System process documentation of processing of moringa leaves into moringa powder.

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Abstract. Moringa oleifera, commonly known as malunggay, has a high nutritional and medicinal value. With these, the global market for moringa ingredients is increasing because of the change to a more essential or healthy lifestyle. The moringa leaves are highly perishable to maintain their quality. This study shows several processing techniques for dried moringa leaves. Furthermore, the study examined the material balance of 25kg of freshly harvested moringa leaves. The weight increased by 4% in the initial washing and 29% in the secondary washing due to the leaves' water absorption capacity. Spin dryer removal was 42%, while mechanical dryer removal was 23%. The study achieved 10% material recovery from harvest to packaging. As a result of the study, one of the major issues for moringa processing is its high investment costs, with a total equipment cost of Php 1,398,355.00, and its labor intensiveness, particularly in the destemming procedure (5 kg per hour). The lack of moringa plantations is one of the constraints for establishing the processing, as this will hamper the operation. As a recommendation, increasing moringa leaves for a stable supply of raw materials or establishing a small-scale processing facility for lower investment costs.

1 Introduction

Moringa oleifera, or malunggay, is a versatile tree with various uses. This plant possesses significant nutritional and medicinal worth. This plant contains more than 90 nutritious chemical components. Moringa is claimed to contain significantly higher levels of specific vitamins and minerals compared to other food sources, making it a highly nutritious option [18]. Moringa phytochemicals, particularly polyphenolic compounds, have a significant free-radical scavenging effect due to their rich antioxidant content, including beta-carotene and vitamin C, providing a strong defence against free radicals and oxidative stress [22]. Moringa is said to have seven times more vitamin C than oranges, ten times more vitamin A than carrots, seventeen times more calcium than milk, nine times more protein than yogurt, fifteen times more potassium than bananas, and twenty-five times more iron, according to Gopalakrishnan [10]. Additionally included are M. oleifera's pharmacological potential and mechanisms of action concerning various illnesses, including diabetes mellitus, cancer, hypertension, ulcers, and more [3].

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The global market for Moringa ingredients is expected to experience significant growth, reaching around Php 561 million or US$ 10.2 million by 2027 [6]. The demand for organic herbal plants and root crops is increasing due to health concerns resulting from lifestyle and evolutionary factors. In Asia, medicinal plants are cultivated for herbal medication, food, and cosmetics, with countries like India and China using at least 8000 products. Herbal industries contribute significantly to the national economic growth of countries like India, China, Malaysia, and Indonesia. Conservation efforts are crucial to prevent species scarcity, especially for endangered species [2]. Evolutionary medicine addresses health concerns, with nutrition being a key factor in developing lifestyle diseases [1]. The quality of traditional treatments and herbal remedies can be compromised by contaminants, affecting their efficacy and safety [21]. The drying process is a crucial element that significantly impacts the nutritional properties of the dried material. Advanced computational methods are being developed to analyze the dehydration process during drying, focusing on product quality, residual moisture content, and nutritional content [3,7]. Numerical modeling of the dehydration of porous materials faces challenges due to the complexity of multiphase transport processes and the variability of material properties [7]. Energy-efficient drying technologies like osmotic dehydration, heat-pump-assisted drying, and solar drying are being evaluated to improve drying efficiency and product quality [7, 20]. Therefore, this study aimed to identify the primary obstacles to the processing of moringa and the financial constraints linked to investing in processing operations. The study's main aim was to determine the method used to process dried moringa leaves as part of its postharvest procedure. The main goals were: (1) to analyze the distinct processing stages of moringa powder; (2) to calculate the material balance for each step of processing moringa leaves; (3) to measure the turnaround time (TAT) for each operation involved in transforming fresh moringa leaves into moringa powder; and (4) to identify the critical challenges in the processing of moringa.

2 Materials and Method

2.1 Materials

The following materials were used in the conduct of the study: fresh moringa leaves, tools such as a stainless basin, mesh net, plastic gloves, and drums; equipment such as a spin dryer, washer, mechanical dryer, pulverizer, weighing scale and sealer, scooper, plastic (packaging), and timer.

2.2 Methods

2.2.1 Preparation of tools and equipment

The tools and equipment, including the facilities, were cleaned and disinfected before processing. The drying creates were cleaned and secured in the tray rack. The washing area was cleaned after every operation.

2.2.2 Collection of Fresh leaves and Processing to Dried Moringa Powder

The moringa leaves were highly perishable, and the harvest was early in the morning at the NEUST Moringa plantation. The leaves that were harvested as samples were young and middle-aged leaves [19]. The fresh leaves arrived in sacks at the processing center. The

samples were weighed and initially washed. Then, the pinnae part of the moringa leaves was separated from the stem [19]. Afterwards, the leaves were subjected to secondary washing to clean the samples further. Every five (5) kg of moringa leaves were spun dry to remove the moisture content. Afterward, the leaves were put in trays for mechanical drying (350 grams per tray). When the leaves were crisp, they were cooled and pulverized. After pulverizing, they were sealed, packed, and labeled. After every operation, the product's input and output were recorded and documented.

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2.3 Data Gathered

The data gathered were the following:

1. Input of materials per processing operation, kg. The input materials refer to the material's weight before processing. The moringa leaves were weighed and recorded using a weighing scale.
2. Output of materials per processing operation, kg. The output materials refer to the material's weight after the processing procedure. The moringa leaves were weighed and recorded using a weighing scale.
3. Duration of processing, hr. The time of each operation was recorded using stopwatch for each operation.
4. Rate of capacity per processing operation, kg/hr. Rated capacity refers to the weight of input materials divided by the hours of operation.

3 Results and Discussion

3.1 Different Processing Flow of Moringa Leaves

Multiple processing flows for dry powdered moringa are depicted in Figure 2 (Medina and Morales, 2020). Early in the morning, the moringa leaves were picked and transported from the plantation to the processing facility. First, the stainless basin was used to wash the fresh moringa leaves. Destemming is the process of removing leaves from the stem. The leaves underwent further washing to remove extraneous objects like dust and grime. After that, the leaves were spin-dried to eliminate any remaining water.

In contrast, air drying doesn't require any energy, including gasoline or electricity. To get rid of extra water, the destemmed leaves are allowed to air dry for 12 hours. LPG fuel and power are needed for the mechanical drying. When the texture was crispy, the dried leaves were taken out. 30 minutes of cooling is required before crushing and packing.

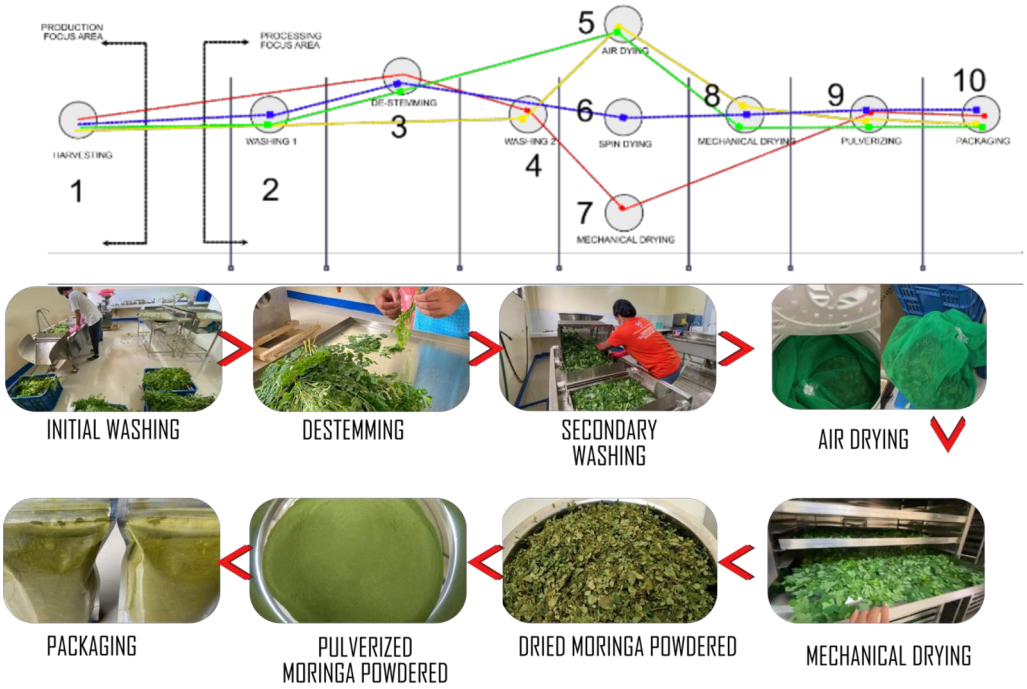

Fig. 1. Four (4) scenarios of processing from fresh moringa leaves to packaging (Modified Adopted to [5,19]).

3.2 Material Balance of Moringa Processing

The processing used in the study for the material balance is shown in Figure 3. The fresh weight of 25kg of freshly harvested leaves was used in the study. Figure 2 shows that there was an increase in weight during the initial and secondary washing. It was revealed that a 4% increase in weight in the initial washing while secondary washing increased by 29%. This is in lieu of the capacity of the leaves to absorb water. Also, it was observed that the amount of water absorbed by the leaves increased when the stem was removed compared to the still intact stem.

Furthermore, the weight removed in the spin dryer from secondary washing was 42%. At the same time, 23% of the weight was further removed when it passed through the mechanical dryer. It was observed that 17% of the weight was removed from the mechanical dryer to the pulverizer. This is rather high according to Martinez [16] as compared to the coffee roasting to grinder. While 1% reduction in the pulverizer operation and packaging operation. In the study, there was 10% material recovery from its harvest to packaging, and it was noted that the pulverizer was needed for further study in lieu of a high weight reduction.

3.3 Turnaround time (TAT) for Moringa Processing

Figure 3 shows the TAT in processing 25kg fresh moringa leaves into 2.50 kg powdered moringa. Among the most labor intensive and require the most hours for the processing operation are mechanical drying and destemming with and mechanical drying with 180 minutes and 150 minutes, respectively. The number of operations associated with the destemming process is because of the labor intensive of manually separating the leaves to their stems. The figure shows an average of 5kg per hour rated capacity per person. On the

other hand, the temperature used in the study was a low temperature setting at 60 0C, which affects the drying time more than higher temperatures. According to Krah [13], increased temperature reduces drying time and the nutritive value of dried leaves.

Furthermore, the study shows that the operations that require fewer hours and labor are pulverizing and packaging with 15 minutes and 18 minutes, respectively.

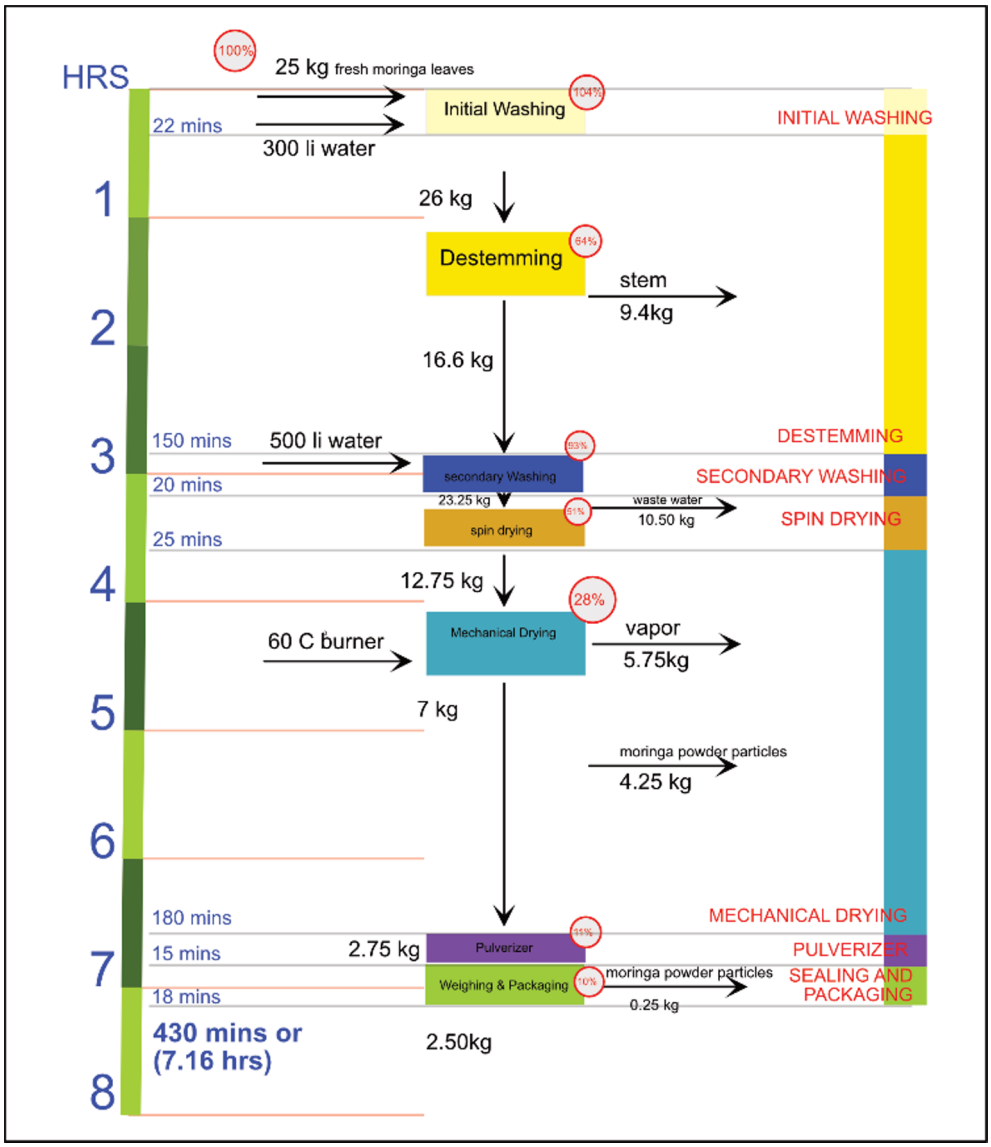

Fig. 2. Turnaround time (TAT) and material balance of moringa processing using fresh moringa leaves as raw materials input

3.4 Initial Investment

The equipment lists utilized to prepare the moringa leaves are displayed in Table 1. The following tools were made available by the university research fund and a partner government agency. The largest investment costs on these lists were for the pulverizing

equipment, vegetable washer, and mechanical drier, which came to Php 550,000.00, Php 453,600.00, and Php 312,805.00, respectively. Together, these three pieces of equipment account for 94% of the investment, or Php 1.316 million. However, a number of tools, including a moisture meter, a laboratory analysis, and a water treatment system, can be used to enhance moringa processing. Php 1,398,355.00 was the initial investment for the machinery needed to create dried moringa leaves. Only with government assistance was the processing equipment purchased. Therefore, a small-scale processing strategy supporting local farmers' businesses is suggested for additional research to reduce equipment specifications and investment costs.

Table 1. Lists of the basic equipment in processing of moringa powder

No	Tools and Equipment	Total Costs, PhP
1	Stainless Basin	Php 25,600.00
2	Multi-purpose vegetable washer	Php 453,600.00
3	Spin Drying	Php 5,350.00
4	Mechanical Cabinet Dryer	Php 550,000.00
5	Pulverizer Equipment	Php 312,805.00
6	Foot sealer	Php 25,000.00
7	Weighing Scale	Php 26,000.00
		Php 1,398,355.00

3.5 Issues and Challenges

The data reveals that destemming, the separation of leaves from the stem, is the most labour-intensive moringa processing process, requiring a mean of 5 kg/hr. This labour-intensive operation offers local employment opportunities, high operation costs, and potential shortages during peak season. Moreover, local farmers plant moringa in backyards, limiting the supply of raw materials for dried powder processing. NEUST Gabaldon Campus has started 3,000 tree moringa plantations, promoting farming in nearby communities through research and extension functions.

3.6 Recommendations

3.6.1 Use of Moisture Meter in Determination of Dried Moringa Leaves

Using a moisture meter is highly recommended to standardize the desired output before removing moringa leaves for the mechanical drying.

3.6.2 To Promote an Alternative Small-scale Processing

PHP 1,398,355.00 was the initial investment for the machinery needed to produce dried moringa leaves (Table 1). Only with government assistance was the processing equipment purchased. Therefore, to reduce equipment specifications and investment costs, a small-scale processing model suitable for local farmers' businesses is suggested for additional research.

3.6.3 Design a Device Equipment in the Destemming Process

The study found that the labor-intensive part of its procedure required a high rate of manpower. One of the advantages of this activity for the community is the benefits of hiring labor. However, due to the labor-intensive activity, the operation expenses will be significant.

There may also be instances of a labour shortage during the busiest time of year for farm laborers.

3.6.4 Optimization of Each Processing and Additional Equipment/tools

Further study on optimising each processing will further increase the material recovery, significantly increasing the operation's profit for the sales dependent on the processed moringa dried leaves. Likewise, the installation of a good water source for the washing area will be taken into consideration. Moreover, additional quality checking, such as a moisture meter and voltmeter, thus requested to monitor the proper moisture content and the power meter of each operation.

3.6.5 Good source of water supply

For FDA application, installing good water sources such as water purifying and underground water as water sources for its operation is necessary for these products for human consumption [12].

4 Conclusion

Malunggay, another name for Moringa oleifera, is a plant with significant nutritional and therapeutic significance. Due to these factors, the global market for moringa components is growing as people return to more basic and healthful lifestyles. Because moringa leaves are highly perishable, several processing processes and techniques have been developed to preserve their freshness. The dried moringa leaves in this study were processed using four (4) distinct methods. Moringa processing's main problems are its high investment costs and labor-intensive nature, especially the destemming process.

Additionally, 10% of the material was recovered from fresh moringa leaves to dried pulverized leaves; however, this could rise even more if the waste from the pulverizer and other processes is considered. Additionally, processing moringa leaves requires a steady supply of raw materials, such as fresh leaves. Furthermore, a business model with lower household or small-scale equipment costs can be further investigated. Finally, the average processing time for turning fresh moringa leaves into moringa powder was 7.16 hours (430 minutes), with a material recovery of 10%.

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