

Review article

A Brief Overview of Biodegradable Pots for Sustainable Environment in Thailand

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Curr. Appl. Sci. Technol. 2024, Vol. 24 (No. 5), e0260109; <https://doi.org/10.55003/cast.2024.260109>

Received: 20 October 2023, Revised: 1 February 2024, Accepted: 26 March 2024, Published: 2 May 2024

Abstract

Keywords

biodegradable pots;
biodegradability;
biopots;
plantable;
compostable;
degradation

Since global plastic production has been excessive over the past half-century, the amount of plastic waste generated has become one of the major environmental issues worldwide. Most plastics are petroleum-based synthetic plastics, specifically polypropylene, polyethylene, nylon, polyester, epoxy, and polytetrafluoroethylene. These plastics are associated with many environmental problems, including intensification of the greenhouse gas emissions, air pollutants, and poor water quality. Waste plastics can take decades and even centuries to decompose in the environment, and this can involve the potential leakage of pollutants into the soil, rivers and oceans, which can be harmful in our daily life. Hence, a reduction in the use of plastic is a major step in alleviating environmental concern. The aim of this article was to review the literature concerned with biodegradable pots or biopots in Thailand. The review also included main characteristics of biodegradable pots, mechanical and physical properties, environmental degradation, and latest applications of biodegradable pots. Biopots have been developed from natural materials, and they thus represent alternatives for plastic pots. In that sense, using biopots may help to better maintain the balance of nature, protect the environment, and provide a better life for future generations.

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1. Introduction

The production of large quantities of plastic has led to huge quantities of plastic waste worldwide over the last five decades. One of the significant factors driving this locally is from the growth of the economy in Thailand that has been expanded extensively over the past several decades. To support this growth, tremendous volume of natural resources has been consumed exponentially in the urban, industrial, and agricultural sectors. This growth in the production and consumption of plastics has caused a massive amount of waste in all sectors of the country. At present, the use of manufactured plastics is a major trend in all sectors of waste management. Unfortunately, only approximately 10% of manufactured plastic waste get recycled, the rest is sent to landfills and discarded into the environment [1, 2]. Several large sources of plastic garbage found in modern agriculture and farming are plant pots and nursery pots. These have been extensively used because of their mechanical strength, durability, resistance to microbial degradation, accessibility, and affordability [3, 4]. However, the use of plant pots can remain in the environment for periods of up to several hundred years because they decompose slowly in the environment.

Recently, people have become more environmentally conscious, and this has led to demand for more ecologically friendly products. Such products, which are functional and yet biodegradable, are derived from renewable natural resources rather than from petroleum-based synthetic plastics [5]. At the life cycle of biodegradable pots, or biopots, which ideally decompose easily within a reasonable time and/or mix well into the soil or composting pile. Therefore, they do not cause waste and help prevent further damage of the soil that may happen to our environment in the future. The use of these alternative replacements for non-renewable plastic containers contributes to environmental sustainability.

Biodegradable pots have been acknowledged for years and they have been used all over the world, especially in many greenhouses and nursery production facilities, as substitutes for plastic ones [6]. Some of the known biocontainers, flowerpot, nursery pot, nursery container, growing container are made from materials such as water hyacinth, coconut coir, straw, sawdust, coffee grounds, shell lime, rubber wood sawdust, tobacco dust waste, compost and cow manure, longan leaves, sugarcane leaves, and so on [7-22]. These pot materials are suitable for the process and are abundant available local materials. Moreover, the use of these materials can continue to fulfill the potential of each region in Thailand.

This brief overview highlights recent work on biodegradable pots in Thailand, including the main mechanical and physical properties and their biodegradability and examine some of the latest applications of biodegradable pots. The use of biodegradable pots as an alternative potential option in all sectors of the waste management is expected to be an essential strategy in the paths towards environmental sustainability.

2. Biodegradable Pots

Biodegradable pots (biopots) appear as substitutes of petroleum-based synthetic plastic products because the latter can remain in the environment indefinitely if not properly eliminated. Biodegradable pots should decompose rapidly when placed into the ground or compost piles and thus not contribute to landfill waste [23]. Biodegradable pots are classified as being plantable or compostable [23], which mean they can be directly integrated in the soil and compost piles. Biodegradable pots are decomposed by bacteria or other living organisms, without processing, recycling or deposition of the waste materials of human society. Plantable pots are container type enables the direct transplant of seedlings immediately into the ground, allowing roots to penetrate the container walls, reducing the shock to the plant associated to this action. In the case of

compostable pots, the plants and the containers must be separated because it is hard for the root plants to get through the walls of the pot. Degradation of this type of container takes time and may leave some residues settle into the soil [24], so it is necessary to remove the pots and compost them separately.

A summary of recent research on biopots is shown in Table 1. There are a number of different names of biodegradable pots and the names varies with the purpose of the pots. When selecting the source material for the pot, factors that should be considered include type of application, availability, and price. Ideally, the material should be abundant, readily available, cheap and environmentally sound.

Biodegradable pots have a lot of benefits for an environmentally sustainable management aspects, especially as an alternative to plastic pots. First, biodegradable pots can be a source of nutrients for the soil because they are created out of natural materials like water hyacinth, coconut coir, and straw; materials that can be degraded by microorganisms in the soil [7, 9, 13, 14, 22]. In general, the weight of some biodegradable pots may be greater than that of plastic pots. However, there are some raw materials, from which biodegradable pots can be produced, that are lighter than plastic pots. Examples of such materials include coconut coir and straw [15]. These products are a more sustainable option than plastic pots. Second, plantable biodegradable pots enable roots to develop more naturally because roots can penetrate the container walls easily and move out into the surrounding soil either in open area, or indoors in larger garden. These containers then provide a sustainable way of preventing root disruption and transplanting shock, which are critical issues that occur with plants grown in plastic pots. Additionally, using plantable biopots not only helps reduce or eliminate landfill waste but it can also save some labor costs to remove pots before planting. On the other hand, there are some economic disadvantages to the use of biopots. Although the raw materials used for biopots are mainly made from agricultural and environmental wastes, the selling price of biopots is usually higher than the plastic ones. In this article, biopots sustainability as mentioned above is emphasized.

3. Mechanical and Physical Properties

The quality testing of biodegradable pots revolves around the measurement of their mechanical and physical properties. As shown in Table 2, each type of biodegradable pots has different characteristics, such as water adsorption, water holding, porosity capacity, thickness swelling, strength and compressive strength. Many natural supplies from renewable and natural sources are used to fabricate biopots. According to previous studies, water hyacinth has the highest water holding capacity, porosity, thickness swelling and compressive strength (Tables 2 and 3). Even though the strength of water hyacinth is lower than tobacco dust, cow manure, and cassava starch, it is sufficient for nursery plant. This means water hyacinth is one of the most suitable materials for producing biodegradable pot (Tables 2 and 3). In general, the characteristics of biodegradable pots are derived from the raw materials that can be employed to develop environmentally safe products.

Table 1. Current studies on biodegradable pots: type, component and study area

Type	Component	Study Area	References
Biodegradable pot	Main material: Water hyacinth Other materials: Cassava starch, cassava pulp	- Physico-chemical characterization - Nutrients - Biodegradation - Application assessment for present-use	[7, 22]
Biodegradable pot	Main material: Coconut coir	- Plant nursery experiments - Application to plants	[8]
Flowerpot	Main material: Water hyacinth, straw, sawdust Other materials: Cassava starch, wheat flour	- Characterization - Performance of potted plant growth - Community application	[9, 22]
Biodegradable pot	Main material: Water hyacinth, straw, coconut coir Other materials: Cassava starch	- Physico-chemical mechanical Characterization - Nutrients - Fabrication - Technology transfer to community	[10, 13, 14, 22]
Biodegradable plant nursery pot/biocontainer	Main material: Coffee grounds, shell lime, rubber wood sawdust Other materials: Cassava starch	- Physico-chemical mechanical characterization - Biodegradation - Nutrients - Plant pot performance	[11, 14, 20, 21, 25]
Biodegradable plant nursery pot	Main material: Coconut bagasse, beverage labelling waste Other materials: Cassava starch	- Physico-chemical characterization - Biodegradation - Cost production and Application	[12]

Table 1. Current studies on biodegradable pots: type, component and study area (continued)

Type	Component	Study Area	References
Biodegradable pot	Main material: Tobacco dust waste, compost and cow manure Other materials: Cassava starch	- Physical mechanical characterization - Biodegradability test - Plant nursery experiments - Field experiments	[16]
Biocontainer	Main material: Straw Other materials: Cement powder	- Field experiments - Application to plants	[17]
Flowerpot	Main material: Sludge of rubber factory, spent mushroom compost Other materials: Palm bunches, cassava starch	- Physico-chemical characterization - Nutrients - Biodegradation - Field experiments - Application to plants	[18]
Nursery container	Main material: Longan leaves, sugarcane leaves, straw Other materials: Cellulose, cassava starch, sodium hydroxide	- Physico-chemical characterization - Decomposition - Plant nursery experiments	[19]
Biodegradable pot/growing container	Main material: Palm oil sludge, spent mushroom compost, Activated sludge cake Other materials: Molasses, cassava starch	- Physico-chemical mechanical characterization - Nutrients - Biodegradation - Field experiments - Performance of potted plant growth	[26-29]

Table 2. Mechanical and physical properties of biodegradable pots

Characteristics	Significance	References
Physical properties		
1. Water adsorption (%)	1.1 Coconut coir: Cassava starch 1:2 (75.60%)	[10]
	1.2 Water hyacinth: Cassava starch 1:2 (72.33%)	[10]
	1.3 Straw: Cassava starch 1:2 (66.51%)	[10]
	1.4 Coffee grounds: Shell lime: Rubber wood sawdust 1:1:1 (131.90%)	[11]
	1.5 Beverage labelling waste: Coconut bagasse 40:60 (53.05%)	[12]
	1.6 Coffee grounds: Water hyacinth 20:80 (99.01%)	[14]
	1.7 Spent mushroom compost (99.18%)	[18]
	1.8 Palm oil sludge: Spent mushroom compost 1:4 (91.18%)	[28]
2. Water holding capacity (%)	2.1 Water hyacinth: Cassava pulp 6:4 (231.06%)	[7]
	2.2 Water hyacinth: Cassava starch 7:3 (192.38%)	
3. Porosity (%)	3.1 Water hyacinth: Cassava pulp 7:3 (92.98%)	[7]
	3.2 Water hyacinth: Cassava starch 6:4 (85.76%)	
	3.3 Palm oil sludge: Spent mushroom compost 1:4 (79.00%)	
4. Thickness Swelling (%)	4.1 Coffee grounds: Shell lime: Rubber wood sawdust 1:1:1 (14.17%)	[11]
	4.2 Coffee grounds: Water hyacinth 60:40 (100.78%)	[14]
	4.3 Spent mushroom compost (81.93%)	[18]
	4.4 Palm oil sludge: Spent mushroom compost 1:4 (91.67%)	[28]

Table 3. Mechanical and physical properties of biodegradable pots

Characteristics	Significance	References
Mechanical properties		
1. Strength (kgf)	1.1 Water hyacinth: Cassava starch 1:4 (1.67 kgf)	[10]
	1.2 Coconut coir: Cassava starch 1:4 (1.53 kgf)	[10]
	1.3 Straw: Cassava starch 1:4 (0.36 kgf)	[10]
	1.4 Tobacco dust: Cow manure: Cassava starch 1.5:0.5:1.5 (390 kgf)	[16]
2. Compressive strength (kgf)	2.1 Water hyacinth: Cassava starch 5:5 (8.25 kgf)	[7]
	2.2 Water hyacinth: Cassava pulp 5:5 (4.18 kgf)	[7]

4. Degradability in Environment

Biodegradable pots have become a better choice for the environment because they decompose rapidly compared to synthetic materials. Environmental degradation is a process that involves depletion of natural resources and loss of quality of water, air and soil. Waste plastic is one cause of environmental degradability since it may take up to five centuries to decompose. The use of biodegradable pots are the ease of degradation and make them worthy for environmental applications. As they compose of organic matters that can be broken down by microorganisms such as bacteria and fungi, and they are transformed into inorganic products and biomass [2, 30]. Degradation of biodegradable pot is dependent on the internal conditions (various local materials) and the external conditions (climate, soil, land and water that interact with the biodegradable pot) [1]. As shown in Table 4, the biomaterials used in pot manufacture displayed different effects on biopot degradability.

5. Application of Biodegradable Pots

Research on biodegradable pot applications was aimed at identifying the potential use of pot materials for sustainable environment, testing physical properties of biopots such as water adsorption and strength, and evaluating the effects of pot makeup and type on the performance characteristics of plants including plant height, plant weight, plant growth, pest infestation and others. The performance of various kinds of biodegradable pots applications is shown in Table 5. Some of the significant advantages of using biodegradable pots in Thailand include:

Environmentally friendliness: Biodegradable pots do not produce plastic contamination. They are made from natural materials that break down over time, reducing waste and pollution. Their use minimizes plastic contamination of soils. This is especially important when considering the growing problem of plastic pollution. Biodegradable pots made of coffee grounds, shell lime, and sawdust were used to grow marigolds [11]. Their use as a replacement of plastic pots was beneficial because the biopots were environmentally friendly and increased the amount of nutrients and organic matter in the soil, further reducing the amount of waste [7-14, 16-22, 25-29].

Root growth benefits: Biodegradable pots provided better aeration and drainage, which helped plant roots to grow more efficiently [7-9] because the roots could penetrate the pot walls and get through the soil directly [18-22]. Additionally, biopots retained moisture, which was one of the profitable features in order to absorb liquids, O₂ and nutrients [25-29]. This resulted in a reduction of the need for watering.

Good water absorption: Coconut coir was selected for cultivation because it absorbed water well (reducing water use), and plants grew well in it [7, 9, 13, 23]. The pots material made from coconut coir was very convenient as it could be used immediately after it had been left in the sun for about 10 minutes [9].

Optimized plant growth without demolition: Straw mixed with cement at a ratio of 1: 2 was used to make various kinds of well-functioning potted products [17]. They were used for planting different types of trees both indoors and outdoors, and proved unbreakable and leak-free. Moreover, the pots were suitable for use at the time of cultivating seedlings before planting them into the ground. Hence, biodegradable plant pots can be planted directly into the ground without the need to break the pot [7-14, 16-22]. This also reduces the risk of damaging the plant's roots and makes planting easier and faster. Kale grown in pots made from tobacco dust waste had an average fresh weight of 47.7 grams which was higher than the average fresh weight of kale grown in clay and plastic pots without fertilization [16].

Table 4. Biopot degradability from various biomaterials

Experimental Design	Degradation			References
	Process	Efficiency	Duration	
Water hyacinth was buried in soil	Weight loss test			
- Condition 1 (buried and watered)		48.49 %	60 days	[31]
- Condition 2 (not buried but watered)		41.58 %	60 days	[31]
- Condition 3 (buried but not watered)		39.36 %	60 days	[31]
- Condition 4 (not buried and not watered)		26.86 %	60 days	[31]
Sago fiber was buried in soil	Weight loss test	100 %	28 days	[32]
Longan leaves, Sugarcane leaves, Straw were buried in soil	Weight loss test	Sugarcane leaves, Straw (80 %) Longan leaves (90%)	4 weeks	[19]
Palm oil sludge and activated sludge cake were buried in soil	Weight loss test			
- Condition 1 (waterlogged soil)		48.05-54.05 %	3 months	[27]
- Condition 2 (watered every 7 days)		38.98-41.95 %	3 months	[27]
- Condition 3 (dry)		7.06-7.71 %	3 months	[27]
Planted with coriander	Pot change observation	-	12 weeks	[7]
Planted with willow trees	Pot change observation	-	4 weeks	[9]
Planted with chili peppers	Pot change observation	-	4 months	[12]
Planted with marigolds	Pot change observation	-	60 days	[21]

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Table 5. Applications of biodegradable pots

Benefit of Biodegradable Pots	Material	References
1. Environmentally friendly	Water hyacinth, Straw, Coffee grounds, Shell lime, Rubber wood sawdust, Coconut coir, Beverage labelling waste, Coconut bagasse, Tobacco dust waste, Compost and Cow manure, Sludge of rubber factory, Spent mushroom compost, Palm bunches, Cassava starch, Longan leaves, Sugarcane leaves, Palm oil sludge	[7-14, 16-22, 25-29]
2. Better for root growth	Water hyacinth, Straw, Coffee grounds, Shell lime, Rubber wood sawdust, Coconut coir, Coconut bagasse, Spent mushroom compost, Palm bunches, Cassava starch, Longan leaves, Sugarcane leaves	[7-14, 18-22, 25-29]
3. Absorbs water well	Coconut coir, Water hyacinth, Straw, Coffee grounds, Shell lime, Rubber wood sawdust, Beverage labelling waste, Coconut bagasse, Spent mushroom compost, Palm oil sludge	[7, 10-12, 14, 18, 28]
4. Optimal to plant and without demolition	Straw, Coffee grounds, Tobacco dust waste, Compost and Cow manure, Water hyacinth, Coconut coir, Beverage labelling waste, Coconut bagasse,	[7-14, 16-22]
5. Pesticide prevention	Tobacco dust waste, Compost and Cow manure	[16]
6. New material approach	Coconut coir, Durian husks, Corn husks, Pineapple leaves, Rice husks, Rice husk ashes, Banana trees, Rice straw, Leaves	[10, 13, 14, 22]
7. Enrichment of soil nutrients	Water hyacinth, Coconut coir, Straw, Coffee grounds, Shell lime, Rubber wood sawdust, Tobacco dust waste, compost and cow manure, Longan leaves, Sugarcane leaves	[7, 8, 10, 13-14, 16, 19-22, 25]

Pesticide prevention: Plant pots made from tobacco dust waste were effective in repelling pests [16]. This was probably due to the nicotine in the tobacco dust waste that had the effect of preventing insect pests.

New material approach: Fiber materials that improved adhesion and thus strengthen the pots were developed and shown to have extended product lifetimes. Biopots were made from a variety of materials and included were coconut coir, durian husks, corn husks, pineapple leaves, rice husks, rice husk ashes, banana trees, rice straw, and leaves [10, 13, 14, 22].

Soil nutrients enrichment: Biodegradable raw materials such as straw, coconut coir, water hyacinth, spent mushroom compost, palm fiber and livestock manure were used to supply the nutrients needed by plants [7, 8, 10, 13, 14, 16, 19-22, 25]. After the plants in their biopots were directly put into the ground, there was no need to purchase additional soil or nutrient, or to transfer the plants into a larger pot. This provided absolute benefits to the soil in term of nutrients that came from the decomposition process of the biopot.

A lot of research into the use of biodegradable pots in Thailand is still needed, particularly if the pots are to be used in large-scale commercial enterprises. Issues of cost effectiveness need to be addressed. The current studies of biodegradable products in Thailand are still at the fundamental level. In contrast, plant pots have been widely used for seeds in nursery or greenhouse pots, household plants, garden in many developed countries (Table 6). Therefore, to be able to reach the goal of economic aspect, we need to conduct further research on reducing the cost of production. According to the information mentioned in this review, the use of biodegradable plant pots is certainly worthwhile. Biopots offer many benefits. They are environmentally friendly alternatives to those made from petroleum-based synthetic plastics, and their use can contribute to a sustainable environmental aspect.

Table 6. Biodegradable pots used in developed countries

Biodegradable Pot Application	Country	References
1. Nurseries, seed starting, greenhouse pots, hydroponic farmers	Europe (England, France, Netherlands, Spain, Germany, Austria, Switzerland, Italy)	[33-36]
2. Nurseries, seed starting, greenhouse pots, hydroponic farmers	North America (USA, Canada)	[33-37]
3. Nurseries, seed starting, greenhouse pots, hydroponic farmers	Asia (Japan, China, South Korea)	[35]

7. Conclusions

Biodegradable pots are an excellent alternative to plastic ones. They can offer many benefits to plants and the environment. Their use enables the minimization of the use of plastics which are problematic for the ecosystem. Replacing synthetic plastics with biodegradable materials can reduce some of the environmental impact associated with global waste. On the other hand, there are some disadvantages to the use of biodegradable pots. For example, the pots may possibly break during production or transportation, and some types of pots may break down too slowly in the soil. Furthermore, biopots are more expensive than plastic one at present. However, the benefits outweigh the disadvantages. The biopots are environmentally friendly, better for root growth, absorb water

well, optimize plant growth and there is no need for demolition. They can also be used as pesticide preventives and sources of enrichment of soil nutrients. In some circumstances, using a pot made from natural material can be exciting to continuously solve problems concerned with plastic waste in the future. Therefore, the use of biopots as an alternative product for promoting the better and more environmentally friendly methods of cultivation that many people are looking for.

8. Acknowledgements

We would like to thank the Faculty of Science and Technology, Valaya Alongkorn Rajabhat University under the Royal Patronage which supported and facilitated the implementation of our project funding request (Biodegradable pot made from water hyacinth for bio circular green economy model project).

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