

Development of Ginger Juice Crystallizer

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Abstract

The performance of the developed ginger juice crystallizer was evaluated in terms of cooking recovery, cooking losses, cooking rate, electrical energy consumption, and fuel consumption. The machine has a body dimension of 64 cm x 108 cm with six major components namely: cooking basin, stirrer assembly, burner assembly, transmission assembly, electric motor prime mover, and machine support. The performance of ginger juice crystallizer was evaluated using 3.5 kg of newly extracted juice from fresh ginger mixed with 1.75 kg of brown sugar per cooking batch for three trials. The crystallizer was driven by a 0.5-hp electric motor with a rated speed of 1,773 rpm. The operating paddle and stirrer speed varied from 40.2-41.8 rpm, cooking temperature ranged from 93.76 - 118.12 °C, operating noise ranged from 80-82 decibels, and the consistency of ginger tea was 0.31mm. For 1.17 hours of cooking, the ginger juice crystallizer had an average cooking recovery of 95.25%; cooking losses of 4.75%; cooking rate of 4.50 kg/hr; electrical energy consumption of 0.048 kw-hr/kg; and fuel consumption of 0.39 kg/hr. Operating the ginger juice crystallizer is financially feasible with a return on investment of 278.0%, payback period of 87 days, and break-even point of 546 kg of ginger brew.

Keywords: Ginger tea, ginger juice crystallizer, cooking recovery, cooking loss, cooking rate.

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Introduction

Ginger (*Zingiber Officinale* Roscoe) is a hot-tasting edible underground stem of an Asian plant used as beverages, perfumes, and medicines. It is favorably and abundantly grown locally and is oftentimes marketed fresh or unprocessed after harvest.

Fresh ginger might be harvested about 5 months after planting (Fikre et al, 2013). The moisture content of fresh ginger at harvest is 80-82% which is brought down up to 10% for its safe storage. The essential oil content within rhizomes increases with age, so plants used for this might be harvested 8-9 months even later (Rajeev et al, 2015).

One popular product that can be made from ginger is ginger tea which is a spicy conventional beverage that is consumed and is enjoyed daily throughout Asia and is also popular across the world (Clain, 2012).

People drink ginger tea for several health reasons. The seven miraculous benefits of ginger include the following: improves digestion, relieves congestion in colds, relieves pain, controls high blood pressure, removes bad breath, cures acne, and promotes hair growth (Ahuja et.al, 2017).

Oftentimes, the commercially available ginger tea or instant “salabat” are prepared manually. This traditional method of cooking ginger tea is tedious and may be stressful. It is done by continuous manual stirring on a wok during the entire cooking, thus requiring much human energy and longer cooking time.

Ginger juice crystallizer is a machine that transforms ginger juice into powder (PAES 236:2008). From this study, an electric-powered ginger juice crystallizer was developed to make ginger tea easier to prepare. The machine mechanically stirs the ginger juice mixture while cooking, thus manual stirring is less necessary. It may help instant “salabat” producers and entrepreneurs earn more income with less drudgery.

Objectives of the Study

The general objective of the study was to develop a ginger juice crystallizer. Specifically, it aimed to:

1. design and develop a ginger juice crystallizer powered by electricity;
2. evaluate the performance of the crystallizer in terms of cooking recovery, cooking losses, cooking rate, electrical energy consumption, and fuel consumption; and
3. perform financial analysis in operating the machine.

Materials and Method

Design Considerations

The performance of the ginger juice crystallizer was expected to conform to the following requirements (PAES 236-237:2008):

1. The minimum cooking recovery shall be 90%;
2. The stirring speed shall be 40 to 50 rpm;
3. The required heat for the operation shall be 800C to 1500C and shall be provided with an enclosure to minimize dissipation of heat;
4. The ginger tea consistency: average particle size diameter of 0.310 mm (pass through sieve # 40); and
5. The operating noise level shall not be more than 96 db measured 50 mm away from the operator's ear level at actual working position

Technical Description of the Ginger Juice Crystallizer

Generally, the crystallizer was fabricated in conformity to the requirements of PAES 236:2008. Food grade materials were used for parts in direct contact of the material being processed. The crystallizer consisted of cooking basin, stirrer assembly, burner assembly, transmission assembly, prime mover, and support frame (Figure 1). The pictorial view of the developed ginger juice crystallizer and the typical design of a crystallizer by PAES 236:2008 are found in Appendices 1 and 2, respectively.

Cooking basin. The cooking basin is a cast iron wok measuring 46 cm in diameter and 13 cm deep (Appendix 3).

Stirrer assembly. The stirrer assembly stirs the mixture by making circular movements. It is comprised of a stainless shaft and paddle made of stainless flat bars with curved edges fitted to the base of the wok. The stirrer shaft is drilled vertically through the center of the cooking basin (Appendix 4).

Transmission assembly. The V-belt and pulley arrangement was adopted to transmit power from the electric motor to the stirrer shaft and paddle. The main reasons for adopting the V-belt drive are its flexibility, simplicity, and low maintenance cost. In addition, the V-belt has the ability to absorb shocks, thereby mitigating the effects of vibratory forces (Gary et al, 1984). The 40-50 rpm required for the stirrer shaft and paddle operating speed was attained using two pulley and belt combination from the power drive. The crystallizer was powered by 0.5-hp electric motor as prime mover.

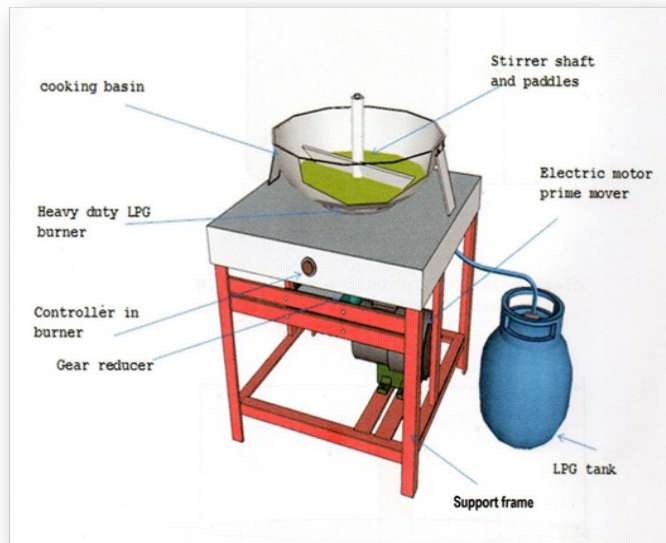


Figure 1. Isometric view of ginger juice crystallizer.
(Note: Not drawn to scale)

Burner assembly. The burning assembly is comprised of a heavy duty LPG burner which provided the required heat for cooking temperature of 80 - 150 and an enclosure made of GI sheet gauge # 18 was provided to minimize dissipation of heat. Support frame. The machine was mounted on a rectangular support frame for structural flexibility, stability, rigidity and to resist vibration during operation. Rollers were provided for ease of mobility.

Crystallization Procedure

The following procedure was followed in the production of crystallized ginger:

1. **Preparation of ginger juice.** The locally produced fresh ginger from a single variety was used as test materials of the study. Extraction of ginger juice was done using the ginger grinder and ginger juice extractor available at the Agricultural Engineering Laboratories of CapSU Buriyas campus.
2. **Filtration.** The extracted ginger juice was filtered using a stainless steel sieve # 60.
3. **Weighing and mixing.** The standard input mixture of 2:1 or 3.5 kg ginger juice and 1.75 kg brown sugar was prepared for every cooking batch.
4. **Crystallization.** The electric motor was turned on to start stirring a mixture. After few seconds, the burner was turned on to start boiling the mixture at a recommended

temperature of 800C to 1500C. A continuous sensible recommended stirring speed of 40-50 rpm during cooking was maintained to keep all crystals suspended and to facilitate the powdering of the mixture.

5. **Sieving.** The final product (ginger tea or instant “salabat”) was then allowed to cool down at room temperature and was strained using a stainless steel sieve #40 (0.31mm). The process was done to ensure uniformity of particle size of the ginger brew.

6. **Packaging.** The ginger brew was packed using plastic jars which were properly sealed and labeled.

Performance Parameters

In evaluating the performance of ginger juice crystallizer, newly harvested fresh ginger samples were secured to provide juice needed for three trials of crystallization.

The performance test for the ginger juice crystallizer was conducted using the parameters and formula based from the Philippine Agricultural Engineering Standards (PAES 237:2008) as follows:

Cooking recovery (%) is the ratio between the total weight of recovered ginger tea (instant “salabat”) and the weight of sugar added to the input juice, expressed in percent. This was determined using the following equation.

$$Cr = \frac{Tr}{S} \times 100$$

where:

Cr = Cooking Recovery, %

Tr = Weight of recovered ginger tea, kg.

S = Weight of sugar added to the input ginger juice, kg

Cooking losses is the total percent of ginger tea (instant “salabat”) loss based on the recovered product. This was determined using the following equation.

$$L = 100 - \text{Cooking recovery, \%}$$

Cooking rate is the quantity of juice that the crystallizer can cook per unit time, expressed in kilograms per hour.

$$R_c = \frac{J_i}{T_o}$$

where:

RC = cooking rate, kg/hr

TO = Time of operation, hr

Ji = Weight of input juice, kg

Electrical energy consumption (kW-hr/kg) was determined using the following equation.

$$E_c = \frac{P_c T_o}{J_i}$$

where:

EC = Electrical energy consumption, kW-hr/kg

PC = Power consumed, kW

TO = Time of operation, hr

Ji = Weight of input juice, kg

Fuel consumption (kg/h) was determined using the following equation.

$$F_c = \frac{F_1}{T_o}$$

where:

Fc = Fuel consumption, kg of LPG/hr

F = Amount of LPG consumed, kg

T = Time of operation, hr

Financial Analysis

The financial feasibility of operating the crystallizer was analyzed using the return on investment, payback period, and break-even point.

Statistical Analysis

The data collected from the study were analyzed using means and percentages.

Results and Discussion

Performance of Ginger Juice Crystallizer

The performance of the ginger juice crystallizer was derived using the following average measurements from three trials:

Weight of input juice with sugar	= 5.25 kg
Weight of recovered ginger tea	= 1.67 kg
Cooking time	= 1.17 hr
Power consumption	= 0.25 kw-hr
Stirrer and paddle speed	= 41.17 rpm
Motor rated speed	= 1773 rpm
Cooking temperature	= 93.76-118.12oC
Noise emission	= 80-82 db

The average performance (Table 1) of the developed ginger juice crystallizer at different parameters showed the following results: The cooking recovery was 95.25%, cooking losses was 4.75%, cooking rate was 4.450 kg/hr, electrical energy consumption was 0.048 kw-hr/kg, and fuel consumption was 0.39 kg/hr. Appendix 5 shows the test results from three trials.

Table 1. Mean performance of ginger juice crystallizer at different parameters.

DESIGN PARAMETERS	MEAN
Cooking Recovery, %	95.25
Cooking Loss, %	4.75
Cooking Rate, kg/hr	4.50
Electrical Energy Consumption, kw-hr/kg	0.048
Fuel Consumption, kg/hr	0.39

Financial Analysis

Table 2 shows the financial analysis of operating the ginger juice crystallizer. The total investment cost amounted to Php 53,300.00.

The total annual income derived from the sales of ginger tea at Php 450.00/kg amounted to Php 721,440.00. The total annual operating cost amounted to Php 573,226.30 which is the sum of annual fixed cost (Php 76,548.70) and total variable cost (Php 496,677.60). The annual net income was computed at Php 148,213.70

Operating the ginger juice crystallizer is financially feasible with a return on investment of 278.07%, payback period of 0.36 year or 87 operating days and break-even point of 546 kg ginger brew. Detailed financial analysis with assumptions is found in Appendix 6.

Table 2. Financial analysis of operating the electric-powered ginger juice crystallizer.

ITEMS	AMOUNT, Php
I. CAPITAL INVESTMENT	53,300.00
II. TOTAL INCOME per year	721,440.00
III. TOTAL OPERATING COST per year	573,226.30
a. Total Fixed Cost	76,548.70
b. Total Variable Cost	496,677.60
IV. NET INCOME per year	148,213.70
RETURN ON INVESTMENT	278.0%
PAYBACK PERIOD	0.36 year (87 operating days)
BREAK EVEN POINT	546 kg

Conclusions and Recommendations

Based on the results of the study, the following conclusions were drawn:

1. The performance of the ginger juice crystallizer is technically efficient. The paddle and stirrer speed (40.2-41.8 rpm), cooking recovery (95.25%), cooking temperature (93.76 - 118.12 OC), operating noise level (80-82 db), and consistency of ginger tea (0.31mm) conformed with the requirements of the Philippine Agricultural Engineering Standards (PAES 236 and 237:2008).
2. Operating the ginger juice crystallizer is financially feasible with a return on investment of 278.0%, payback period of 87 days, and break-even point of 546 kg of ginger brew.

Based on the findings of the study, the researchers recommend the following:

1. The ginger juice crystallizer may be used in making ginger tea or instant "salabat" for cooking convenience and economic profitability.
2. Further study using the ginger juice crystallizer may be conducted with varying stirring speed to optimize its performance.
3. The ginger juice crystallizer may be operated using rice hull, corn cobs, coco shells, and other biomass fuel to make it more environment-friendly and to reduce fuel cost.
4. Trials may be done using the crystallizer in making tea from turmeric, lemon grass, pandan, and other fibrous herbs and also for coco sugar production.

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