# Design, Fabrication, and Performance Evaluation of Sweet Potato (Ipomoea batatas L.) Flour Mill for Small-scale Applications

Nervine Dave C. Docdoc
Caraga State University

Beverly S. Morales
Caraga State University

Cindy May C. Belivestre

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# Design, Fabrication and Performance Evaluation of Sweet Potato (Ipomoea batatas L.) Flour Mill for Small-Scale Applications

Nervine Dave C. Docdoc[1], Beverly S. Morales[2], Cindy May C. Belivestre[3]
[1]Caraga State University, [2]Caraga State University, Caraga State University.
Corresponding author email: ccbelivestre@carsu.edu.ph

**Abstract:** *Utilizing sweet potato to consumable flour was projected as the best solution to the problem of storage, transportation and increasing the shelf life of the crop. This study was conducted to evaluate the most recommended moisture content level of a sweet potato during milling. The three different treatments used were 8%, 10% and 12% moisture content level which were manually chipped at 2 mm thick. Two layers of stainless-steel wire mesh were used, #100 for fines and #200 for the very fine output of the machine. The machine's performance was evaluated through measuring its milling capacity, efficiency and starch recovery. Results indicated that the highest milling capacity, milling efficiency and starch recovery were both achieved at 8% moisture content level with 17.45 kg/hr, 96.07% and 65.9% respectively. Therefore, the lower the moisture content, the higher the milling capacity, efficiency and starch recovery. The level of significance was also determined using ANOVA with completely randomized design (CRD). Statistical analysis identified that there were high and significant differences among the treatments.*

**Keywords:** Sweet potato; moisture content; flour mill

## 1. INTRODUCTION

Mechanizing agricultural processing operations to enhance efficiency and capacity has long been a key interest for engineers, innovators, and scientists. However, this task is complicated due to the non-homogeneous nature of most agricultural products. To improve designs, it is essential to understand the critical stages and components of each operation, as well as the properties of the materials involved [20].

Sweet potato (Ipomoea batatas (L.) Lam) is a starchy root crop grown in tropical and subtropical countries like China, the USA, India, Japan, Indonesia, the Philippines, Thailand, Vietnam, and Nigeria [1]. It is one of the most important crops for farmers in the Philippines and other developing countries worldwide. According to the International Potato Center [20], sweet potato ranks as the sixth most cultivated food in the world, following rice, wheat, potatoes, maize, and cassava. Typically, this crop can be stored for 2-3 months, considering factors such as room temperature, humidity, and carbon dioxide levels, which are essential for respiration.

According to the Philippine Statistics Office, sweet potato production grew at an average annual rate of 1.0 percent from 2011 to 2015. However, the harvested area declined by an average of 4.6 percent annually. In 2015, sweet potato production was estimated at 536.0 thousand metric tons, a 3.10 percent increase from the 2014 level of 519.86 thousand metric tons. It remains one of the most harvested crops in the region.

Sweet potato is a rich source of beneficial nutrients and offers many health benefits. Dried sweet potato contains 17.14-28.57 g of dietary fiber per 100 g and is rich in minerals like potassium, iron, zinc, and copper, with a balanced amino acid composition [2]. Besides minerals, sweet potato is rich in carbohydrates, protein, lipids, carotenoids, anthocyanins, and phenolic acid. It provides substantial nutritional value and has become a crucial food resource for addressing food shortages caused by population growth and desertification [3]. During crises, it often serves as a substitute for rice for less fortunate families. Given its ability to grow in both rainy and drought seasons, it is well-suited for cultivation in the Philippines.

Sweet potato also shows great potential as a source of flour, which could substitute wheat flour. The starch content of sweet potato flour ranges from 36.4 to 79.8%, with an average value of 63.49% [8], indicating significant potential for breeding and cultivating high-starch content varieties [4]. Using sweet potato starch is cost-effective compared to other crops, yet this abundant resource is not fully utilized. Starch has various applications, not only in food processing but also in the production of textiles, paper, fuel, adhesives, plastics, and paints [5]. It can also enhance food products through its color, flavor, sweetness, and nutrients.

However, sweet potato is hygroscopic, meaning it is prone to water loss and moisture absorption, which contributes to its deterioration rate and substantially reduces its shelf life. This crop's instability and unwieldiness affect its economical transportation distance unless converted into other more stable products [6]. One of the most effective ways to utilize sweet potatoes is to mill them into flour. By doing so, farmers can extend the storage life of the crop, allowing them to achieve higher profits compared to selling the raw crop directly to the market. Sweet potato flour is an excellent substitute for wheat flour and cake flour, offering a nutritious and cost-effective alternative that can be used in a variety of culinary applications.

Therefore, there is a need to design and fabricate a flour milling machine that can help farmers minimize storage issues with sweet potatoes. This machine should be easy to operate, affordable, time-saving, and safe to use. Consequently, this study aims to design, fabricate, and evaluate the performance of a sweet potato flour mill. Specifically, it aims to evaluate the performance of the machine in terms of its milling capacity, milling efficiency, and flour recovery.

The development of this machine will be highly beneficial to farmers and farmer associations that cultivate sweet potatoes, significantly extending the crop's storage life and reducing its deterioration.

Additionally, by minimizing crop waste, this innovation can help address the increasing problem of agricultural waste, which has a substantial environmental impact.

The study utilized sun-dried and chipped sweet potato tubers and considered three different moisture content treatments: 8%, 10%, and 14%. As the machine is a prototype intended solely for testing and research purposes, the materials used did not conform to the standards for food-grade processing machinery. Consequently, an economic analysis of the machine was not included in this study.

## 2. RELATED WORK

### 2.1 The Sweet Potato

Sweet potato (Ipomoea batatas (L.) Lam), known as "kamote" in the Philippines, is a dicotyledonous plant from the morning glory family (Convolvulaceae). The plant's large, starchy, and sweet-tasting roots, as well as its edible leaves and shoots, are widely consumed. Native to Africa and Asia, sweet potatoes are grown by many farmers due to their ease of cultivation, low cost, and ability to thrive in various weather conditions. The edible tuberous roots come in various colors, including yellow, purple, orange, white, and violet, with white or pale varieties being less sweet.

Sweet potatoes are a rich source of nutrients and offer numerous health benefits. Dried sweet potatoes contain 17.14-28.57 grams of dietary fiber per 100 grams and are high in minerals like potassium, iron, zinc, and copper, with a balanced amino acid composition. In addition to minerals, they are rich in carbohydrates, protein, lipids, carotenoids, anthocyanins, and phenolic acids, providing antioxidative, hepatoprotective, anti-inflammatory, antitumor, antidiabetic, antimicrobial, anti-obesity, and anti-aging effects.

Sweet potatoes have significant potential as a food source, particularly as flour that can substitute for wheat flour. Processing sweet potatoes into flour not only extends their shelf life but also enhances nutritional intake. For instance, the Tanzania variety yields 27% flour from 30% dried chips with an 11% moisture content. Sweet potato flour has a swelling power of about 3.55 (g/g) and a solubility rate of approximately 9.18%.

### 2.2 The Uses of Sweet Potato

Sweet potato root, often regarded as poor man's food, is consumed as food, animal feed, and as a raw material for starch and noodle manufacturing. Its high nutritional value, as depicted in Table I, makes it a crucial food resource for addressing food shortages caused by population growth and desertification. During crises, it commonly substitutes for rice among less fortunate families. Its ability to grow in both rainy and drought seasons makes it particularly suitable for cultivation in the Philippines.

In the Philippines, Thailand, and Malaysia, sweet potato is considered a vital confectionery food with significant potential in food processing. Despite being cultivated in Asia for nearly 200-450 years, sweet potato has seen limited commercial processing and remains a native crop due to its low market introduction and the lack of extensive research and support.

Table I. Sweet Potato Nutrition per 100 grams (USDA National Nutrients Data Base)

| Principles | Market Value | Percentage of RDA |
|---|---|---|
| Energy | 86 kcal | 4% |
| Carbohydrates | 20.12 g | 15.5% |
| Protein | 1.6 g | 3% |
| Total Fat | 0.05 g | <0.5% |
| Cholesterol | 0 mg | 0% |
| Dietary Fiber | 3 g | 8% |
| | **Vitamins** | |
| Folates | 11 mg | 3% |
| Niacin | 0.557 mg | 3.5% |
| Pantothenic Acid | 0.8 mg | 16% |
| Pyridoxine | 0.209 mg | 15% |
| Riboflavin | 0.061 mg | 5.5% |
| Thiamin | 0.078 mg | 6.5% |
| Vitamin A | 14,187 IU | 4.73% |
| Vitamin C | 2.4 mg | 4% |
| Vitamin E | 0.26 mg | 2% |
| Vitamin K | 1.8 mg | 1.5% |
| | **Electrolytes** | |
| Sodium | 55 mg | 3.5% |
| Potassium | 337 mg | 7% |
| | **Minerals** | |
| Calcium | 30 mg | 3% |
| Iron | 0.61 mg | 7.5% |
| Magnesium | 25 mg | 6% |
| Manganese | 0.258 mg | 11% |
| Phosphorus | 47 mg | 7% |
| Zinc | 0.3 mg | 3% |
| | **PHYTO-NUTRIENTS** | |
| Carotene-A | 7 mg | - |
| Carotene-B | 8,509 mg | - |
| Crypto-xanthin-8 | 0 mg | - |

### 2.3 The Starch Properties of Sweet Potato

Sweet potato is a cost-effective source of starch with a wide range of applications, including food processing, textiles, paper, fuel, adhesives, plastics, and paints. Although typically consumed cooked, it can also be processed into flour, which enhances food products with its color, flavor, sweetness, and nutrients. Fresh sweet potatoes are hygroscopic, leading to high deterioration rates and reduced shelf life. However, converting them into flour extends shelf life and improves the nutritional value of products like bread. Additionally, sweet potato waste can yield crude oil and protein. The starch content of sweet potato flour varies from 36.4% to 79.8%, with an average of 63.49%, highlighting its potential for high-starch variety cultivation [8].

### 2.4 Sweet Potato Flour Processing

Peeling sweet potato roots enhances flour quality but results in losses, ranging from 11.4% to over 23% of root weight, depending on the root's form [8]. Although peeling reduces processing time, it necessitates thorough washing. Processing sweet potatoes into flour or starch addresses storage and transportation challenges. Properly washing the roots before peeling minimizes losses. Sweet potatoes intended for chips should be peeled with a stainless-steel kitchen knife and sliced into 2mm thickness using a domestic slicer. [11]

Drying is the most critical step in processing sweet potato flour, impacting its final quality. Among various drying methods, sun drying is most frequently used due to its use of free, non-polluting energy and minimal equipment costs. This process preserves the product and extends its shelf life by removing moisture, which prevents microbial growth. Processing costs depend on the technology used; inexpensive technology minimizes costs and is beneficial for small farmers and rural processors. It should be easy to use, low-cost, and versatile for periods when sweet potato processing is not possible. Countries like China and India practice sun drying for sweet potatoes, converting them into chips before sending them to starch factories. Despite its disadvantages in energy control and quality, sun drying is the most common method in the Philippines due to its low cost and suitability for small-scale use.

### 2.5 Temperature and Moisture Content

The flour milling process of sweet potato involves several steps to achieve the desired output from the machine. In practical storage conditions, moisture reduction occurs more slowly and can vary depending on ambient temperature and humidity. Drying the sweet potato roots is crucial to efficiently pulverize them. Dehydration at 60°C for 10 hours reduces moisture content by 6% - 7%. This accelerates the moisture removal process, which may lead to different textural and structural changes in the sweet potato flour compared to a gradual drying process. The choice of 60°C for 10 hours in this study was based on the need to achieve a rapid and consistent reduction in moisture content, ensuring that the sweet potato flour is suitable for subsequent milling and processing stages [15]. This method was selected to streamline the process and maintain consistency in the experimental conditions. However, it is acknowledged that this accelerated drying could potentially alter some properties of the flour compared to those produced under more gradual drying conditions. For example, rapid dehydration might affect the starch gelatinization or the overall texture of the flour. Sweet potato starch typically has a moisture content ranging from 8% to 11.8%. Higher moisture content facilitates microbial growth and accelerates starch deterioration. In starch production areas, safe storage requires moisture content below 13%, with sweet potato starch ideally kept below 14% and not exceeding 15%. National standards for sweet potato starch moisture content are currently lacking [16].

## 3. METHODOLOGY

Figure 1 illustrates the design flow implemented in this study, serving as an effective tool for evaluating the machine's performance. The process begins with preliminary sizing and conceptual design, where the machine's configuration is sketched to meet specifications, including considerations for desired moisture content to optimize performance. Testing and adjustments follow to enhance machine performance.

Fabrication involves material selection and procurement, prioritizing availability and accessibility for future maintenance. Cost estimation for materials is conducted through canvassing. Flour processing includes cleaning, peeling, chipping, drying, and milling of sweet potatoes. Manual peeling and chipping with a 2mm kitchen grater facilitate sun drying.

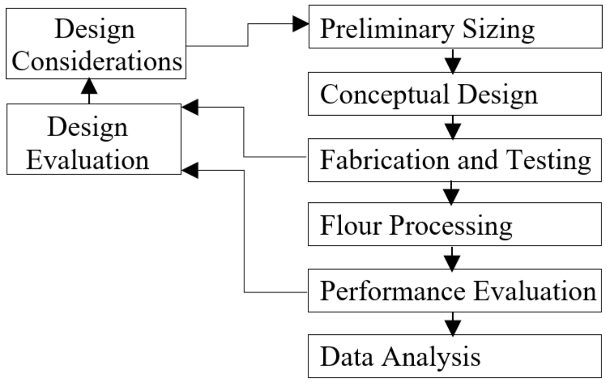



Fig. 1. Process flow

Performance evaluation and data analysis measure mechanical power requirements for milling sweet potatoes. Parameters such as flour recovery, milling efficiency, and capacity are assessed to gauge machine performance.

### 3.1 Design Consideration

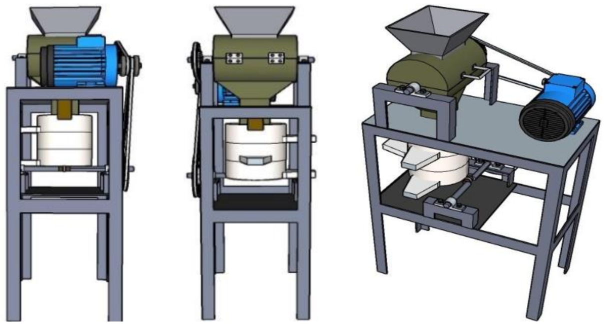
The flour milling machine is designed to ensure effective and efficient operation. To ensure a well-milled output product from the hammer mill, the thickness of the sweet potato chips was carefully selected based on the recommended thickness for optimal milling. The materials used in this machine were chosen to be locally available, ensuring convenient procurement and easy access for replacements and repairs when needed.

To ensure efficient machine performance, it is crucial to match the speed and power requirements with the desired output. Efficiency and speed are integral factors in machine design, directly influencing effectiveness and overall performance. Moreover, the safety of the operator was paramount in the design of the machine, focusing on ergonomic principles and ensuring that moving parts are positioned away from body contact areas. Risks were minimized within acceptable limits, adhering to state-of-the-art practices and technical regulations. The milling system employed in the machine was a hammer mill, selected in accordance with the Philippine Agricultural Engineering Standards (PAES) requirements.

### 3.2 Preliminary Sizing and Conceptual Design

The sweet potato flour mill is comprised of five main components: the hopper, hammer blades, chamber, sifter, and frame. Powered by a 1.5 horsepower electric motor, it is designed to mill manually chipped and sun-dried sweet potato tubers into consumable flour. The hopper has a capacity of 400 grams per batch, feeding the dried samples to the 1400 rpm hammer blades housed within the chamber for milling. After milling, the flour passes through a perforated screen sheet into a vibrating sifter equipped with stainless steel wire mesh (#100 for fine and #200 for very fine particles). Particles remaining above the #100 mesh are considered coarse products.

The hopper takes inspiration from the cacao pod crushing machine of Osoteo et.al. [21] which was designed to have a hopper compartment for the crop to be dumped or fed inside. In this study, the hopper was made of galvanized iron sheet, which serves as the inlet for the dried sweet potato chips into the flour mill chamber. It measures 6 x 4 inches at base 1, 5 x 3 inches at base 2, and stands 6 inches tall. Hammer blades, comprising 36 swinging blades each 3 inches tall and spaced 0.6 inches apart, crush the dried chips to the desired size.



(a) (b) (c)

Fig. 2. Perspective view (a) front view, (b) right side view, and (c) isometric view of the machine

Figure 3 illustrates these blades, attached to a rotating shaft via three 5/8-millimeter-thick, 5-inch diameter steel plates.

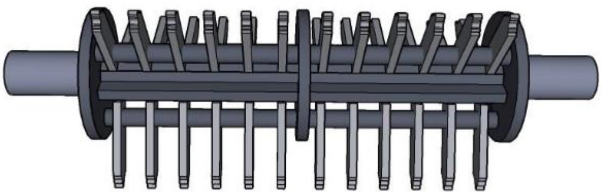


Fig. 3. Hammer blade

The chamber encloses the milling process, preventing spillage of sweet potato chips. A perforated sheet with 1mm x 20mm openings at the chamber's base partially sieves the milled chips.

A funnel beneath directs the sieved flour to the sifter. Located beneath the chamber, the sifter separates fine and very fine flour particles. Figure 4 outlines its design, featuring two inclined sieves with dimensions specifying a total height of 1 foot, diameter of 7 inches, and height of 4 inches each.

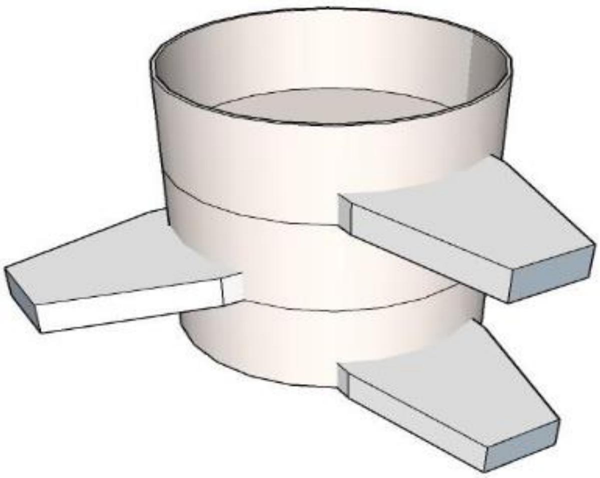


Fig. 4. Sifter

Supporting all components, the frame is constructed from a single 2 x 2 inches angle bar measuring 25 feet in length, 16 inches in width, and 32 inches in height. An electric motor, positioned at the upper right part of the machine, powers the rotational motion of the hammer blades and vibration of the sifter. With a 1.5 horsepower capacity and operating at 1,740 rpm, it facilitates the machine's operations efficiently.

### 3.3 Material Selection and Fabrication

The materials used to fabricate the prototype flour milling machine are locally sourced, ensuring easy access for adjustments and maintenance. As this machine was intended solely for testing and research, the materials used do not meet standard requirements for food processing machinery. The materials used in fabricating the prototype flour milling machine are listed in Table II.

Table II. Material Selection

| Item | Quantity | Unit | Specification |
|---|---|---|---|
| Electric Motor | 1 | Pc. | 1.5 hp |
| Pillow Block | 4 | Pcs | 1" hole |
| Pulley | 3 | Pcs | 4", 5" and 7" (by l' hole) |
| GI Sheet | 1 | Sheet | Gauge 16 |
| Angle Bar | 1 | Pc. | 2"x 24' x 5mm |
| Steel Plate | 1 | Sheet | 3/8 x 10" x10" |
| Steel Brace | 5 | Pcs | 1" x28" x5mm |
| Steel Gate | 2 | Pcs | 3/4 |
| Rubberize V-Belt | 2 | Pes | B50 and B42 |
| Rubberize Gasket | 1 | Pc. | 6'x3' |
| Stainless steel wire woven mesh | 2 | Pcs. | #100 and #200 |
| Round Bar (plain) | 2 | Pcs | 1" and 16mm |
| Bolts and Nuts | 18 | Pcs | |

### 3.5 Flour Processing

Sweet potato tubers were sourced from Mainit, Surigao del Norte, and transported to Ampayon, Butuan City. The tubers were cleaned with tap water, peeled, chipped, and dried for 6 hours at 105 degrees Celsius using an oven dryer at ASCI laboratory. Initial moisture content (MC) of the sweet potatoes, recorded at 65% upon harvest, was determined through this process.

After manual peeling to a thickness of 2mm using a kitchen grater, the chipped sweet potato samples were weighed using a digital scale and dried outdoors for 2 days using sun drying methods. The samples were periodically weighed until achieving the desired moisture content for each treatment: 8%, 10%, and 12%.

Three treatments were used to assess the milling efficiency, capacity, and flour recovery of the machine. Each treatment comprised four replications with 1 kg on a wet basis. Randomization was employed to prevent data bias. To determine the machine's power requirements and operational speed precisely, a stopwatch was used to evaluate performance and measure operational outputs.

### 3.6 Performance Evaluation

The milling capacity was calculated by dividing the operating time (hr) from the milled sweet potato (kg). Where $W_o$ is the milled sweet potato and $T_o$ is the operating time consumed during the milling of the sample.

$$C_M = \frac{W_O}{T_O} \quad (1)$$

The milling efficiency of the machine was determined by the weight of milled sweet potato divided by the weight of the sweet potato chips. Where Wo is the weight of the milled sweet potato and the Wn is the weight of the dried sweet potato chips.

$$Eff = \frac{W_O}{W_N} x\, 100\% \quad (2)$$

Flour recovery is the ratio of the weight of the milled starch collected to the weight of the input dried sweet potato chipped, in percentage. Where Ws is the weight of the starch collected and $W_1$ is the weight of the dried sweet potato chips

$$R_S = \frac{W_S}{W_1} x\, 100\% \quad (3)$$

### 3.7 Data analysis

The data collected during testing was recorded and analyzed using Analysis of Variance (ANOVA) in a Completely Randomized Design. A layout featuring three treatments (A, B, and C) with four replications each was employed to ensure unbiased results.
Significant differences among treatments were identified using the Statistical Tool for Agricultural Research (STAR). To determine which treatments showed significant differences from each other, Least Significant Difference (LSD) tests were conducted.

## 4. RESULTS AND DISCUSSIONS

Presented in Figure 5 are actual photos of the fabricated sweet potato flour mill. This prototype machine was built to evaluate its performance across different moisture content levels.

All materials used were intended solely for research and data gathering purposes. Testing and adjustments were conducted as well to achieve the desired machine output. The total cost of the fabricated machine was approximately Php 23, 042.00.

(a) (b)

Fig. 5. Fabricated machine (a) side view and (b) isometric view

Fig. 6 Machine flour output

### 4.1 Performance Evaluation

The milling capacity of the machine was observed during the performance evaluation, and the results are shown in Table III and Figure 7. Milling capacity was calculated by dividing the time consumed in each replication by the weight of the dried sweet potato chips. Based on the gathered data, treatment A achieved the highest average milling capacity at 17.45 g/min, while treatments B and C achieved 16.50 g/min and 15.46 g/min, respectively. This indicates that the machine performs more efficiently at lower levels of moisture content, highlighting the influence of moisture content on milling capacity.

Table III. Tabulated data for milling capacity

| TREATMENT | OBSERVATION (kg /hr) | | | | |
|---|---|---|---|---|---|
| | $R_1$ | $R_2$ | $R_3$ | $R_4$ | Mean (g/min) |
| A (8% MC) | 18.25 | 17.08 | 17.48 | 17.00 | 17.45 |
| B (10% MC) | 15.80 | 16.44 | 15.91 | 17.86 | 16.50 |
| C (12 % MC) | 14.90 | 15.33 | 15.71 | 15.86 | 15.46 |

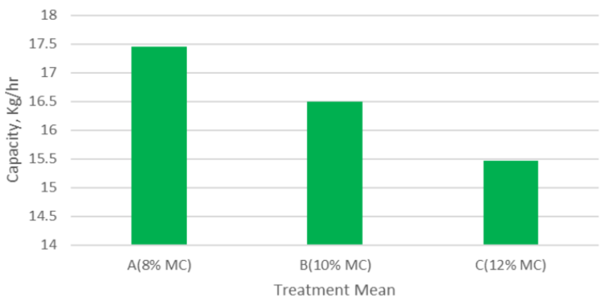



Fig. 7 Graphical presentation of the milling capacity

Depicted in Table IV are the ANOVA results for milling capacity, where the computed F-value of 8.407 exceeds the tabular values at both 5% and 1% levels of significance, indicating significant differences among treatments in terms of milling capacity. Lower moisture content samples resulted in higher milling capacities.

Table IV. ANOVA for milling capacity

| SOURCE OF VARIANCE | DF | SS | MS | COMPUTED F | TABULAR F | |
|---|---|---|---|---|---|---|
| | | | | | 5% | 1% |
| Treatment | 2 | 7.93 | 3.97 | 8.41 ** | 4.26 | 8.02 |
| Error | 9 | 4.25 | 0.47 | | | |
| Total | 11 | 12.18 | | | | |

Cv = 4.17%

** highly significant at 1% level

To identify significant differences between treatments, a least significant difference (LSD) test was conducted, and the results are presented in Table V. Based on the test conducted, treatments $T_1$ and $T_3$ did not show significant differences from $T_2$, likely due to the proximity of their data points during testing.

Table V. LSD test of Milling Capacity

| TREATMENT | MEAN | N GROUP |
|---|---|---|
| $T_1$ (8%) | 17.45 | 4a |
| $T_2$ (10%) | 16.50 | 4ab |
| $T_3$ (12%) | 15.46 | 4b |

The milling efficiency was determined by dividing the mass of the milled sweet potato flour by the mass of the dried sweet potato chips, and the results are presented in Table VI. Treatment A, with 8% moisture content, exhibited the highest average milling efficiency at 96.06%, while Treatment C had the lowest average at 90.97%. This highlights that the machine's milling efficiency is notably higher at lower moisture content levels compared to treatments with higher moisture content. A lower moisture content is thus recommended for achieving optimal milling performance.

Table VI. Tabulated data for milling efficiency

| TREATMENT | OBSERVATION (%) | | | | |
|---|---|---|---|---|---|
| | $R_1$ | $R_2$ | $R_3$ | $R_4$ | Mean (%) |
| A (8% MC) | 94.80 | 97.37 | 96.10 | 96.00 | 96.07 |
| B (10% MC) | 93.59 | 92.30 | 88.60 | 96.15 | 92.66 |
| C (12 % MC) | 91.14 | 92.50 | 90.00 | 90.24 | 90.97 |

The dryness of the samples significantly influenced the milling efficiency of the machine, with drier samples being more thoroughly ground, pulverized, and sieved compared to those with higher moisture content. Figure 8 provides a graphical representation of the milling efficiency data of the machine.

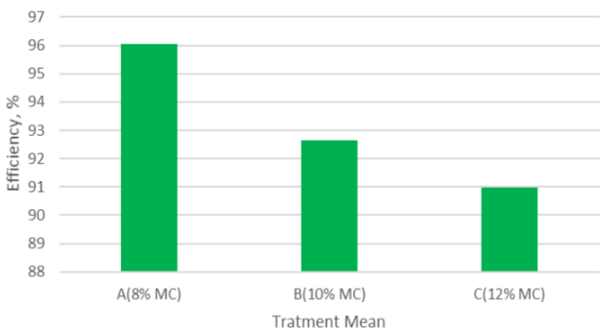



Fig. 8 Graphical presentation of the milling efficiency

The ANOVA results for milling efficiency (Table VII) indicate that treatments were statistically significant at the 5% level, as the computed F-value exceeded the tabular values at this significance level.

Table VII. ANOVA for milling capacity

| SOURCE OF VARIANCE | DF | SS | MS | COMPUTED F | TABULAR F | |
|---|---|---|---|---|---|---|
| | | | | | 5% | 1% |
| Treatment | 2 | 53.94 | 26.97 | 6.59 ** | 4.26 | 8.02 |
| Error | 9 | 39.81 | 4.09 | | | |
| Total | 1 | 90.75 | | | | |

Cv = 2.169%

* Significant at 5% level

Table VIII, showing the least significant difference (LSD) test results, confirms that Treatment A was significantly different from the other treatments. Treatments $T_2$ and $T_3$ did not show significant differences from each other.

Table VIII. LSD test of milling efficiency

| TREATMENT | MEAN | N GROUP |
|---|---|---|
| $T_1$ (8%) | 96.07 | 4a |
| $T_2$ (10%) | 92.66 | 4b |
| $T_3$ (12%) | 90.97 | 4b |

Table IX presents the data gathered for the flour recovery of the machine. The results showed that Treatment A had the highest percentage mean of 65.9%, while Treatments B and C had only 59.87% and 57.18%, respectively. The flour recovery was higher when samples with lower moisture content were used, indicating that the machine performed more efficiently with drier samples. Thus, the moisture content of the samples influenced the flour recovery of the machine.

Table IX. Tabulated data for flour recovery

| TREATMENT | OBSERVATION (%) | | | | |
|---|---|---|---|---|---|
| | $R_1$ | $R_2$ | $R_3$ | $R_4$ | Mean (%) |
| A (8% MC) | 68.83 | 63.16 | 64.94 | 66.67 | 65.90 |
| B (10% MC) | 62.03 | 57.69 | 55.69 | 64.10 | 59.88 |
| C (12 % MC) | 56.96 | 56.96 | 56.25 | 58.56 | 57.18 |

Figure 9 graphically represents the fluor recovery.

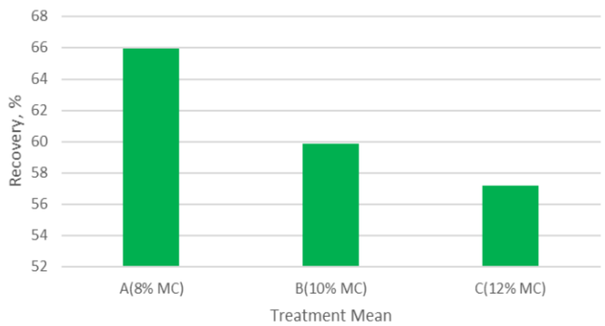



Fig. 9 Graphical presentation of the flour recovery

The flour recovery data was analyzed using ANOVA, as depicted in Table X. The results revealed that the treatments were highly significant, with a computed F value of 10.99, higher than the tabular F values of 4.26 at the 5% level and 8.02 at the 1% level of significance.

Table X. ANOVA for flour recovery

| SOURCE OF VARIANCE | DF | SS | MS | COMPUTED F | TABULAR F | |
|---|---|---|---|---|---|---|
| | | | | | 5% | 1% |
| Treatment | 2 | 159.37 | 79.69 | 10.99** | 4.26 | 8.02 |
| Error | 9 | 65.26 | 7.25 | | | |
| Total | 1 | 224.63 | | | | |

Cv = 4.41%
** highly significant at 1% level

The analysis of variance was supported by the least significant difference (LSD) test conducted, as shown in Table XI. Treatments $T_2$ and $T_3$ were found to be not significantly different from each other, while $T_1$ was significantly different from the other treatments.

Table XI. LSD test of flour recovery

| TREATMENT | MEAN | N GROUP |
|---|---|---|
| $T_1$ (8%) | 65.90 | 4a |
| $T_2$ (10%) | 59.88 | 4b |
| $T_3$ (12%) | 57.18 | 4b |

## 5. CONCLUSIONS AND RECOMMENDATIONS

Sweet potato has significant potential as a substitute for the more expensive wheat flour available in the market. To capitalize on this potential, a sweet potato flour mill for small-scale applications was designed and fabricated to address shelf life, storage, and transportation issues. The results of this study revealed that samples with an 8% moisture content level yielded the highest machine output in terms of milling capacity, milling efficiency, and starch recovery, with recorded average outputs of 17.45 kg/hr, 96.07%, and 65.9%, respectively.

Using analysis of variance (ANOVA), the treatments were found to be highly significant in terms of the machine's performance, specifically in milling capacity, milling efficiency, and starch recovery. This was further supported by the Least Significant Difference (LSD) test, which showed that samples with 8% moisture content were significantly different from the other treatments. Therefore, it was concluded that using samples with lower moisture content is recommended to achieve the most efficient performance of the machine.

For the optimization of the machine, the following are recommended:

1. Widen the hopper to lessen the backflow of the sweet potato small particles.
2. Widen the diameter of the sifter for the machine to sieve efficiently.
3. For actual production of the machine, use food grade material specially in fabricating the hopper, hammer blades, chamber and sifter; and
4. Fabricate sweepers inside the chamber to sweep the stocked flour at the side of the chamber.
5. Based on the findings of this study, it is recommended to use a lower moisture content for the sweet potato flour treatment to optimize machine performance and improve storage stability. While an 8% moisture content level showed the highest performance metrics in milling capacity, efficiency, and starch recovery, exploring a range of lower moisture contents (e.g., between 6% and 8%) could provide additional benefits. Lower moisture content can enhance shelf life, reduce transportation costs, and potentially improve product quality.
6. Future research should focus on determining the optimal lower moisture content that balances these factors while maintaining or enhancing performance. This approach allows for a more flexible and comprehensive evaluation of how different moisture levels impact the flour's characteristics and overall efficiency in practical applications.
7. Further studies could be conducted to compare the properties of flour produced under accelerated drying conditions with those produced under more gradual, realistic storage conditions to provide a more comprehensive analysis of how different drying methods could impact the quality of the sweet potato flour.
8. Assess the acceptability of sweet potato flour to the market/consumer.

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