A Review on Utilization of Domestic Waste in Rooftop Vegetable Gardening

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ABSTRACT

Populations living in urban and peri-urban areas around the world are increasing rapidly. Rapid urbanisation is placing enormous demand on urban food supply systems and causing problems like a rapid decrease in green space and an increase in heat island effects in urban areas. Rooftop vegetable gardening can reduce the temperature of roofs and the surrounding air, help to lessen the urban heat island effect, and absorb carbon and noise. In some urban rooftop gardens, mineral fertilisers and pesticides are used. Researchers observed that compost can be used as a source of nutrients instead of mineral fertilizers. Moreover, it can control pests, weeds, and diseases; reduce soil erosion; and increase soil moisture content. Kitchen waste compost might be a suitable supplement in rooftop vegetable gardens because domestic garbage is common in every household in urban and peri-urban locations. In India, rooftop gardening is quite a new phenomenon. This review work will help to understand rooftop gardening and conduct research on rooftop gardens in the future.

Keywords: Domestic Waste, Rooftop Garden, Composting, Vegetable, Gardening, Waste Management.

Introduction

In the world, urban areas house 54 per cent of the total population, with that figure expected to rise to 66 per cent by 2050 (United Nations, 2014). Rapid urbanisation and population growth place enormous strain on urban food supply systems. Furthermore, many cities around the world are experiencing issues such as a rapid decrease in green space and an increase in heat island effects. Urban agriculture or rooftop farming is recommended as a potential solution to these problems (Smit et al., 2001). When food is produced locally, there is no need to travel long distances to obtain fresh and pure foods, which reduces the use of fossil fuel for transportation and, as a result, has a positive impact on the environment (SGUFS, 2014).

Rooftop vegetable production can help to reduce the temperature of roofs and surrounding air, which helps to cool a local climate (Ries, 2014) and can help to reduce the urban heat island effect (Hui, 2011). Rooftop farming can also help

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to reduce carbon emissions and noise pollution (Dubbeling, 2014). Rainwater is captured and absorbed by plants, reducing the impact on infrastructure (Ries, 2014). Rooftops with vegetation can be a great place to relax, and this type of farming can easily provide employment (SGUFS, 2014). Rooftop vegetable production contributes to biodiversity by providing habitat for a variety of insects and birds (Higher Ground Farm, 2019). Farming on urban rooftops is typically accomplished through the use of green roofs, hydroponics, organics, aeroponics, or container gardens (Asad and Roy, 2014). Different types of fertilizers, insecticides, and pesticides are used in agricultural production, but their widespread use harms human health, degrades the environment, and raises crop production costs. Currently, agriculture universities and research institutes are focusing on integrated pest and nutrient management through the use of various microbial natural resources as biofertilizers and by modifying several conventional practices (Sinha et al., 2010). Every day, various types of domestic waste are generated in homes, canteens, mess halls, and hotels. Domestic waste can be vegetable and fruit waste of different types (fruit, vegetable, and vegetable remains and peelings), eggshells and coffee sediments, tea and coffee filter bags, tainted food, non-liquid cooked food waste, bones, stale bread and biscuits, tissues, paper towels, and paper sacks that are biodegradable. Domestic waste can be composted by various microorganisms, such as bacteria, fungi, and actinomycetes, in the presence of oxygen. Humus can be used to grow vegetables on rooftops, which is extremely beneficial (Wilson, 2009).

Rooftop Vegetable Gardening

Rooftop vegetable production refers to the growth of numerous types of vegetables on city building roofs (Sustainability Television, 2019).Cultivation on the rooftops of buildings in urban areas is usually done by using green roofs, hydroponics, organics, aeroponics, or container gardens (Asad and Roy, 2014). The most fruitful form is hydroponics techniques using a specially designed greenhouse (Sustainability Television, 2019). Rooftop vegetable farming could benefit the environment and provide a significant proportion of vegetables for urbanites (Liu et al., 2016). Rooftop vegetable production also offers many environmental and social benefits to densely populated urban cities (Hui, 2011). By utilising rooftops for vegetable cultivation, it is possible to obtain social, economic, and environmental sustainability for buildings in urban cities. Because it can contribute to the development of urban food systems by enhancing local food production, meeting the nutrition demand of the people through access to nutritious food, reducing air pollution, increasing storm water retention capacity, improving public health, enhancing the aesthetic value of the urban environment, and amplifying community functions (Localize, 2007).

Worldwide Scenario of Rooftop Vegetable Gardening

The practice of producing vegetables on rooftops has been increasing in recent years to facilitate agricultural sustainability in urban areas. Rooftop agriculture allows urban areas to become more sustainable in their resource exploitation and to help develop food security for residents. Rooftop gardens are becoming an important part of the recent regeneration of urban agriculture and provide alternative spaces to grow vegetable products for urban markets (Ouellette et al., 2013).

The production of vegetables on rooftops should not be thought of as an alternative to massive-scale vegetable production in rural areas (Gaglione et al., 2010), but rather as an enhancement to the urban food movement by providing another source of local, fresh foods (Tomalty et al., 2010). Many urban areas are now producing over 20% of their vegetable needs within city boundaries. Urban agriculture is widely utilised in developing countries, although some cities in developed countries worldwide strive to source at least a portion of their food requirements locally (MacRae et al., 2010). The contributions of urban agricultural activities to local food supplies are now significant in several cities, including Italy (Bologna), the USA (Chicago, Cleveland, New York, Portland, and Seattle), China (Hong Kong, Shanghai), Canada (Montreal, Toronto, and Vancouver), Taiwan (Taipei), and Japan (Tokyo) (MacRae et al., 2010). In Bologna, if all suitable flat roof space is used for urban agriculture, rooftop gardens in the city would produce around 12,500 tonnes of vegetables annually, which would meet 77% of residents' needs for vegetables, and an estimated 624 tonnes of CO2 would be captured each year (Science for Environment Policy, 2015). Lufa Farms, Montreal, produces over 25 types of vegetables, and production is enough to meet the needs of over 1000 people (Carrot City, 2014). The farm at Brooklyn Navy Yard produces more than 50,000 pounds of organic produce annually. The Gary Comer Youth Centre of Chicago grows 450 kg of food per year (Clarke, 2015). For urban agriculture to be most successful, there is a need to increase vegetable crop cultivation within city boundaries.

However, land that has traditionally been used for agricultural purposes within urban areas, such as vacant lots, is vulnerable to potential development. Thus, urban agriculture is challenged by the lack of available space in cities to meet current demands for locally produced foods. Green roofs can be used in this capacity to effectively replace green space lost during building construction. Therefore, rooftop agriculture (particularly green roof production systems) has become an attractive possibility to increase localised urban agriculture (Ouellette et al., 2013).

Rooftop Vegetable Gardening in India

Rooftop farming is increasing very quickly throughout the country. Nowadays, many people are interested in rooftop gardening, especially in city areas. Many have already turned their passion into a commercial endeavour. Retired government and private service holders, businessmen, and industrialists have passed their leisure time by getting involved in rooftop agriculture. Their efforts are helping to make the cities greener, despite the lack of cultivable lands there. Some people even rent others' roofs for the purpose. It's also expanding because people always prefer chemical-free organic vegetables and fruits. They can easily get organic and fresh food from rooftop gardening. Moreover, through the spread of greenery on rooftops, these people are also contributing to creating a healthy environment in urban areas.

Composting of Domestic Wastes

Composting can be defined as a natural process of 'rotting' or decomposition of organic matter by microorganisms under controlled conditions. Raw organic materials such as food garbage, animal wastes, crop residues, some municipal waste, and suitable industrial waste increase their suitability for application to the soil as a fertilising resource after having undergone composting. Composting can also be defined as a natural process that turns organic material into a dark, rich substance. This substance is called compost or humus (FAO, 2002).

Compost is a rich source of organic matter. Soil organic matter plays a vital role in sustaining soil fertility and, hence, in sustainable agricultural production. In addition to being a source of plant nutrients, it improves the physicochemical and biological properties of the soil (FAO, 2002).

Types of Composting

Based on the nature of the decomposition process, composting can be classified into the following types.

Aerobic Composting

Aerobic composting occurs in the presence of oxygen. Aerobic microorganisms break down organic matter and release carbon dioxide (CO2), water, heat, humus, and ammonia, the relatively stable organic end product in this process. Although aerobic composting may produce some intermediate compounds, such as organic acids, aerobic microorganisms decompose them further. The resultant compost, with its relatively unstable structure of organic matter, has little risk of phytotoxicity. The heat generated enhances the breakdown of proteins, fats, and complex carbohydrates such as cellulose and hemicellulose. Hence, the processing time is shorter. Moreover, this process destroys many microorganisms that are human or plant pathogens, as well as weed seeds, provided they undergo sufficiently high temperatures. Although more nutrients are lost from the materials by aerobic composting, it is considered more efficient, fruitful, and useful than anaerobic composting for agricultural production. Most of this publication focuses on aerobic composting (FAO, 2002).

Anaerobic Composting

Anaerobic composting takes place where oxygen is absent or in limited supply. Under this method, anaerobic micro-organisms dominate and improve intermediate compounds, including methane, organic acids, hydrogen sulphide, and other substances. In the absence of oxygen, these compounds accumulate and are not metabolised further. Many of these compounds have vigorous odours, and some present phytotoxicity. Anaerobic composting is a low-temperature process that leaves weed seeds and pathogens intact. Moreover, the process usually takes longer compared to aerobic composting. These drawbacks often offset the merits of this method, viz., the little work involved and fewer nutrients spoiled during the process (FAO, 2002).

Vermicomposting

The term vermicomposting refers to the use of earthworms for composting organic residues. Earthworms can consume practically all types of organic matter, and they can eat their body weight per day, e.g., 1 kg of worms can consume 1 kg of residue every day. The excreta (castings) of the worms are rich in nitrate and available forms of P, K, Ca, and Mg. The passage of soil through earthworms enhances the growth of bacteria and actinomycetes. Actinomycetes develop well in the presence of worms, and their content in worm casts is more than six times that of the original soil (FAO, 2002).

Vermicomposting of Domestic Waste

Composting of Domestic Waste can be carried out by the following steps:

Collection of Wastes

Domestic waste materials are collected from houses and hotel canteens, then air-dried and grinded into small pieces. This ground waste material is mixed with cow dung in the ratio of 4:1 (w/w) and is subjected to aerobic composting to start microbial activity. The moisture content of the materials is controlled at 60% to 70%, and this mixture is then transferred into plastic containers covered with paper that has holes to facilitate aeration to get the final composted material. This mixture is hand-manipulated at regular intervals and remoistened for sufficient microbial activity (Bharadwaj, 2010).

Earthworms Collection

When the temperature becomes constant and the colour of the mixture changes from brown to black, it is used as a substrate for vermicomposting. For vermicomposting, earthworms (Eisenia foetid) were collected.

Assessment of physicochemical properties

The material is analysed for different physicochemical attributes such as pH, organic carbon, total nitrogen, available phosphorus, exchangeable potassium, C: N ratio, and organic matter as per the methods suggested by other workers, as well as for earthworm number, biomass, cocoon production, and weight loss of organic substrate during the composting process. During the course of the investigation, the samples are examined at periodic intervals after 15, 45, and 75 days of vermicomposting (Bharadwaj, 2010).

Table 1. Effects of Vermicomposting on various Physicochemical Parameters of Domestic Waste (Bharadwaj, 2010)

S. No.	Parameters	Duration of vermicomposting			
		0 days	15 days	45 days	75 days
1.	pH	9.32	9.22	8.9	8.37
2.	Organic carbon (%)	7.25	5.265	5.078	3.696
3.	Total nitrogen (%)	0.241	0.301	0.361	0.771
4.	Available phosphorus (%)	0.110	0.12	0.16	0.18
5.	Exchangeable potassium (%)	0.0086	0.132	0.196	0.386
6.	C:N ratio	30.08	17.49	14.06	4.79
7.	Organic matter (%)	12.499	9.076	8.754	6.371

Benefits of Compost in Rooftop Gardening

The following sub-section describes the potential benefits of composting:

Nutrient Supply

Compost can be used as a source of nutrients instead of mineral fertiliser (Blanco et al., 2013). The quantity of substituted fertilisers depends on the content of nutrients in the compost and their application rate (Audsley et al., 2003; Hansen et al., 2006). Furthermore, compost is considered a fruitful option for phosphorous recycling (Cordell et al., 2009), which is a growing issue as a result of the foreseen lack of mineral P for agricultural fertilisation (Syers et al., 2008).

Carbon Sequestration

Sequestration of carbon into soil can be seen as the removal of carbon from the atmosphere and its relocation to save CO2 emissions (Blanco et al., 2013). The time horizon used in the assessment plays an essential role in estimating the benefit of carbon sequestration. A time frame of 100 years is considered relevant for estimating contributions to global warming (Favoino and Hogg, 2008).

Suppression of Diseases, Weeds, and Pests

Pests, weeds, and diseases can be controlled by using compost instead of herbicides and pesticides. It is also beneficial for the environment to reduce the use of herbicides and pesticides (Martnez-Blanco et al., 2013).

Minimise Soil Erosion

The utilization of compost could reduce soil erosion and thereby avoid losses of arable land (Blanco et al., 2013). The degradation of the soil occurs because of land transformation and land occupation (Saad et al., 2011). Because of soil erosion, carbon losses and net productivity reduce (Núñez et al., 2013).

Soil Moisture Content

One potential benefit of compost is to enhance the capability of soil to retain green water, i.e., rainfall and irrigation water stored in the soil as soil moisture, to decline irrigation and consumption of blue water, i.e., water from surface and groundwater resources. This may result in two different consequences: Blue water is saved, and crop yield could increase in those areas where irrigation water is not available (Blanco et al., 2013).

Biological Properties of Soil and Biodiversity

Changes in soil biodiversity after compost application might influence either positively or negatively (e.g., hydrological processes, nutrient cycling, and pest incidence), with consequences in terms of impacts associated with the substitution or compensation of those ecosystem services. However, data linking compost use, biodiversity, and ecosystem services do not exist apart from a first attempt at establishing a preliminary relationship (Nemecek et al., 2011). In addition, the effects of land management practises are highly variable depending on regional and scale-dependent factors (Bengtsson et al., 2005). An alternative approach is to consider biodiversity and ecosystem services as independent endpoint categories (Zhang et al., 2010).

Composting's Drawbacks

Composting is considered an environmentally clean method that allows, on the one hand, to recycle waste and, on the other, to obtain organic fertilizer. But it is not safe, especially for people involved in this process (Kokhia, 2013). Waste management using any technique involves many risks, which are described quite well by different scientists (Panikkar et al., 2004).

The labourers who are involved in the composting are often unaware of the hygienic composting criteria. Moreover, there may be an adverse impact that will facilitate the rejection of composting on the whole. Thus, it is necessary to shed light on the risks encountered during composting. Many kinds of bacteria (≈2000) and at least 50 species of fungi take part in the composting process (Kokhia, 2013).

In this process, not only bacteria, fungi, and actinomycetes are actively involved, but also invertebrates play a significant role. These are the main soil inhabitants: ants, beetles, and cutworms; fruit beetle larvae; millipedes; mites; nematodes; earthworms; earwigs; woodlice; springtails; spiders; enchytraeids (white worms); and others. Many soil microbes and worms participate in the process of composting material in terms of its physical grinding. These animals also help mix the various components of compost (Kokhia, 2013).

Earthworms play the main role in the last stages of the composting process and the further insertion of organic matter in the soil in temperate climates. Thus, composting is a complex, multi-step process. Each stage is characterised by its various consortiums of organisms (Shalanda, 2009).

Occupational hazards are associated with the composting process; these include pathogenic, allergenic, and microbial toxins. The sources of these hazards are common pathogens of faecal origin (bacteria, viruses, cysts, and eggs of intestinal parasites). The second danger is associated with the development of meso- and thermophilic fungi and actinomycetes, which play an important role in the degradation of waste. Among these microorganisms' infectious pathogens, allergic diseases are detected (Kokhia, 2013).

Epidemiological and experimental studies have proved that pathogenic mould can be developed potentially during the production of compost. This has very adverse consequences, especially for people involved in the production. A clear link between the atypical development of allergic rhinitis, conjunctivitis, and asthma and contact with the spores of fungi was detected (Kokhia, 2013).

Despite some drawbacks, composting is useful for managing domestic waste and producing organic manure for vegetable production as well as other agricultural activities.

Conclusion

The agricultural lands in India are decreasing due to human pressure for accommodation and food. In many parts of the world, the scenery is similar. Rooftop vegetable production may be a viable alternative to soil-based agriculture. If domestic waste compost can be used for a higher quantity of food production in urban areas, this will reduce the use of chemical fertilizers, pesticides, and hormones in food production. Rooftop vegetable farming is becoming more and more common in India, which is undoubtedly good news for the country. However, more research is required to determine the best ways to use waste on agricultural lands to address the nation's waste management issues.

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