Feasibility Study of Organic Waste for Biobag Production in the Maldives

Iffath Abdullah[1], Aishath Naila[2], Mizna Mohamed[3] and Mohamed Hoodh Hameed[4]

HIGHLIGHTS

- Evaluates local organic waste feasibility for biobag production in a small island context
- Applies a cross-sectional survey across households, food outlets, and producers
- Identifies rice waste, banana peels, and potato peels as viable starch inputs
- Demonstrates sufficient local waste to support pilot-scale biobag production
- Informs circular economy and plastic reduction strategies for island communities

ABSTRACT

The widespread use of non-degradable plastic bags contributes significantly to long-term pollution and contamination of oceans and landfills, highlighting the need for biodegradable alternatives. Biobags from starch-based bioplastics are one such alternative for plastic bags. Using a quantitative survey approach, this study aimed to assess the feasibility of sourcing organic food and agricultural waste for biobag production in Haa Dhaalu Hanimaadhoo, a small island in the north of the Maldives. Currently, biobags are manufactured from engineered corn-starch biopolymer pellets that behave like conventional plastics and are classified as plastic biopolymeric materials designed to be compostable under industrial conditions in compliance with EN 13432. The study objectives included surveying plastic bag usage, alternative habits, usage patterns of starch sources such as banana and potato peels, cassava, and leftover rice, along with participants' willingness to provide these raw materials for biobag production. Of the 121 households surveyed, 91% used plastic bags, primarily shopping bags from supermarkets and convenience stores (97%). Most households reused plastic bags as trash bin liners (68%) and for shopping (59%). Eighty seven percent of participants used non-woven bags, and 31% used biodegradable bags. Most households used rice (103 households), potatoes (65 households), and bananas (50 households) daily, with under 1 kg of organic waste discarded. Over 85% of households, along with farmers and cafés/restaurants, were willing to provide their waste for biobag production, although concerns about refrigerating the waste until collection were raised. Based on this willingness, for a monthly input demand, our estimates deduced that all three raw materials can be feasibly obtained from the island for the pilot phase. The study hence contributes by demonstrating the feasibility of collecting organic waste for biobag production on the selected island, for the pilot production phase, while highlighting the need for an efficient collection system, incentivization and targeted awareness campaigns.

KEYWORDS

Biobags
Organic Food Waste
Sustainable Alternatives
Maldives
Environmental Biotechnology

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INTRODUCTION

Owing to its ubiquity, low cost and versatility, plastics consumption has increased annually with a considerable proportion of it being used in packaging (Alam et al., 2018). This is especially the case for low-density polyethylene (LDPE) bags, which is desirable both at the consumer level due to durability and versatility, and at the producer level for its cost–efficiency. In the context of the Maldives, LDPE in assorted sizes is widely used as carrier bags in retail shopping, businesses and as household waste bin liners (Small Island Geographic Society, 2022). For instance, in 2018, 104 million non-biodegradable bags, including LDPE, were imported into the country, highlighting its overreliance and prevalence of use (Miolene, 2019). This overreliance presents a particularly precarious situation for the ocean nation as much of the plastic waste including these carrier bags end up as ocean litter, thereby posing a significant environmental threat to the delicate marine life.

Efforts to curb the plastic waste issue included the government stipulating bans on certain sizes of single use plastic bags in 2021. Following this government initiative, alternative options such as non-woven bags became more common for similar purposes. However, these bags, while reusable, are made from propylene plastic and are limited to dry goods as they are semi-water resistant unless laminated (Garg, 2024). This necessitates the search for an alternative that parallels the desirable features of LDPE bags but are more consumer friendly and environmentally sustainable. Among the most promising alternatives are starch-based bioplastics, which are more biodegradable in natural environments compared to petroleum-based plastics (Anitha et al., 2024). Common raw materials for these bags include corn, cassava, potato peel, banana peel, and waste rice, all of which are organic sources of starch. While these inputs can be obtained as imported pellets, studies suggest that production costs can be reduced by using food waste resources as they are renewable (Emadian et al., 2017).

The Small Island Geographic Society (SIGS), under the REmoving PLAstics from our Coastal Environment (REPLACE) project, funded under a grant from the Plastic Free Rivers and Seas for South Asia (PLEASE) project has piloted a biobag production facility in Haa Dhaalu Hanimaadhoo, initially using imported corn pellets. The production cost can be reduced by locally sourcing these raw materials from locally available sources. As this is the first biobag production initiative in the Maldives, there is no prior research on feasibility of sourcing local raw materials. Hence, this study provides a baseline assessment to determine the feasibility of obtaining starch-based waste materials such as potato peels, banana peels, leftover cooked rice, and cassava in Hanimaadhoo, and the findings of which can be extrapolated to islands in the nearby catchment area.

METHOD

Study Design

This study adopted a cross-sectional quantitative survey that targeted four main population groups: households, cafes and restaurants, farmers, and home gardeners (the latter as a subset of households) in Haa Dhaalu Hanimaadhoo. A structured questionnaire was designed for each group in English and Dhivehi, with an inclusion criteria of adults aged 18 years and above residing or operating within Hanimaadhoo. The questionnaire covered areas such as demographic background, plastic (LDPE) bag usage habits, food consumption or use patterns, food waste production, management, and willingness to contribute the waste to the facility for biobag production.

The survey questionnaire for each category was checked for content validity by experts as well as pretested to ensure validity and reliability. Pilot testing was conducted on 10 households in Greater Male, and confusing or ambiguous items were identified based on respondent feedback and revised to compile the final survey. This also helped maintain face validity. To ensure content validity, a literature review and expert judgement was carried out to ensure the questionnaire covered all aspects of the concept.

The surveys were conducted via in-person interviews from 17th to 19th April 2024 by 11 local enumerators, who received training from the Small Island Geographic Society (SIGS) team. The training also included components to ensure that recordings of responses are as consistent as possible between the different enumerators for inter-rater reliability. The training also included guidance on interview methods and role-playing exercises using realistic scenarios to prepare them for the data collection process. Informed consent was obtained from all of the participants.

Sampling and Data Collection

The proposed location for the biobag production facility is Hanimaadhoo located at 645'N and 7310'E in Haa Dhaalu (HDh.) atoll which is the second northern atoll in the Maldives (Figure 1). Hanimaadhoo has a household size of 560 (Census 2022) and a population size of 2423 (Census 2023). Figure 1 also shows the sourcing catchment area where there are 12 potential islands to source raw materials. Hence, as potential sourcing locations, Hanimaadhoo was the main study site for the survey, along with potential extrapolation of

results to twelve other islands in the catchment area that are agriculturally active. There is also an established agricultural center on Hanimaadhoo for exclusively developing agriculture and training personnel.

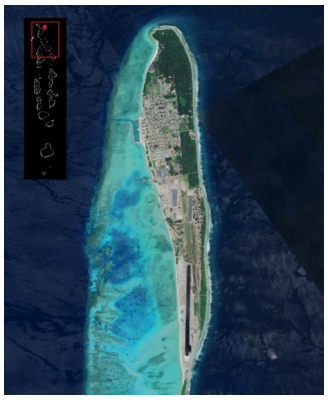

Figure 1. HDh. Hanimadhoo, the survey site

Note: Red rectangle in inset map shows raw material sourcing catchment area

Households and cafes were expected to use bananas, potatoes, and rice for food preparation; hence these were the target materials for these two groups. Both cassava and banana are grown locally in the Maldives and hence farmers were interviewed on the production of these in Hanimaadhoo, along with attempts to grow potatoes and rice. Many households also grow these crops within their homes and hence questions on home gardening were included along with the household survey as a separate but related aspect.

For sampling, a combination of probabilistic and non-probabilistic sampling strategies was used. Based on a 95% confidence interval, 5% margin of error and an anticipated rate of 50% response rate, the required sample size for 560 households was calculated as 229 households using the Raosoft sample size calculator. However, upon arrival on the island it was observed that there were many empty plots as well as homes that had been temporarily leased to foreign workers working on an airport construction project on the island. Therefore, the available households were 242 and hence the target sample size was reduced to 149. Of the target sample, 121 households agreed to participate in the survey with a response rate of 81%. A systematic random sampling of these 121 households was done, selecting every 2nd household along each housing block.

For cafes and restaurants, census sampling of all 8 cafes operating within the island were done, while purposive sampling was conducted on 6 farmers and 42 home gardeners.

Data Analysis

For each target group, the resulting survey data was exported to MS Excel for cleaning and coding, and subsequent coded data was analyzed using SPSS version 27. Descriptive statistics in the form of frequencies, percentages, mean, and median data were generated for each aspect assessed. From these data, monthly required raw material for each starch source was estimated for households, cafes, and restaurants and compared to the input required by the facility to determine the feasibility.

RESULTS AND DISCUSSION

Households

Of the 121 households, the majority (65%) consisted of 5 or more members, followed by 19% of households that had 4 members, and 16% which had fewer than four members. Among the respondents, 55% were males and 45% were female. The majority of participants were between 55-64 years (29%), followed by 25-34 (26%), then 35-44 years (20%), then 45-54 years (19%), and 18-24 years (7%).

Plastic Bag Use

From the households, 110 (91%) reported using plastic bags. Nearly all households (99%) reported obtaining plastic bags as carrier bags from stores such as supermarkets/grocery stores and convenience stores. Only one respondent reported that they obtained plastic bags from overseas. The majority, 68%, reported that they used plastic bags as trash bin liners, followed by 59% who said they used plastic bags for shopping. Additionally, 23% said they keep plastic shopping bags for reuse, while 8% throw them away immediately.

Among the 117 respondents, 36% used fewer than 5 plastic bags per week, 32% used 5-10 plastic bags per week, 15% used 11-20 bags per week, and 18% used more than 20 bags per week. The majority of participants use less than 10 plastic bags per week. Furthermore, the majority of households (88%) used medium size plastic bags with 23% and 19% using large and small bags, respectively. In terms of alternatives, among the 121 respondents, 87% used reusable cloth (non-woven) bags, 31% used biodegradable plastic bags, and 2% used biodegradable plastic bags exclusively. Additionally, 12% did not use alternatives to plastic bags.

Banana, Rice, and Potato Consumption

When comparing the use of rice, potatoes, and bananas, 85% of respondents use rice daily, 31% use bananas daily, and 14% use potatoes daily. However, an additional 54% of households consume potatoes 2-3 times per week, 45% consume bananas, and an additional 13% of people consume rice on a weekly basis.

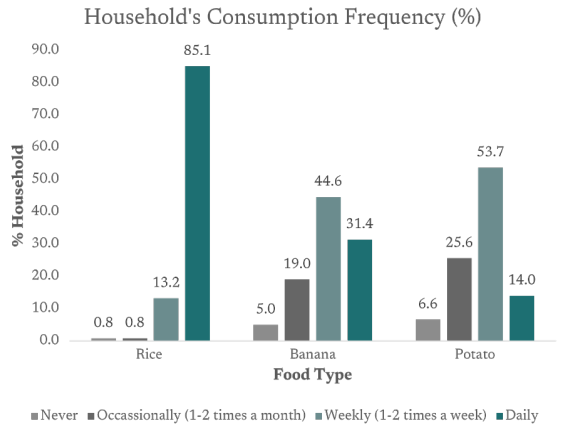

Figure 2. Frequency of consumption of rice, potatoes, and bananas in households of Hanimaadhoo

The majority of households discard leftover peels of bananas (n=67), potatoes (n=66), and rice waste (n=66). Some households use bananas (n=45), potatoes (n=44), and rice (n=20) for composting and other purposes. The majority of households discard rice (n=33), potato (n=48), and banana (n=51) peels weekly, followed by those who discard them rarely and daily (Figure 3). The households that said they never discarded these wastes also mentioned that they do not use them.

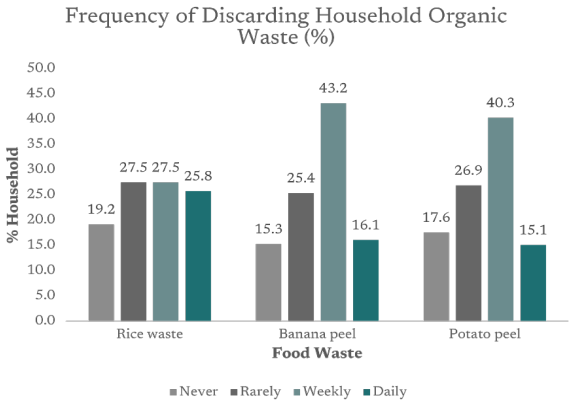

Figure 3. Frequency of discarding household rice, potato and banana peels

The majority of households discard less than 1 kg of rice waste, banana peels, and potato peels daily (Figure 4).

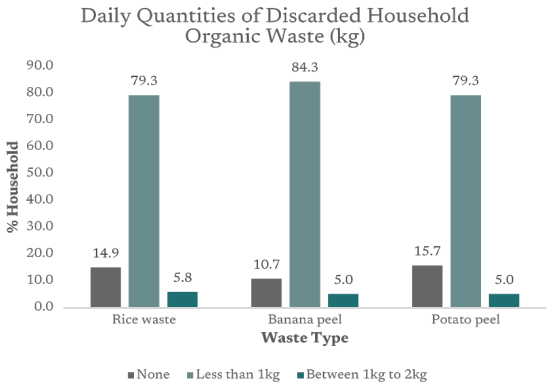

Figure 4. Amount of rice waste, banana peel and potato peel discarded daily

Willingness to Source Raw Materials

The household survey also inquired on the willingness of households to source raw materials for the biobag production facility. The participants responding 'yes' or 'maybe' were also of a similar percentage, respectively. The majority of households (about 90%) were willing to handover the leftover banana peels, potato peels, and rice waste to the production facility instead of discarding them. However, the willingness to weigh the food waste was divided with about 32% not willing to weigh.

Respondents were also asked about their willingness to separate and store the waste food for collection. The majority of the respondents said 'yes' or 'maybe' (73%) when asked if they are willing to separate the leftover banana peels, potato peels, and rice before collection. However, many of the participants disagreed (39%) and 29% responded 'maybe' with refrigerating the leftover banana peels, potato peels, and rice before collecting. Some gave reasons that they do not have enough space in the fridge and no space to keep an extra fridge for this purpose.

The participants were also asked about possible other sources of waste food such as fruits, vegetables, milk and dairy products, cereals (bread and bakery items, durum wheat), meat, fish, eggs, and pasta to see if there were other potential starch waste produced in the households. The majority of respondents said that no food waste is generated from these items, citing reasons such as making only required quantities for cooking.

Cafes/Restaurants

The cafes/restaurants that were surveyed were mostly small to mid-sized establishments with 63% classified as cafes and 38% as casual dining restaurants. Half of the establishments were new, operating for less than 3 years, while only a quarter operated for more than 6 years. As for staffing, most establishments had between 6-10 employees (50%), with a small proportion having less than 5 or between 11-20 staff.

Plastic Bag Usage and Alternatives

All the establishments that were surveyed reported regular usage of plastic bags, for takeaway and delivery purposes (63%), with some using them for waste disposal purposes (25%) and ingredient storage (13%). The bags were primarily obtained from supermarkets (71%) as part of grocery item packaging, and 29% from wholesale suppliers. The volume of bags varies with 38% using between 20-50 bags per week, and a quarter using over

100 bags per week (Figure 5). About 75% of establishments used medium-sized bags with 12% and 13% using large and small bags, respectively. In terms of alternatives, 63% of respondents do not use any alternatives to plastic bags, with only 25% using paper bags and 13% using reusable cloth bags (non-woven bags) mostly for short-eats or small takeaway items.

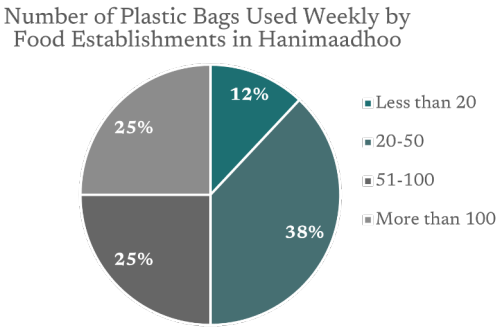

Figure 5. Number of plastic bags used in cafes and restrautants

Banana, rice, and potato consumption

Rice and potatoes were used daily in all establishments surveyed but only 3 used bananas daily and occasionally. More than half use between 1-10kgs of rice and potatoes daily, with some exceeding 10kg, while only one establishment uses over 5kg of bananas daily (Figure 6). Despite the considerable use of rice and potatoes, most of the establishments do not track how much is generated from the peels or leftovers, with only 3-4 of cafes/restaurants tracking it informally. The waste generated is generally under 1kg daily for each ingredient, although for rice and potatoes, 1-5kg was also reported. Most of this waste is discarded in general waste.

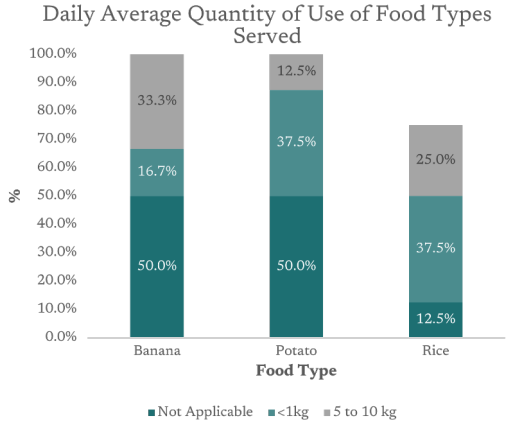

Figure 6. Quantity of rice, banana and potatoes used in cafes and restaurants

The majority of cafés/restaurants generate less than 1 kg of waste from potato peels, banana peels, and rice waste, while a few businesses generate waste between 1 and 5 kg (Figure 7). The majority of cafés/restaurants (87%) throw away banana peels, rice, and potato peels in general waste.

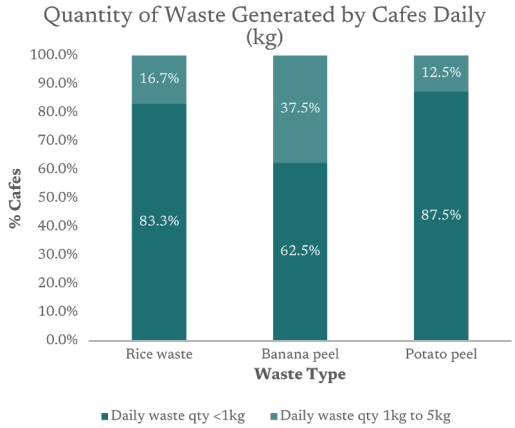

Figure 7. Daily waste generated from bananas, rice and potatoes

We also discussed the challenges faced by cafés/ restaurants to manage their waste, A majority mentioned the lack of a proper waste management system, followed by the unavailability of composting or recycling facilities nearby, and limited awareness of food waste reduction methods. Staff training, better inventory management, collaboration with waste management groups and broader community involvement were some of the recommendations from the participants.

Willingness to Source Raw Materials for Biobag Production

The majority of cafés/restaurants agreed to provide leftover banana peels, potato peels, and rice waste to a production facility and they were also open to adopting the required steps such as separation, storage and weighing of the food waste materials. Due to the low usage of bananas, less cafes were able to contribute the peels to the facility. Willingness was lower for weighing and refrigeration than handover and separation.

Farmers and Home Gardeners

A total of 5 farmers and 42 home gardeners participated in the survey. The size of the farms ranged between 3,000 and 5,000 square feet, with 60% of the farms having a size of 5,000 sq ft. The majority of farms surveyed (60%) were 5,000 square feet. About 60% of farmers reported having 1-5 years of experience while some of the respondents have been farming for over a decade. Forty-two households out of the 121 households surveyed reported practicing home gardening in their household areas or in a separate plot away from home. About 93% of home gardeners maintained a cultivation space under 100sqft, with only 7% using plots between

100-500sqft.

Crop Cultivation and Challenges

The majority of farmers used traditional/manual farming (80%), followed by mechanized farming (20%). Twenty percent of farmers practiced organic farming. According to the survey, only one farmer grew cassava and potato while three farmers grew bananas. All farmers grew other types of crops such as papaya, lettuce, chili, and watermelon. Farmers reported allocating more than 2,000sqft for growing bananas while less than 500sqft was allocated for growing potatoes and cassava. They reported a yield of fewer than 50 kg per sqft per season for cassava and potato while a yield of 101-200 kg per sqft was reported for banana. All of the farmers grew crops to sell at local markets and to send to Male.' Additionally, 40% of the farmers said they also grew crops for their own consumption, followed by 20% of those who sell them to nearby inhabited islands and resorts.

Home gardeners grew a diverse range of crops such as fruits (49%) especially banana, papaya, mango, and watermelon, with 46% growing vegetables, and 5% growing herbs and spices. None grew cassava. The dominant use of home gardening was for household consumption (85%), with less than 10% selling their produce locally. Two percent of home gardeners shared their produce with neighbors or relatives. Crop waste was commonly used in home composting, rather than disposal at waste facilities, by most households.

The survey also inquired about current challenges faced by farmers to understand barriers to production and supply of raw materials for biobag production. The main challenges reported by the farmers were lack of quality seeds (100%), pests and diseases (80%), unstable market prices (20%), and limited access to fertilizers (20%).

Willingness to Source Raw Materials

80% of farmers were willing to provide crop residues such as cassava leaves, banana leaves, and trunks as they were not used for specific purposes. Only 33% of home gardeners were willing to provide their crop waste to the biobag production facility.

DISCUSSION

Plastic Bag Consumption

Both households and cafes used plastic bags ubiquitously for their storage and waste disposal needs, with cafes using more bags per week due to the higher turnover rates of plastic bags. The small percentage of respondents who reported not obtaining plastic bags may indicate households that have made behavioral shifts away from plastic bag usage, potentially due to environmental concerns or availability of alternative sources such as reusable non-woven bags following the plastic bag ban. Regardless, majority do not use alternative bag types, indicating both a reliance on conventional plastic bags and possibility of a demand gap that biobags could fill, provided that the latter matches the size, durability, strength, and affordability of current plastic bags in use.

Since 31% of households currently use biodegradable plastic bags, this shows an encouraging possibility of smoother adoption of biobags from the Hanimaadhoo facility. 12% of households who do not use alternative bags may indicate a segment that may be resistant to switching from plastic bags. However, this could be due to other reasons such as current lack of ready access to alternatives on the island or higher confidence in the quality of conventional plastic bags (strength, durability, cost). For this group, greater access, and promotion of more sustainable sources or incentivization may need to be considered as strategies for adoption of biobags. Furthermore, fibers in non-woven bags are mainly from non-biodegradable polypropylene (Pratima et al., 2019) and though meant to be reusable, they are often used once and discarded. The biobags produced at the facility can potentially replace these non-woven bags and contribute to less degradation of the environment.

Prior to the June 2021 ban on using single use plastic bags in shops, plastic bags were widely available both as retail and wholesale options in Male, and large plastic bags (more than 20L capacity) obtained from shopping were widely reused for bin liners. However, the ban on plastic bags below 30x30cm and a MVR2 per bag tax on sales of other plastic bags led to price escalations that led many individuals to switch to free alternatives such as non-woven liners even for bin lining. Despite this, some households continued to rely on plastic bin liners by buying them in bulk. This high dependence on plastic bags for trash disposal also presents an opportunity for widespread dissemination of biobags as a viable alternative. The high frequency of use for shopping indicates the continued use of plastic bags in everyday shopping experiences. These results also signal a high potential of distributing biobags to these stores which serve as bag sources for households.

Potential Sourcing of Raw Materials from Food and Agricultural Waste

The majority of households discard less than 1 kg of rice waste, banana peels, and potato peels daily. This suggests that the daily waste from these materials is small

per household but may still make up a considerable amount across the entire island's population. The frequency of the waste generated along with the low quantity per household indicates that despite the small amounts generated, they could still be collected and used in bulk in the facility if properly coordinated. The survey found that the majority of households typically discard the three types of food waste: rice, banana peels, and potato peels. A considerable number of households also compost peels and waste rice, indicating that alternative uses have been a part of their waste management practices.

Most cafes generate under 1kg of potato and rice waste daily, similar to households. Presence of some issues such as lack of proper waste management system can hinder sustainable practices. However, one establishment reported no challenges in this regard, suggesting that best practices may already be implemented on a small scale at the cafe level where the issue ceases to be significant.

Home gardeners practiced composting food and crop waste, which is a low-cost alternative to using commercial fertilizers to enrich crop yields. Apart from organic farmers who practiced recycling crop waste back to the farm, some farms opted to discard waste such as banana leaves and stems. For the latter, the conversion of these plant residues into plant food may be dependent on time and convenience.

All three groups were willing to contribute their starch-based waste to the biobag facility. However, they all posed various logistical challenges to contribute their waste to the biobag facility. Both households and café/restaurants asserted greater willingness if a suitable collection mechanism was in place and they were aligned with their current practices such as timely collection to reduce daily storage. Both households and café/restaurants mentioned prolonged storage, especially in cold storage for perishable waste as a challenge stating the lack of current space in fridges. To address this issue, the facility may have to incentivize by providing air-tight collection containers and storage space or speed up collection timings or frequency to reduce the need for cold storage at point of collection, working in collaboration with the island council waste collection system. While café/restaurants were willing to weigh the waste at point of collection, households were less inclined, suggesting a weighing service within the collection system will be more feasible as well as accurate.

Overall, the findings of the survey indicated a strong community support for contributing organic waste in various categories. However, for the program to succeed, logistical barriers such as cold storage, and efficient schedules may need to be optimized. By implementing targeted solutions with proper incentivization and awareness programs, the challenges of obtaining raw materials for the biobag production could be mitigated.

When we compare households and food establishments, both farmers and home gardeners were less willing to contribute the waste materials for biobag production. For home gardeners, this was intuitive as they grew more diverse crop types than farmers, thereby producing less waste due to their composting habits. One farmer who practiced organic farming, however, sustained a habit of recycling all plant waste materials for composting, which makes their contribution also less certain. A vital insight we gained from the farmer survey was that most farmers were not as willing to contribute their crops (bananas and cassava tubes) for biobag production as it is one of their income sources. However, farmers were willing to handover their crop residues such as leaves and pseudo-stems towards biobag production. While these parts are not rich in starch, they contain lignin or cellulose that has potential for use as bioplastic reinforcement (Mathijsen, 2016, Yang et al., 2019). Regardless, the general expression of willingness to support the biobag production endeavor from farmers was a promising insight and shed light on opportunities for mutually beneficial future collaboration between farmers and the production process. Additionally, since the farming area is a centralized location on the island, having a waste depository would also make the logistical process of collection more efficient.

Only a minority expressed a willingness or mixed thoughts on contribution, indicating that targeted outreach or education programs may be necessary for this group to encourage or incentivize these groups to become involved in the process towards mutual benefit. This reluctance may also stem from the fact that many of the plants produced were on a small scale; they may not feel that their contributions would be substantial enough to have an influence on the production process. Therefore, this group may only serve as a supplement group to any potential shortage in raw materials at a given time in the production process.

One of the main factors that can impact ready availability of raw materials from farmers is pests and diseases, as noted by farmers for banana plantations. As banana plantations are grown with plants close together in one site, this infestation could be whitefly or powdery mildew, which are commonly occurring pests in tropical climates in settings of high humidity and limited airflow (Bous, 2024). This can either reduce crop yield by reducing farmers' willingness to sustain the crop amidst recurring bouts and high pest burden. A few farmers also mentioned fluctuations in market prices and limited fertilizer access as other challenges they face. Both of

these could be mitigated by offering farmers a financial incentive to sustain these crops, such as exploring the possibility of selling banana plant residues (trunk and leaves) as potential waste material for biobag production.

Estimation of feasibility of raw material availability for biobag production

For the purpose of our estimation, we only included rice waste, banana peel and potato peel from households and food establishments as they comprised the bulk of contributions. The results of the survey indicated that on average, at least 1kg of each food waste item can be willingly obtained daily from these two groups in Hanimaadhoo. Tables 1 and 2 provide estimations of potential raw materials from households and food outlets, respectively. The calculations were performed as below.

The total available households on the island, N = 242
Sample households, n = 121
Daily available quantity of waste from sample households = a. This is estimated using the following formula where midpoint of the value range is used (e.g., midpoint of < 1kg is 0.5 and midpoint of 1-5 kg is 2.5)

$$a = ((RAN1 \times 0.5) + (RAN2 \times 2.5) \div n \qquad 1$$

Mean monthly waste quantity from the sample households, n is b and is calculated as below

$$b = a \times n \times 30 \qquad 2$$

Mean monthly waste quantity from the available households, N is c and is calculated as below

$$c = a \times N \times 30 \qquad 3$$

Table 1. Mean monthly potential waste (kg) raw materials sourced from households

Waste Type	Daily qty of waste generated from those willing to contribute (frequencies)		Mean daily qty of waste available from sample, *a* (kg)	Mean monthly qty of waste from sample, *b* (kg)	Mean monthly qty of waste from population, *c* (kg)
	<1kg (RAN1)	1 to 5kg (RAN2)			
Rice waste	96	7	0.54	1965	3930
Banana Peel	102	6	0.55	1980	3960
Potato Peel	96	6	0.52	1890	3780

For cafes/restaurants all outlets on the island participated in the survey and hence sample size, n and population size, N are the same. Similar to households, the mean daily waste available from cafes/restaurants is a and calculated as in Equation 1 and the mean monthly waste available is b and calculated as in Equation 2. Total monthly available raw materials from households and food outlets are given in Table 3.

Table 2. Mean monthly potential waste (kg) raw materials sourced from food outlets (n=8)

Waste Type	Daily qty of waste generated from those willing to contribute (frequencies)			Mean daily qty of waste, *a* (kg)	Mean monthly qty of waste, b (kg)
	<1kg (RAN1)	1 to 5kg (RAN2)	Total		
Rice waste	5	3	8	1.25	300
Banana Peel	5	1	6	0.63	150
Potato Peel	7	1	8	0.75	180

Table 3. Total monthly available raw materials from households and food outlets

Waste Type	Monthly available waste (kg)		
	Households	Food outlets	Total
Rice waste	3930	300	4230
Banana Peel	3960	150	4110
Potato Peel	3780	180	3960

A biobag facility feasibility study conducted for imported corn starch pellet bags indicated that the monthly quantity of pellets required was 200kg for a target of 40,000 bags to be produced. For these bags, the percentage of corn starch was 27%. For banana peel bioplastics, existing studies have indicated that 40% of weight can be successfully used for synthesis (Huzaisham & Marsi, 2020.) For potato peel and cooked rice, percentage used with selected fillers ranged between 3-40% and 30-100% respectively (Xie et al., 2020; Miescher et al., 2025; Hasan et al., 2020). Based on these studies, we used a conservative estimated composition of 40% banana peel, 10% potato peel and 70% rice, subject to subsequent refinement upon validation of pilot phase. Based on this, the amount of raw material required was calculated as below:

Amount of raw material required = % starch per pellet mass x monthly quantity of pellets needed.

Based on these assumptions, a total of 173,400 bags can be produced per month from all three raw materials in Hanimaadhoo (Table 4). At the current pilot stage, the target is to produce 40,000 bags per month, hence this can be viably produced from local raw materials from Hanimaadhoo only. This amount is sufficient to supply households in Hanimaadhoo with biobags based on their monthly demand for garbage disposal. For commercial scale, targeting wider distribution across Maldives, the production will be higher and sourcing from the nearby 12 islands in the catchment area should be considered.

Table 4. Monthly number of bags produced from available raw materials

Starch source (wet mass)	Raw material available from food outlets & households per month (kg)	% of starch in raw material	Number of pellets produced per month (kg)	Number of bags produced per month
Rice waste	4230	70	60	12,000
Banana Peel	4110	40	411	82,200
Potato Peel	3960	10	396	79,200
Total				173,400

Limitations and Recommendations

This study's findings are based on self-reported data which may be subject of bias. In order to improve accuracy, the biobag facility should consider a waste audit from the households to get more accurate values. Although the feasibility estimates calculated that potato peel, banana peel and rice waste from households and food establishments were available in surplus, there were some assumptions in the calculations made as well as some caveats. This includes drying and processing losses of raw material, storage and spoilage (pre-processing capacity) and actual reliability of the target groups in obtaining the quantities according to schedule. Furthermore, the study focuses on specific types of food waste and may not account for other potentially more significant waste options.

It is also recommended to expand this survey to the nearby 12 islands in the catchment area to get estimates of available raw materials from these islands. These surveys should also inquire on potential logistical burdens that may arise when transporting goods between islands and Hanimaadhoo in order to improve the raw material collection process. With further research, the number of raw materials could also be expanded to include other plant waste that could be viable in producing biobags. This may include washed up seagrass, which is found in large quantities in Huvadhoo, Meemu and Laamu atoll in the Maldives (Floyd et al., 2024). Furthermore, the bioplastic films made from these raw materials could be expanded as an alternative for other plastic packaging, such as that used to sell local food items. Further research will need to be conducted to produce food-grade packaging that meets acceptable standards. Finally, to encourage more participation, education, and outreach programs, incentivization programs and infrastructure development for the pre-production process may improve the feasibility of obtaining raw materials and thereby increase production yield.

CONCLUSION

The survey conducted in Hanimaadhoo revealed that households generated a significant volume of food waste varieties of interest (banana peels, potato peels, and rice waste) for biobag making. Cafes and restaurants were also major contributors to food waste especially for potato peels and rice waste. Farmers were a reliable source of banana residual waste, while home gardeners produced a more diverse array of tropical plants. All the groups expressed a willingness to contribute the waste generated from these food varieties towards the biobag production process. Feasibility estimates revealed that if households and cafes do reliably contribute at least 1kg of waste per month, there would be a surplus of raw material available for biobag production in the facility during the pilot stage. For commercial scale production, sourcing raw materials from nearby catchment islands should be considered. Some limitations include assumption of reliability, processing losses, and reluctance of some respondents to contribute. Much of the reluctance stemmed from factors such as difficulty in prolonged storage in their refrigerators due to space constraints, as well as requirement of farmed crops such as cassava and banana harvests for their own commercial or recycling and composting (in the case of organic farmers and home gardeners). With proper incentivization, awareness and education campaigns, infrastructure development for efficient collection, all four groups on the island are likely to demonstrate support for the production of biobags from the required raw material waste. This could then ensure a steady supply of raw materials as demanded by the facility's input demand, aligned with the study's feasibility estimates.

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