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OPTIMISING BALCONY FOR GREEN SPACES: APPLICATION OF EDIBLE BIOFAÇADE ON URBAN HIGH-RISE SETTING

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Abstract

The trend in vertical sprawl of building have initiated the experts in greening high-rise buildings in the urban setting. This phenomenon has been captured by many scholars in conducting studies on the benefits of greeneries in limited space in urban buildings, especially in the form of biofaçade as one of the Vertical Greenery Systems (VGS). Besides its cooling effects, biofaçade could be optimised as a vertical edible landscape, hence it could also address food security issue in the urban context. In a high-rise building, transitional or buffer space, such as in the balcony, is a space with less economic value. Regardless, the presence of transitional space is important and could be optimised in the application of biofacade. This paper reviews the potential of biofaçade as one of the methods for urban greening in a limited space. However, there are many factors that need to be consdiered in growing edible plants on the balcony of high-rise building. Those factors are the plant type and species, the climatic considerations in high-rise building setting, and the technical and maintenance issue.

Keywords: biofacade, Vertical Greenery System (VGS), balcony, high-rise buildings, edible plants

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INTRODUCTION

Vertical sprawl is becoming a trend in the cities due to rapid growth of population. The idea of growing vertical to reduce the sprawl and distribute the energy and resources efficiently is in line with sustainability agendas. Thus, rapid trend of tall slender towers and iconic skylines are transforming the cities today. It symbolises the development, advancement of technology, richness, and efficiency. Palme and Ramirez (2013) stated that it is not the argument of whether vertical or horizontal growth increases consumption of energy and matter, but more towards both strategies will increase the size of the city as population grow. The population growth will incur high demands for human needs.

Food is one of the primary needs for all mankind. It is a key aspect for most cultures, and has contributed to and inspired many creative aspects of our lives from local cuisine to urban form (Gorgolewski, 2008). Over the years, the activity to fulfil this requirement has created an evolution in human settlements and cultures. The issue of safe food on the table is a never-ending concern for the government particularly in the developing countries. This concern is also triggered by the increasing population growth rate resulting in the decreasing amount of land for food production in the urban area. This causes the source of food production is relatively far from the urban area and increases health hazard due to the need of using chemicals to prolong the post-harvest life (Tayobong, Sanchez, Apacionado, Balladares, & Medina, 2013). They also agreed that the most vulnerable to the food security is the depressed communities. The issue about food availability is expected to raise awareness of the government and the public to produce safe and readily available food (Yusoff, Mohd Hussain, & Tukiman, 2017). Therefore, there is a need to investigate alternative method to supply food to the urban community in a sustainable manner.

As future cities are moving towards vertical sprawl, one possible idea in tackling food shortage is by growing food plants vertically, or known as vertical farming. According to Al-chalabi (2015), the concept of vertical farm is growing fruits, vegetables, and grains inside a building in an urban setting. This is also in line with Despommier (2009), who defines vertical farm as a large-scale extension of urban agriculture within a building. It is expected to provide food supply for 60% urban people who will be migrating to the cities in the year 2030 (Despommier, 2013). Thus, it can be concluded that vertical farming is growing edible plants within a building. Its basic system and technology can be a guiding principle in establishing edible landscaping (EL). Edible landscaping could be defined as the use of food-producing plants in landscaping. It could be a combination of fruit and nut trees, edible flowers, berry bushes, vegetables, and herbs along with ornamental plants to create an aesthetically pleasing landscape design (Mansor, Zakariya, Harun, & Bakar, 2017). It is becoming a norm for those living in homes with backyard to do gardening. This can be seen especially in rural areas where houses come with spacious yards and gardening becomes a habit and to some, a source of income.

According to Naranja (2011), edible landscaping is a combination of science and creativity to create an integrated food production technology. Edible landscaping is not merely about crop production, it involves several complex activities: planning, design, implementation, and maintenance (Tayobong et al., 2013). The common application of edible landscaping is on horizontal plane. However, due to land scarcity, vertical edible landscaping could be a promising solution in providing accessible food.

Edible plants are grown vertically as in the Vertical Greenery System (VGS), be it a living wall system or green façade. Perini, Ottelé, Haas, Raiteri, and Ungers (2011) defined living walls as growing plants from modular panel that contains natural or artificial growing medium on each of its panel and using the hydroponic system to provide the plants' water and nutrition. While green façade is greening the wall by growing plants directly or indirectly from the ground or planter box. As illustrated on Figure 1, Tan, Chiang and Tan (2009) divided VGS into carrier system and support system. The carrier system is commonly termed as the 'living wall'. This system is designed for planting on the vertical surface and able to host a greater diversity of plants (Figure 1a). The support system allows climbing plants to grow and climb the support structure (Figure 1b). This system is also known as 'green façade'.

(a) Carrier System/Living Walls (b) Support System/Green Façade

Figure 1: Vertical Greenery Systems

Source: Tan et al. (2009)

This paper highlights the potential of vertical EL in the urban high-rise setting focusing on the tropical climate despite of the space limitation. With its abundant sunlight and rainfall, tropical countries have wide possibilities to maximise agriculture growth. By growing our food near to us, we can reduce the food dependency from imported sources. This could be done with the application of VGS in building such as biofaçade.

BIOFAÇADE APPLICATION IN HIGH-RISE SETTING

In the emergence of high-rise movement in cities, researchers are focusing on the environmental benefits and energy use of tall buildings. Increasing green approach to urban environment has been the policy for sustainable cities. Biofaçade is categorised as VGS, which is also known as vertical garden, green wall technologies, or vegetated façade. There are many similar terms, phrases or keywords of biofaçade established by previous researchers. As stated by Sunakorn and Yimprayoon (2011) biofaçade could be defined as a vertical climbing plant. Meanwhile, Ip, Lam, & Miller (2010) used the term bioshader instead of biofaçade although the meaning is similar. According to them, bioshader is a bio-shading device using a vertical layer of deciduous climbing plant canopy that trails on a metal framework and mounted external to the building façade.

Biofaçade alone have been proven to contribute towards tackling the climate problems. For instance, biofacade can provide space for food crops to meet the needs of growing cities population. Biofaçade could also be an alternative for urban farming where food crops are grown vertically to overcome the issue of land scarcity in cities. Additionally, biofaçade has been significantly proven to lower the temperature as well as sequestering the carbon in the cities. Table 1 shows previous studies in the South East Asia context on the use of biofaçade for space to plant edible and/or medicinal plants.

Table 1: Previous research on biofaçade as a vertical edible landscape

Author	Plant used	Biofaçade system	Result
Sunakorn & Yimprayoon (2011) Location: Bangkok, Thailand	- Blue trumpet vine (*Thunbergia grandiflora*) - Ivy gourd (*Coccinia grandis*) - Mexican creeper (*Antigonon leptopus*)	Green façade: Indirect greening system with planter box	*T. grandiflora* selected in this study due to the growth performance. Air temperature reduced by max. 4.71ºC.
Rahman, Yeok, & Amir (2011) Location: Penang, Malaysia	Winged bean (*Psophocarpus tetrogonobulus)*	Green façade: Indirect greening system with pots	Outdoor wall surface temperature reduced by maximum 11ºC
Amir, Yeok, Abdullah, & Malek (2011) Location: Penang, Malaysia	- Winged bean (*P.tetrogonobulus)* - Kidney bean (*Phaseolus vulgaris)* - Long bean (*Vigna unguiculata sesquipedalis)* - Sweet pea (*Pisum*	Green façade: Indirect greening system with pots	Four legume plants are suitable for biofaçade application in hot and humid climate

	sativum)		
Safikhani, Abdullah, Ossen, & Baharvand (2014) Location: Johor, Malaysia	Blue trumpet vine (*T. grandiflora)*	Green façade: Indirect greening system with planter box Living wall: Modular with trellis	The living wall & green façade can reduce indoor temperature up to 3ºC and 4ºC respectively The living wall and green façade reduce the wall cavity temperature by 8ºC and 6.5ºC respectively
Amir, Yeok, & Rahman (2014) Location: Penang, Malaysia	Winged bean (*P. tetrogonobulus)*	Green façade: Indirect greening system with pots	Average of carbon sequestration 2.35 µmole CO_2 m^{-2} s^{-1} was converted to kg CO_2 per year per m^2, equal to 9357.83 kg CO_2 year-1 hectar-1
Basher, Rahman, & Zaman (2016) Location: Penang, Malaysia	Winged bean (*P. tetrogonobulus)*	Green façade: Indirect greening system with planter box	Maximum surface temperature drops until 6.4ºC

Based on the findings of previous research, legume plants such as winged bean (*Psophocarpus tetrogonobulus),* kidney bean (*Phaseolus vulgaris*), long bean (*Vigna unguiculata sesquipedalis),* and sweet pea (*Pisum sativum)* are suitable to be grown as a biofaçade of a building in the tropical climate (Amir, et al., 2011; Basher et al., 2016). These plants are common vegetables that one can consume every day. Winged bean has been proven to reduce outdoor wall surface temperature by a maximum of 11ºC (Rahman et al., 2011) and effective in sequestering carbon up to 9,357.83 kg CO_2 year^{-1} hectar^{-1} (Amir et al., 2014). By using the same plant, which was planted by indirect greening system with planter box, Basher et al. (2016) found that the maximum surface temperature could reduce until 6.4ºC.

Sunakorn and Yimprayoon (2011) planted three different medicinal climbing plants: blue trumpet vine (*Thunbergia grandiflora*), ivy gourd (Coccinia grandis) and Mexican creeper (*Antigonon leptopus*) by using indirect greening system with planter box. Their finding shows that blue trumpet vine could reduce the air temperature by a maximum of 4.71ºC.

Hence, it could be concluded that by creating living and growing space in a dense vertical format, it could reduce the need for reduce food travel distance, create a living architecture that is part of an urban ecosystem, and improve the thermal comfort of the building. This indirectly minimises the carbon footprint of the cities.

Moreover, Tayobong et al. (2013) stated that edible biofaçade could increase the diversity and promote the use of endemic plant species. Biofaçade could also attract insects, butterflies, and small birds. The addition of natural habitats in the urban area will enhance its biodiversity. Furthermore, biofaçade harvests could be sold and become additional source of income for the community.

GROWING VERTICAL EDIBLE LANDSCAPE ON TRANSITIONAL SPACE IN HIGH-RISE BUILDING

As mentioned earlier, majority of urban dwellers are currently residing in high-rise residential buildings with limited access to greeneries. According to the United Nations (2018), 55% of the world's population today live in the urban areas. The figure is expected to increase up to 68% by the year 2050, with Asia and Africa contributing the most (almost 90%). The urban population level in Malaysia is also increasing rapidly (World Bank, 2015). It increases from 10.2 million (43% of the total population) to 15 million (53% of the total population) in a decade, making it among the most urbanised countries in East Asia after Japan, Republic of Korea, and Singapore.

Growing population and land scarcity would increase demand for high-rise residential buildings as well as other infrastructure in the urban areas. This would result in the separation of human from nature. However, Lohr (2010) and Shibata & Suzuki (2002) agreed that nature brings positive impact on human's cognition, psychology, and physiology. Therefore, the connectedness of human with the nature needs to be re-established by integrating greeneries on the building.

Due to the space limitation in the high-rise building, transitional space could be utilised as a green space. Transitional space, or buffer space could be defined as a space in between the interior and exterior environment. Chun, Kwok, & Tamura (2004) categorised transitional space into 3, which are (1) contained space within a building, e.g. lobby or atrium; (2) space that is covered, connected to the building, and affected by outdoor air, e.g. balcony, corridor, porch etc. and (3), space that is not attached to a building and fully influenced by outdoor air, e.g. pergola, pavilion. Although this space has less economic value, transitional space has the potential to be optimised in replacing the greeneries on the ground floor since it is often related with open area. Thus, it is easily influenced by the variable weather conditions since it is close to the natural environment. It is expected that by integrating vertical plants on building, it could help to filter out the airborne pollutants as well as to improve the thermal comfort (Prihatmanti &

Taib, 2017). Furthermore, the presence of greeneries could enhance the well-being of the building occupants.

Balcony planting is focused in this study because balcony is considered as the most accessible and privately owned transitional space compare to the others. In Figure 2, it illustrates the application of biofacade in a typical balcony on high-rise building. It is recommended to place the biofaçade on the sidewall, hence it will not obstruct the view as illustrated by the dotted lines. The view of scenery outside the balcony should be maintained since it will be a stress-reliever for the occupants. Moreover, by placing the biofaçade on the sidewalls, it allows the daylight to penetrate into the interior space. In reality, balcony is commonly used for other domestic purposes. Therefore, the biofaçade should not consume too many spaces in the balcony.

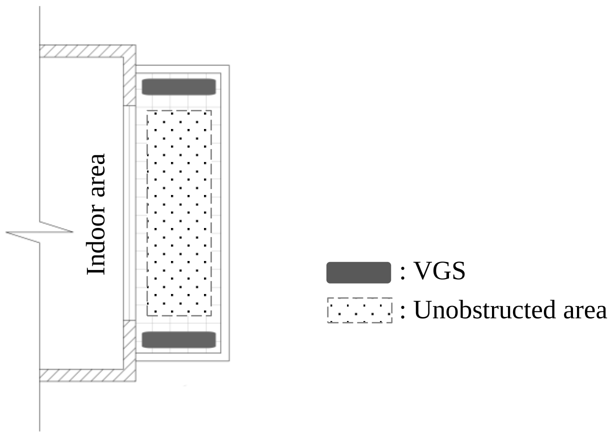


Figure 2: Application of biofaçade in a typical balcony
Source: Adopted from Prihatmanti & Taib (2017)

In a high-rise development where there is no private balcony or space for planting, a shared space such as open corridor can be an option. This communal area will also create platform for activities for the neighbourhood, thus indirectly improve the social interactions in the neighbourhood. Pomeroy (2012) also agreed that planting on communal space, such as in the skycourt, is beneficial. Not only for improving thermal comfort and reducing urban heat island due to the evapotranspiration, but also could offer a more conducive environment for socio-physiological interaction.

KEY SUCCESS FACTORS

Vertical edible landscape is an innovative concept of space management that uses edible plants to substitute ornamental plants commonly used in conventional landscaping. In vertical edible landscape, edible plants can be intercropped with other ornamental plants and planted in accordance with the design. To create a successful vertical edible landscape, Gorgolewski (2008) stated 5 factors to consider: available spaces, climate, topography, soils, and needs of the community. However, according to Tayobong et al. (2013), the key for successful cropping is the selection of desirable species, varieties, and cultivars. The desirable crops should be resistance to pests and diseases, high yield, and adaptable with the wide range of soil and climatic conditions.

Generally, edible landscape consists of fruit trees, vegetables, cereals, and herbs, which serve as screens, accents, hedges, and ground covers in the landscape (Tayobong et al., 2013). Since this paper reviews the biofaçade for addressing the food security issue, thus only food or edible plants are reviewed. Nevertheles, plants that have medicinal properties could be considered as well in biofaçade application.

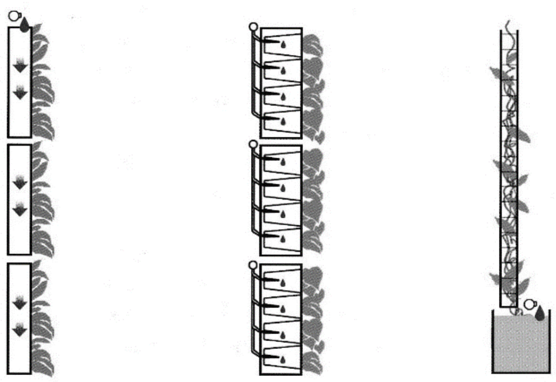
Many studies have been conducted on edible biofacade as stated in Table 1. Moreover, Tayobong et al. (2013) stated that bitter melon (*Momordica charantia*), cucumber (*Cucumis sativus*), sponge gourd (*Luffa cylindrical*), and yardlong bean (*V. unguiculata* subsp. *sesquipedalis*) are recommended to be applied on small-scale edible biofaçade. These mentioned species have the suitable size and characteristic that suits the high-rise planting.

Amir et al. (2011) suggested that legumes are suitable to be applied in biofaçade due to its drought tolerance to suit the different growing conditions, especially if planted in the tropical climate. Legumes are considered as an easy-growing plant and it requires fertile soil with good drainage to prevent water logging. Moreover, leguminous plants have the symbiotic property associated with Nitrogen-fixing Rhizobium in its root nodules resulting Nitrogenous-fertilised soil. This symbiosis could reduce the maintenance cost in terms of fertilization as well as to ensure the sustainability of the biofaçade.

In applications in tropical climate, plants must able to withstand the hot and humid conditions. Hopkins and Goodwin (2011) emphasised on the importance for selecting suitable plants before application, particularly when applied in different weather conditions. Climatic conditions need to be taken into account when applying biofaçade in high-rise building since plant growth is fully depending on the quality of the climate. According to Hui and Jie (2014), transitional space is characterised as a dynamic, transient, unstable, variable, or fluctuating microclimate condition. Hence, the wind velocity and heat intensity in the balcony strongly affect the growth performance of plants.

Will and Burch (1984) also stated that building orientation determines the intensity of the light that is crucial in the photosynthesis process. The East-facing area receives the morning sun for few hours, which is ideal for plants. This is also agreed by Amir et al. (2011), legume plants should be planted facing the morning sunlight as this is the best radiant for food production. However, late morning sun may begin to cause heat problems, which might affect the plants. On the other side, West-facing area receives the highest amount of daylight as well as the heat. Therefore, biofaçade that grows on a transitional space, such as balcony, must able to tolerate the high light intensities.

The dimension of the container for planting also needs to be taken into consideration. Tan et al. (2009) explained that a minimum of 30 cm soil depths is recommended for healthy plant growth. Small container will inhibit the roots to spread into the soil. Another concern in planting is the irrigation matter. Water is an essential element for plants, particularly to plants that are grown in planter box. According to Tayobong et al. (2013), plants will dry out faster because of the limited amount of growing medium, especially when the intensity of the heat and wind is high. If the planting is sparse, wide surface of substrate media is exposed, and thin profile of VGS, moisture will evaporate rapidly. This issue could be solved by the irrigation system as illustrated in Figure 3 or by using inorganic lightweight substrate media with high moisture absorption capability.



(a) Cascading Drip (b) Precision Drip (c) Inline Drip

Figure 3: Irrigation systems for vertical greeneries

Source: Tan et al. (2009)

To reduce the hassle in conventional farming caused by the climatic factors, hydroponic and aeroponic systems are currently in the trend for growing with soil-less system. Besides being easily maintained, these systems could also increase the yield by more than 23 times and reducing the water usage up to 30 times compared to conventional farming (Despommier & Ellingsen, 2008). The environmental factors could be elucidated by (1) evaluate the climate condition on the location, (2) select the most suitable plants including the substrate media, and (3) structural modification, if possible.

CHALLENGES OF BIOFAÇADE IN HIGH-RISE SETTING

Regular maintenance is very crucial since plants are living things that may lead to overgrown species or die. Regular watering is required but it should not be excessive that could harm plants and triggers the unwanted species to grow.

Limited exposure to daylight also contributes to negative effect, where plants could not optimally grow. However, excessive daylight also might be harmful to the plants themselves. The idea of planting in balcony allows for some coverage from the harsh climate conditions on the high-rise building. Good landscape criteria should fulfil its function with efficiency, aesthetic, enhances the welfare, and can be maintained in a viable condition. Hence, maintenance is important to maintain the growth performance and the yield, where yield is a priority in vertical edible landscape. Some simple practices conducted during maintenance are watering, pruning, fertilizing, harvesting, and management of pests.

Although located above the ground, biofaçade in the balcony is still at risk of being attack by pests and diseases. The use chemical pesticides and herbicides as a pest management are widely applied and easy to use. However, it will bring the short and long term adverse effects to the environment as well as to the human. Chemicals with natural extracts, such as *Cymbopogonnandus* liquid could be considered as an alternative (Amir, Yeok, Abdullah, & Rahman, 2011). Fertiliser made from excrement should be avoided to prevent the spread of numerous viral, bacterial, and eukaryotic infectious agents (Despommier, 2013). Tayobong et al. (2013) suggested companion planting can be applied as one of the pest management practices. It is known that onion (*Allium cepa*), marigold (*Tagetes spp*.), and garlic (*Allium sativum*) are repellent plants that are commonly used in companion planting to repel pests.

CONCLUSION

Lack of green spaces on the ground level has initiate many people to integrate the greeneries with the building regardless the limitation of the space allocated. This subject has attracted attention among the researchers and related professionals in combining edible and medicinal plants as a biofaçade, which is planted on a transitional space in high-rise building. Providing food to accommodate the basic human need now is possible in an urban context in a way that is socially, economically, and ecologically benefitting. The main objectives of edible landscaping in urban areas is to engage the community in growing their own vegetables by having their own sources of food even at the smallest scale possible and it would increase vegetable consumption.

Growing food plants in the urban areas will lower the consumption of fossil fuel for transportation as well as to increase the vegetable consumption in the household level. Maximising the transitional spaces such as balcony can be an alternative for biofaçade planting in a high-rise setting. Creating social communal neighbourhood in urban context may have shifted from landscape gardens on the ground to small gardens on high-rise setting. The plants selected for biofaçade application should thrive in high daytime temperature, able to tolerate dry conditions, and intense sunlight. The substrate media, dimension of container, building orientation, and the amount of water need to be considered in balcony planting.

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