficient indoor cultivation process. It requires a single-phase electricity supply to power lighting and air removal pump and humidistat and clean water. The system and the process are based on integrating basic biology and technology and can be sited in

the built living environment both rural and urban. The growing process is composed of two elements both of which take place in converted insulated 20ft shipping containers with basic freely available equipment and fittings. The containers in Figure 20 are from The Mushroom Garden Snowdonia.

Figure 20: Growing Containers

Container 1 - Preparation of growing substrate

The substrate (wood chip and sawdust) is sterilized in purpose made plastic bags with breathers in large pressure vessels. Heat from burners fuelled by gas cylinders is used to raise the temperature in the pressure vessels to 120°C for 4 hrs Then the vessels are allowed to cool, removed and inoculated with mushroom spawn (the germinating spores). This is kept for 8 weeks in a warm environment (25°C) until the bag is completely colonized and forms a block with a hard outer crust.

Container 2- Cultivation and harvesting.

The bags are removed from the incubating container to the fruiting container where the temperature is 15° C with 97% humidity and hourly air change to keep CO2 levels low. The process requires 12 hrs light per day - this can be ordinary fluorescent tube lights or preferably LED. The combination of these changes shock the fungal mycelia to form fruiting bodies i.e. the mushrooms. This process takes 2 weeks to complete, as shown on Figure 21 and Figure 22.

For the first few years the unit grew only Shiitake mushrooms, then following enquiries and requests from customers to supply other mushroom species it was decided to explore the cultivation of Wood Oyster mushrooms, and to attempt to grow both species in the same environment. It was discovered that there are no negative effects in terms of mushroom yields per block. Neither has there been an incident of cross infection ie Wood Oyster mushrooms growing on the shiitake blocks or vice versa, therefore with careful management each species can be harvested separately. This provides the opportunity to widen the range of species grown at the same time in the same environment thereby adding to the diversity of production, thereby increasing attractiveness, sustainability and productivity of the system. The energy efficiency of the cultivation process has been monitored closely with energy input and distribution of heat and light within the growing container. The change from Fluorescent to LED while increasing the Vitamin D content of the Shiitake mushrooms had no effect on the yields of mushrooms or their quality.

Figure 21. Inside Container 2

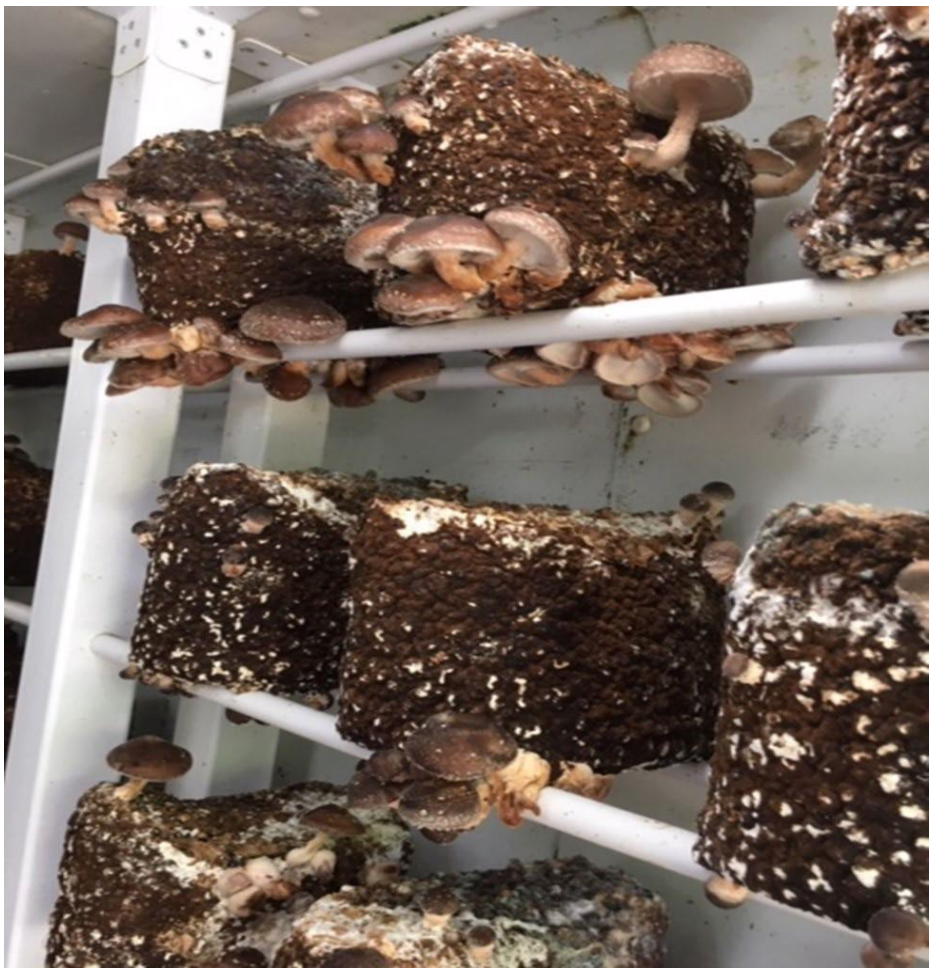

Figure 22. The growing blocks fruiting with Shiitake mushrooms

THE APPLICATION

This section will illustrate the application of the container and the flexibility of the system on three case studies in different locations.

Case Study 1: The Mushroom Garden Snowdonia- Wales

This original cultivation unit has been operational since 2006. The unit can hold 300 growing blocks and produce yields of 150kg/week of Shiitake or Wood Oyster mushrooms. Below is shown the proprietor harvesting the mushrooms in container 2 (see Figure 23). The business soon developed products based on the mushrooms, for example Dried Shiitake mushrooms and dried Oyster mushrooms - this means that there is very little waste, and the shelf life and storage time of the mushrooms is greatly increased from 7 days in a chiller for fresh to 12 months ambient for dried. Recent development has seen the production of blended seasonings based on the mushroom powders made from the dried mushrooms. The fresh mushrooms are sold to local restaurants, delis and farm shops thereby supporting the principles of the foundational and circular economies. The dried products and seasonings are sold further afield all over the UK as they travel well and have a long shelf life. These products provide added value to the business, avoids waste and create an income stream that helps the sustainability of the business. The used mushroom blocks are composted and offered to local gardeners as a mulch again closing the loop in a circular economy.

Figure 23. Harvesting the Shiitake mushrooms

Case Study 2: The Battlesteads Hotel Hexam Northumberland England.

The Hotel is situated in the village of Wark in Northumberland. The establishment is more than a traditional Hotel with accommodation a bar and restaurant. The business prides itself on serving locally sourced produce, complimented by their own home-grown fruit and vegetables, prepared to an exceptional standard by their chefs and kitchen team. They are a foundational economy business as they supply a basic need i.e. food for the community which is produced locally. Composting waste to be used in the hotel's market garden closes the loop in the food production cycle.

The Mushroom Garden system, as described in the first case study fitted in to the ethos of the hotel perfectly enabling the sustainable cultivation of quality products all year round. The power, heat and water for the growing unit is provided from sustainable sources at the hotel and the spent mushroom growing substrate is composted with other hotel organic waste (see Figure 24).

Figure 24. Battlesfield Hotel Vegetable Garden

Case Study 3 - Awen Cultural Trust Bridgend Wales -B-Leaf

Awen Cultural Trust was established in 2015 as a charitable organisation with objectives to enhance cultural opportunities in Bridgend and the wider region. Its purpose is to make people's lives better by providing space and opportunity for people to enjoy vibrant cultural experiences that inspire and enhance their sense of wellbeing. Their values of social inclusion and opportunities for all are enshrined in everything they do, from how they interact with customers and partners to how they work internally with colleagues, staff and trainees.

One project within Awen Cultural Trust do is the B-Leaf work-based initiative for adults with disabilities located in the Bryngarw Country Park. It operates as nursery and garden centre and provides an extensive training programme in horticulture and grounds maintenance. Trainees and staff are all local to the Bridgend area. The Park with its and extensive grounds provide much needed opportunities for leisure and exercise for a highly populated post-industrial community on their doorstep. The addition of the market garden and shop adds value to the Park experience and as such this is a prime example of a Foundational Economy project which the mushroom growing enterprise enhances (see Figure 25).

As a means of increasing the training and business opportunities at B -Leaf, the Mushroom Garden was approached with the aim of establishing a Shiitake and Oyster mushroom growing enterprise. This activity would provide new experiences for the service users, diversify the range of products cultivated and create a new income stream to the project. In these days of economic uncertainty, a consistent income stream as is provided from the sale of the cultivated mushrooms the new enterprise increases the sustainability of the business and provides the local community with a regular supply of nutritious foods. This is an exciting development for the Mushroom Garden as the company has always believed that the system is ideally suited to a social enterprise and specifically an enterprise working with people who have learning challenges.

Figure 25. Staff and Trainees at Awen Cultural Trust

Critical concepts for the future of cities and regions as demonstrated by the case studies

The mushroom growing system is robust and flexible to meet the needs of a range of communities. Individuals can be trained to use the system in a few days and the skill level required is low. Initial training is 2 days intensive input either at The Mushroom Garden site or on the location where the growing facility is to be established, followed by up to 10 days mentoring on site to ensure that the growing conditions are working and that the operators understand how to control the conditions and to0 harvest the mushrooms. As the system is modular (i.e., based on converted shipping containers) upscaling is achieved by commissioning more containers. In an urban area public services can be very useful in upscaling eg by organising supplies of wood chip from municipal parks and roadside tree surgery. This is where input from public services can be very helpful e.g. sourcing and transporting the substrate from municipal sites to the growing facility, and also on the demand side by distributing the mushrooms to the communities and neighbourhoods that need them. The system fits perfectly with community food growing projects, city gardens and farms. Upscaling is not a problem as the process is modular so commission more shipping containers.

There are opportunities to explore using other substrates to grow certain nutritious mushrooms (eg Wood Oyster) such as spent ground coffee and hops from breweries.

Sustainable production of food

The substrate to grow the mushrooms is wood oak chip and sawdust. It is sourced from local sustainably managed woodlands and traditional furniture makers. Energy input is low, at a daily cost of approximately £6.00 and there is continuing development on increasing the energy efficiency of the process. In addition to this, the Battlesteads Hotel generates its own electricity by solar panels. The growing rooms are of low maintenance in respect to the equipment and fittings so that it keeps costs to a minimum. Labour input is low grade in terms of skills and the work is not heavy. Therefore, it is ideal for part time workers and/or family members on shared households to undertake.

The Circular Economy

The growing substrate is waste product from wood production. The used substrate, ie after the mushrooms have been cultivated and harvested is returned to the land through gardeners and farmers as mulch/compost/soil build up material and water retention material. The Handbook of Waste Management from 2009 discusses the importance of reducing and reusing waste in the food industry **[11].** The book demonstrates that there are clear economic benefits to the industry if a circular economy approach is taken in food production in general. It secures clear environmental benefits to the planet by efficient use of ingredients and raw materials and reducing waste. The book discusses strategies to address the issues of waste production and reusage are discussed such as tight supply chain management, capture and re use of water and the re usage of organic waste from production to cultivate other foods. These approaches have been developed by mushroom growers in recent years eg growing Oyster mushrooms on used coffee grains and also spent hops from breweries. Both these substrates have been trialed successfully by The Mushroom Garden.

The Mushroom Garden system mirrors such strategies. Closed circle food production is critical to future development as it keeps production locally, thereby reduces the carbon footprint of the enterprise as well as waste and pollution. Another Circular aspect of the system is that income generated from the sale of mushrooms is spent locally by the business. The economic impact of keeping spending locally is demonstrated by a report by the New Economic Foundation [12] The findings were that for every £1.00 invested or generated in a community 52p is retained in the local economy , furthermore every £1.00 spent generates a further 71p in the local economy.

The Foundational Economy

A basic principle of the foundational economy is to supply a community's needs as the basis of a local economy, those needs are physical eg basic services, utilities and food but also social needs eg health education and security. All three case studies demonstrate the process of local production distribution and purchasing of food within their communities and as such demonstrate a perfect fit for the foundational economy principle. The units are very robust and can be sited within most communities, urban or rural such as city courtyards, urban farms, traditional or vertical or garden. In fact any communal space with access to clean water and single phase electricity. The main advantage is that the produce can be grown all year round as the cultivation conditions are carefully controlled.

It therefore makes it possible to provide a consistent supply of nutritious food to a community from within that community.

Food Security

In all cases studied the products travel very little food miles, no more than 20 miles and in the case of the Battlesteads Hotel about 20 meters! therefore the food is produced and purchased in the same vicinity. The raw material used to make the substrate can be sourced locally, wood chip and sawdust for Shiitake, straw for Oyster mushrooms, or in fact any organic material including processed organic material such as paper. Reducing food miles is crucial to reduce food insecurity and carbon footprints, and to shorten the food chains. Such measures have been brought into close focus recently with the Covid -19 crisis and ongoing uncertainties with supply chains from the EU following Brexit. This discussed model is looking to the future of Agro-architectural application for transition to Post-Anthropocene era cities and regions where people, other species and technology benefit from each other and flourish. These growing units are situated within the communities they serve reducing food miles and dramatically reducing supply chains.

NOTES

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