VERTICAL RABBIT FARMING INTEGRATIVE SYSTEMS FOR CITIES: MODELS AND OPPORTUNITIES – A BIBLIOGRAPHIC REVIEW

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ABSTRACT

A recent development in human history is the fact that most people now live in cities. With many serious issues or challenges that affect current food production levels including the rising demand for food, it has become increasingly evident that urban inhabitants must contribute a significant share of global food production. With recent advancements in technologies applied to the development of vertical farming systems, this challenge is presently being embraced with fortitude in some major cities. Such systems are now beyond the mere blueprint stage and even involve closed-loop or circular ecosystems where solar energy and wind power are harnessed, and rainwater is collected. Such systems much farther limit the carbon footprint compared to traditional rural farms. It is forecasted that soon, some cities will become food self-sufficient. This paper will describe several innovative and applicable vertical farming models (e.g., aeroponics, aquaponics, and hydroponics), which could potentially include a rabbit meat component. Unlike poultry and fish, rabbits are ideal because they can subsist largely on plant wastes. Moreover, their fecal and urine wastes can be recycled and processed as fertilizer to grow vegetables and other crops or even to fertilize ponds used for aquaculture. An opportunity exists for rabbit scientists to engage in research programs that address the need to solve preliminary problems in order to promote rabbit production in futuristic vertical farming systems that are used for urban food production.

Key words: Rabbit, Food production, Sustainability, Urban agriculture, Vertical farming.

INTRODUCTION

It is a well-known fact that most humans today live in cities. This event, however, creates a paradox in terms of the demand for food, especially by millions of people who inhabit the world's largest cities. Notwithstanding this, some experts contend that a doomsday scenario would make urban populations highly vulnerable to the exhaustion of food supplies in stores within a matter of only a few days, resulting in social mayhem such as food riots and looting (Wolny, 2010). One solution is to develop sustainable systems of food production in cities. There are additional benefits with respect to employment opportunities as well as to the environment in terms of reduced nutrient and water inputs as well as greenhouse gas emissions associated with food transportation. Fortunately, growing food in cities is not a new development. In several cities, urban farmers are now producing nearly one-third of the food consumed by its inhabitants (FAO, 2019a). One stellar example is Havana, Cuba, where about 90% of the food consumed is produced according to the Cuban Ministry of Agriculture. The United Nations established a program in 2001 to promote urban food production. Educational materials on urban agriculture are available (FAO, 2019b).

On the occasion of the International Conference on Rabbit Production in Hot Climates held in Selangor, Malaysia, Gidenne (2019) presented a provocative paper entitled: Urban Rabbit Farming. The comparative features of the rabbit to other livestock species were extolled in the context of urban food production, but largely involving conventional management systems. With an emphasis on land

and nutrient use efficiency, R&D efforts to design and implement multi-storied and eco-efficient, vertical farming systems are key to mass food production efforts in cities (Vyas, 2018). Such ambitious innovations are certainly achievable. The addition of a rabbit component, via in integrative models, is without question a serious proposition, considering all of the advantages that this species has to offer. The objectives of this concept paper is to describe various potential models that include rabbits as a component in vertical farming systems employed in cities that strive to become more food self-sufficient.

POTENTIAL VERTICAL FARMING MODELS

Vertical farming models

The following discussion of various vertical farming models is based to a large extent on the recent popular article by Vyas (2018) entitled: 13 vertical farm innovations that could revolutionize agriculture. A brief description of each model will be presented. An overview of these models is provided in Table 1.

Table 1: Vertical farming models modified by Vyas (2018) that include a potential rabbit component

Model	Description	Rabbit contribution[1]
Hydroponics	Growing plants without soil	Rabbits consume plant wastes
Aeroponics	Growing plants without soil and very little water	Rabbit manure is recycled as fertilizer
Aquaponics	An ecosystem that promotes plants and fish	Rabbit manure as fertilizer for fish tanks
Lokal	Serving fresh food right where it is grown	Rabbit meat is consumed right there too
AeroFarms	The smart vertical farming innovation	Rabbits are fed smart diets
Plantscapers	A building that provides food for its occupants	Rabbits raised in tiered cage racks
VertiCrop	A sustainable farming technique for urban areas	Rabbits are fed precision-balanced diets
Modular farms	Produce fresh plants virtually anywhere in the world	Rabbits can be raised in any climate
Cubic farming systems	The next generation of sustainable farming	Rabbits are raised using automation
Bowery	A technologically sophisticated commercial farm	Rabbits are fed a high-variety plant diet
ZipGrow	Vertical farming for modern farmers	Rabbits are raised using system controls
Skyfarm	A wind-powered vertical farming tower	Rabbits are raised in a high-efficiency tower
Sky Greens	The world’s first hydraulic-driven vertical farm	Rabbits are raised using a hydraulic system

[1]The same contribution listed may apply to several other models.

The **Hydroponics** model is simple and is already widely popular. It involves growing plants without soil where plants are grown in containers that are immersed in a nutrient-rich solution that can be circulated and monitored for quality control purposes. **Aeroponics** involves the cultivation of plants without soil which uses very little water. This system was developed by NASA whereby plants are literally grown in air and receive water through mist applications. **Aquaponics** includes both plant and fish farming. Tilapia is the fish species of choice, in part, because they can be largely fed algae and then harvested by 6 months of age. Being of tropical origin, they do not require colder water temperatures as do salmon and trout. In Singapore, a vertical fish farming system has been developed by the consulting firm of Surbana Jurong and Apollo Aquaculture Group (Koh, 2017). Cultures of algae are grown using solar panels which are fed to tilapia fish. Plants are grown to purify and filter waste water from fish farming, which in turn is recycled to the fish tanks. This same system contains tanks for rearing breeding fish stocks to produce fry as fingerlings. Six-time higher fish yields have been reported with this integrated system.

The **Lokal** model features the availability of fresh local food to consumers where it is produced. The Space10 innovation lab of IKEA developed this hydroponic-based system that employs LEDs. Plants are reported to grow three times faster than from conventional gardens. Plants are grown in multiple trays and represents a “kitchen garden” or “Mini-farm”. In addition, Smartphone technology can be applied to monitor plant growth development. **Aerofarms** integrates several smart-based technologies into an aeroponic system for plant food production in an effort to minimize negative environmental impacts. In fact, the focus is on accelerated food production involving a whole farming system with less land use and with the environment in mind. The **Plantscapers** model involves tall, multi-story buildings that provides both home and office spaces for people and space to produce food. The

Swedish company, Plantagon, developed this system wherein one building can annually produce 550 tons of vegetables to feed 5,000 people. The greenhouse system utilizes solar energy. Hydroponic food racks are moved by automation to synchronize plant stage growth with optimal levels of solar energy (sunlight and temperature) and nutrients. Here too the focus of this system is on sustainability. Another sustainable and innovative farming model is **Verticrop** which involves a closed-loop system. Both artificial and natural lights are optimally utilized, as well as the nutrient needs for individual plants. This system uses only 8% of the water than traditional farming. It is claimed that 20X more food is produced by this high-precision system that involves use of plant trays on conveyer belts. Moreover, herbicide and pesticide use are avoided.

Modular farms or "container urban farms" represent an entirely different concept. The use of self-contained modular buildings are suitable for almost any climate. Internal controls of temperature regulation, nutrient and water use, LED exposure, etc., are featured. This system is scalable and can be customized to produce the desired quantity of food. The **Cubic farming system** is similar to the previous system but is considered as the next generation of such systems. This Dutch-patented development claims that food production and income earnings are more predictable because of the precise control of automated controls that involve plant trays on rotating conveyers, LED lights, and nutrient delivery. In addition, this system utilizes only about 1/26 of the water used in conventional farming. The **Bowery** is an operational, hydroponic-based system that also uses precision technology to grow over 100 varieties of herbs and vegetables. Data are collected from plants to determine ideal growing conditions and time of harvest. The U.S.-based company recycles 95% of the water and claims to produce 100X more food per square-foot than a farm in the U.S. The **ZipGrow** model involves another hydroponic- and vertical-based system. However, it is a different concept that applies to inexperienced producers with sub-optimal growing conditions who can be assisted by consultants (i.e., involving high-tech, workflow innovations) to design a custom-made system.

The last two vertical farming systems are the Skyfarm and the Sky Greens prototypes. Both systems are touted as being revolutionary. The **Skyfarm** involves a hyperboloid tower that is comprised of different strata: the bottom floor consist of fish tanks, the middle stories produce plants using solar energy and hydroponics or water mist systems (nutrients are recycled between the fish and plant components), while wind turbines and water storage tanks are found at the top of the tower. **Sky Greens** is an innovation developed in Singapore that is based on a hydraulic-driven, low-carbon input system. Plants grown on shelves are periodically rotated to efficaciously expose plants to sunlight and water. The company extolls that 10X more food is produced than on conventional farms.

POTENTIAL APPLICATIONS OF THE RABBIT COMPONENT

Benefits of the rabbit component in vertical farming systems

In vertical farming systems, a rabbit component would complement the effort to grow food more efficiently and sustainably while providing high-quality animal protein. Unlike poultry and tilapia, plant food wastes could be fed directly to rabbits while their wastes could be recycled as plant fertilizer. The inclusion of rabbits could even expand the number of plant species that are farmed. To minimize labor, rabbits could be raised in proximity to rooms or floors where plants are grown or processed. In aquaculture-based systems, both fish and rabbit wastes can be processed and recycled to produce nutrients for algae and crop production.

Production figures of rabbits compared to other seemingly suitable livestock species for vertical farms are presented in Table 2. In the Netherlands, Viviano (2017) described on a vertical-rack system of broiler production. However, one key disadvantage of broilers is that they require grain and have 2-3X higher water requirement than rabbits. On a fresh forage diet, rabbits would consume even less water. Neto and Ostrensky (2015) reported that only 26.4% of organic matter in feeds was digestible for tilapia fish and that only 35 and 28% of nitrogen and phosphorus, respectively, were retained from the diet. Tilapia also take over twice as long as rabbits to reach harvest size. Swine are likely too large for the mentioned vertical farming systems.

Table 2: Comparative production aspects of livestock species with the potential for vertical farming[1]

Species	**Diet base**	**Dietary CP%**	**ADG g/d**	**FCR**	**Weight at harvest, kg**	**Age at harvest, d**	**No. animals/m^2**	**Carcass yield %**	**Meat Protein%**	**Nitrogenous waste**
Rabbits	Forages	16	40	3:1	2.0	63	16	55	21	Feed proteins
Broilers	Grains	20	56	1.9:1	2.6	47	18	71	20	Uric acid
Pigs	Grains	12-14	668	3:1	114	170	0.1-0.65[2]	72	12	Multiple
Tilapia	Algae	30-40	1.5-1.8	1.6:1	0.40	150-180	3	52	20	Ammonia/ Urea

[1]Figures obtained from various literature sources.
[2]Range accounts for a pig weighing from 5 to 100 kg.

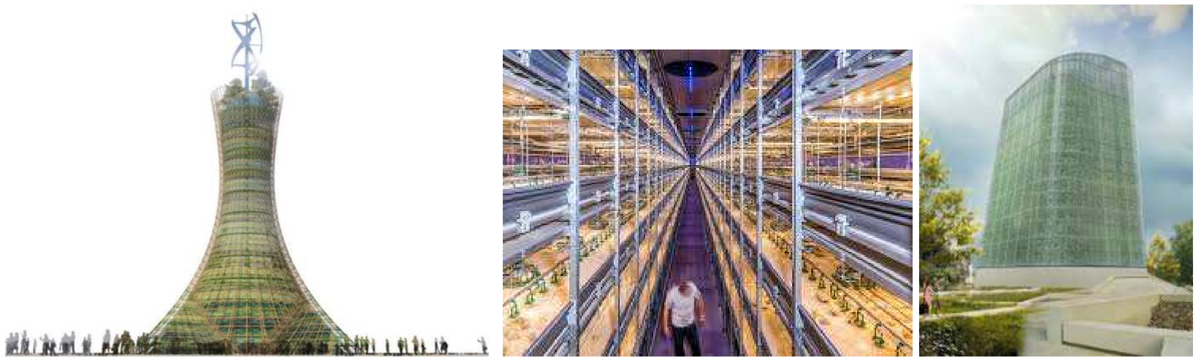

Figure 1: A Skyfarm hyperboloid tower (left) that harnesses solar energy and wind power and collects rain water to grow food (Vyas, 2018), a vertical system of broiler production in the Netherlands (middle; Viviano, 2017), and the Plantscapers system developed by Plantagon that provides space for homes and offices and food production (right; Vyas, 2018).

CONCLUSIONS

Overall, vertical farming focuses on mass food production at reduced costs while being sustainable in terms of land and eco-efficiency. Ideally, food grown in cities should be consumed locally as well as processed for long-term storage to enhance food security. An opportunity exists for rabbit scientists launch R&D programs that address the potential integration of a rabbit component into such futuristic vertical farming systems, as well as to create awareness. One obvious issue would involve concerns by animal rights groups.

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