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ORIGINAL ARTICLE

Development of a Vacuum Type Pan Evaporator for *Kithul* Treacle and Jaggery Production

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Abstract
Kithul (Caryota urens) treacle and jaggery considered to be most important traditional sources of sweeteners. Sap of the *Kithul* palms is used to produce treacle and jaggery, which fetch high nutritional and export market value. In the whole traditional treacle production process, moisture removing step consumes more time, labor and energy. There is no new mechanical application for rapid removal of moisture other than traditional method. Therefore, the aim of this study was to develop a suitable device for efficient moisture removal from the sap. A simple vacuum type pan evaporator of 8 L was developed and tested at faculty of Agriculture, Rajarata University of Sri Lanka. The most salient feature of this device was, ability of controlling the inside pressure of the container to enhance the moisture evaporation under low temperature. The performance of the device was evaluated with *Kithul* sap over the manual method with three replicates for each process using LP gas and firewood as energy sources. When gas was used as the energy source, the average time taken for the initiation of the moisture removing, duration of moisture removing and the total process has been reduced by 41%, 37.6% and 30.6% respectively compared to the traditional method. Those values were computed as 40%, 27% and 24.5% respectively when firewood was used. The statistical comparison revealed that new method was significantly performed than that of traditional method($p<0.05$) and gas was the best energy source for the new method.

Keywords: *Kithul jaggery, Kithul treacle, Moisture removing, Vacuum type pan evaporator.*

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1. Introduction

Caryota urens. L, "*Kithul*" called in *Sinhala* is indigenous plant and wildly prevailed in the wet interior and highland regions in Sri Lanka. Young inflorescence of the *Kithul* plant is tapped for sap which is then used to produce fermented beverages, *Kithul* treacle and jaggery. In Sri Lankan society, *Kithul* treacle and jaggery usually use as sweeteners for culinary purposes, since it is nutritionally rich and contains a mixture of simple sugars such as sucrose, glucose and fructose (Somasiri et al. 2008). Moreover, genuine *Kithul* sweets have several health effects. These products show anti-diabetic properties (Ranasinghe et al. 2007). The unadulterated *Kithul* jaggery is called *Beheth hakuru*, which is used in the indigenous medicine (Seneviratne and Dissanayake 2016). Therefore, a huge demand has been developed for *Kithul* treacle and jaggery in both local and international markets.

Kithul tapping is a cottage industry in Sri Lanka, from that 7% of the *Kithul* tappers are tapping inflorescence for making treacle and jaggery (Seneviratne 2009). Mainly household labor involves to produce the treacle and jaggery, which is divided along gender lines as men involve in tapping young inflorescence for sap and women engage in a process of treacle and jaggery from sap (Everett, 1995). In order to produce one bottle of treacle requires 4-6 liters of sap and production of 1 kg of jaggery requires 6-8 liters of sap (Hettiaranichchi 2008).

water contained in the sap is evaporated in order to concentrate solid by heating the sap in an open pan. Evaporation is a process of emission of water vapor by a wet or a free surface of water, in liquid or solid state at a temperature below boiling point (Akerman 2016). Different types of evaporators are in use to concentrate food in liquid form in food industry. Some of them are centrifugal evaporators, agitated thin film evaporators, plate evaporators, tong tube evaporators and short tube vacuum evaporators etc. However, none of them are appropriate to *Kithul treacle* production process.

Traditionally at the household level trapped sap filtered by passing through a filter and pours it into an aluminum pan for boiling treatment which is done by exposing the pan for hot and pass burning fire. Then water in the sap is getting evaporated, reducing the sap juiciness up to 70% of total solid and produced high sugar, concentrated syrup (*Kithul* treacle) while boiling (Abeysinghe 1991). When the foam begins to appears, the heat supply should reduce and the boiling sap should be stirred well to avoid foam until the sap become to syrup. This process is called skimming. Produced treacle allows to cool down until it becomes desired viscosity and then pour in to glass bottles for consumption or sale. The moisture removal process from sap until produce treacle takes 2.5- 3.5 hours (Everett 1995).

It is a drudgery operation which, consume more time, labor, energy and cause health

hazards for the operator. Due to this reason this valuable industry is becoming disincline among the rural people in Sri Lanka. By introducing an efficient vacuum type pan evaporator, this industry can be popularized among people and it will be an additional source of income for the rural farmers. Therefore, main objective of this study was to introduce an efficient vacuum type pan evaporator for *Kithul* treacle and jaggery industry by reducing the boiling point of the sap. The performance of the vacuum type pan evaporator was evaluated and compared to traditional *Kithul* treacle and jiggery process.

2. Materials and Methods

The design and fabrication were carried out at the Engineering workshop, Faculty of Agriculture, Rajarata University of Sri Lanka, which is properly maintained and equipped with all required facilities for fabrication of machineries for researches. The performance evaluation was carried out at *Kithul* treacle producing houses in *Mirigama* area of *Gampaha* district and *Kothmale* area of *Nuwara Eliya* district in Sri Lanka.

2.1.Factors considered during design the device

High efficiency of work, the safety of the operator, reduction of labor requirement and time, ergonomic factors, affordability, low energy consumption, easy operation and maintenance, durability, quality of the final product were highly considered in designing. The boiling point of any liquid mainly depends on the external pressure exert on the liquid. When the pressure is increased the boiling point is also increased. Therefore, in this design, the boiling point of *Kithul* sap is supposed to reduce by forcefully reducing the pressure in the sealed container in order to reduce the time consumed for evaporation of moisture. In addition to the pressure controlling, the evaporated moisture is also planned to remove from the surrounding of the *Kithul* treacle.

Therefore, the design is mainly consisted with sealed container for boiling *Kithul* sap, pressure controlling system, stirring system and the moisture removal system. Since, the samples should be checked time to time at the preparation process to determine the quality of *Kithul* treacle, a sample observation unit is designed with the container. Fig.1 shows the assembly of all the main systems together.

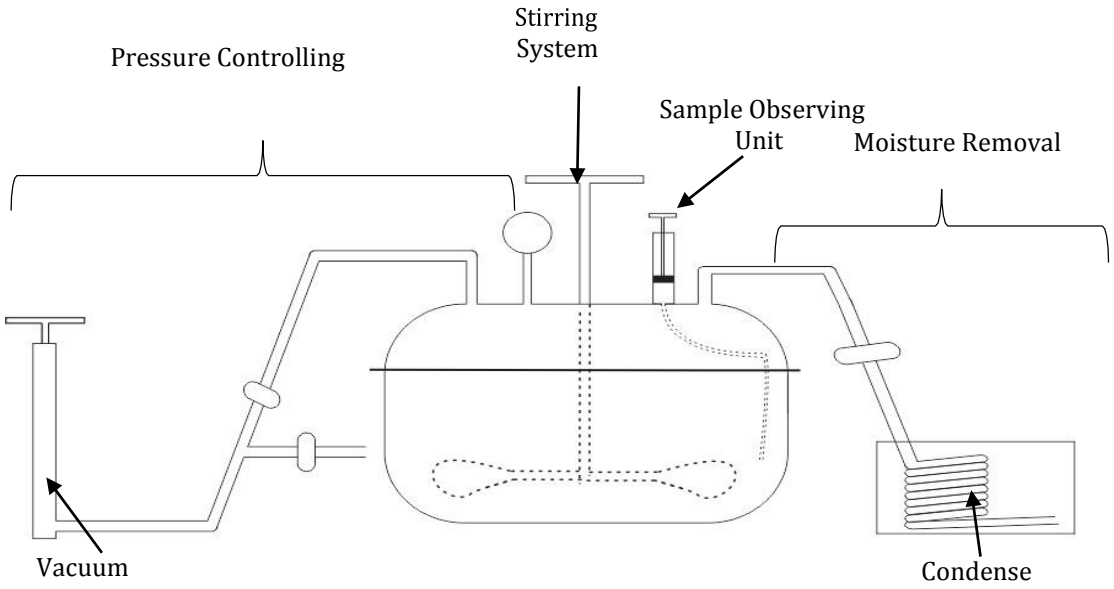

Figure 1: Vacuum type pan evaporator

A few preliminary trails with the conventional *Kithul* treacle and jaggery production were carried out at the selected *Kithul* treacle and jaggery producing houses in the *Mihirigama* and *Kothmale* areas to get an idea about time consumption for production of 750 ml of *Kithul* treacle, way of stirring for a better quality, required volume of sap to produce 750 ml of treacle and required amount of fuel (firewood) to produce 750 ml of treacle. In addition to that the average moisture content and sugar content of treacle and viscosity of producing treacle were measured. Base on the collected data from the preliminary test, some important componentsweredesigned.

2.2. Determination of volume of the pan

It was intended to develop the system to produce 750 ml of treacle at one batch so that the volume of the pan was determined as follows,

According to the data collected by the trails with the conventional method, 6000 ml of *Kithul* sap is required to produce 750 ml of *Kithul* treacle.

Therefore,

Sap to treacle conversion ratio = 8: 1

Required amount of sap to produce 750 ml of treacle = 6000 ml

Normally foam is produced while boiling the sap. Therefore, one third of the total volume should be allowed for foam.

Therefore, required volume for foam

=initial sap volume X1/3

= 6000 ml X 1/3

= 2000 ml

Therefore; total volume for the pan was 8000 ml.

The pan should possess a lid which should be able to create a seal condition within the pan for better controlling of pressure and moisture. Therefore, a stainless-steel container with 8000 ml capacity was selected as the sealed pan.

2.3.Pressure controlling system

The pressure controlling system is to control the pressure inside the sealed pan. It comprised of a vacuum pump, a gate valve, two one-way valves, a pressure gauge and a rubber hose which is withstand under high temperature and pressure. The total length of the rubber hose of the pressure controlling system is 2 m. Fig. 2 shows how all these components are arranged into pressure controlling system.

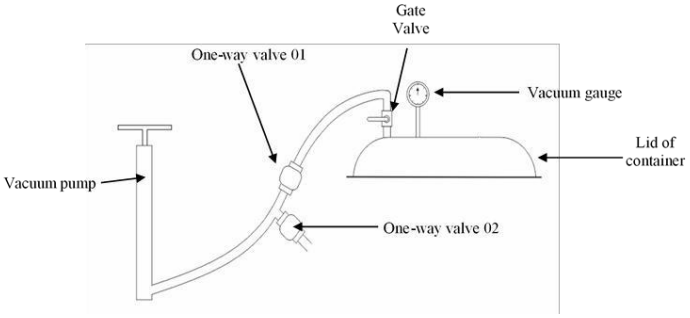

Figure 2: Arrangement of the components in Pressure

The one-way valve 01 allows to move air molecules from evaporator to vacuum pump while the pump's piston is moving up. Air molecules trapped inside the vacuum pump at the upstroke, pushed to outside during downstroke through one-way valve 02. As the pressure gauge shows the pressure inside the container, desired pressure can be achieved by operating the vacuum pump several times.

2.4.Moisture removal system

The moisture, evaporated in the process of making treacle should be continuously removed from the surrounding to facilitate the evaporation process as the pan is fully sealed. Moisture removal system was designed with transparent rubber tube, a one-way valve and a condenser. One end of the rubber tube is connected with the lid of container and other end extends to the condenser.

A one-way valve was fixed in between the container and the condenser, so that evaporated moisture is allowed to move only from container to condenser and avoid the condensed water returning back to the container due to the low pressure of it. Condenser tube is dipped in a water bath, in order to condense water vapor and prevent air entry into the container. Transparent tube was used to improve the visibility of moisture removing.

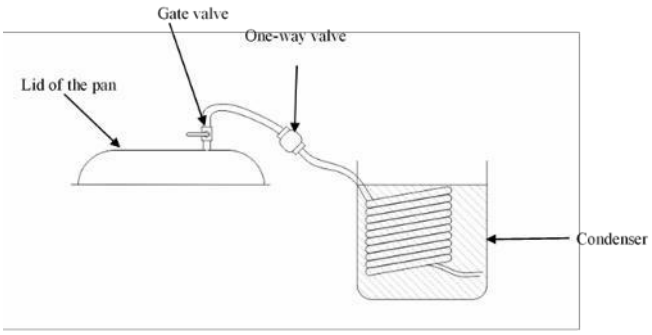

Figure 3 : Arrangement of the components in moisture removal system

2.5.Stirring system

Stirring is an essential operation of treacle production process to reduce the foam generation, uniformly distribute the heat throughout the pan and to improve the quality of treacle. The stirring system comprises of an operating handle and two aluminum spatulas. Rotatable aluminum spatulas were fitted inside the pan and the operating handle which is connected with spatulas was at the outside of the pan to stir the sap when it is required. Stirring is done by manually and it should continue after foam generation until end of the process.

The average time frequency of stirring was 12 minutes. Stirring system with the lid of the pan is shown the Fig.4.

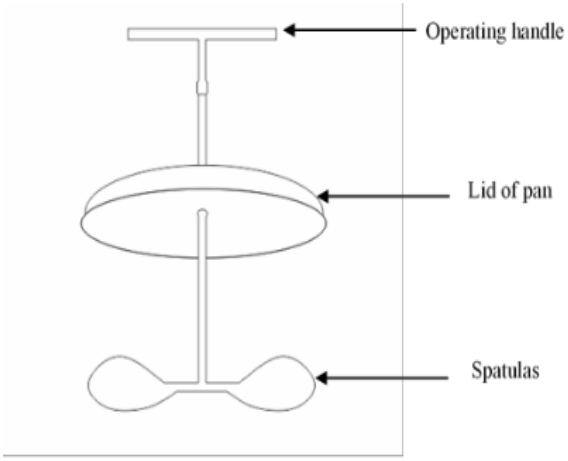

Figure 4: Stirring system

2.6.Sample observing unit

A transparent piston, cylinder device with 150 ml cylinder capacity was used as the sample observing unit. The cylinder is connected with a glass tube which extended up to the bottom of the pan so that sap can be sucked into the cylinder to visually observe the condition of sap at any moment of the preparation process. Fig. 5: shows the sample observingunit.

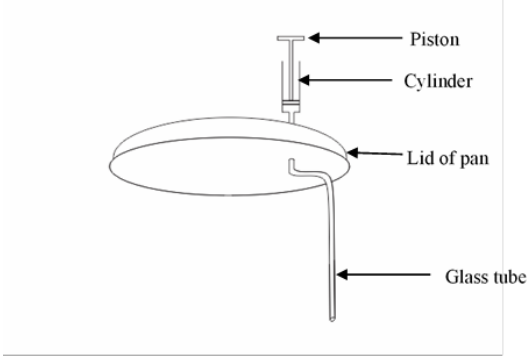

Figure 5: Sample observing unit

2.7.Preliminary test

After developing the whole system,few trails were carried out to identify practical drawbacks of the design and required modifications were done accordingly. Following procedure was used to develop the system with minimum practical problems.

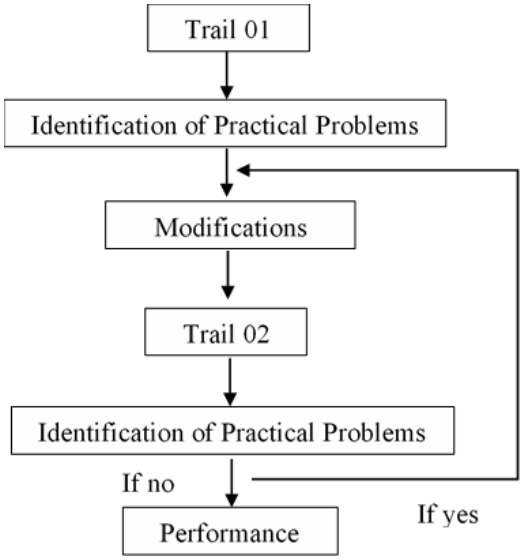

Figure 6 : Preliminary testing procedure

2.8. Performance evaluation of the device

After conducting several trials, the minimum pressure inside the pan was found as 0.2 atm. The performance of the newly developed moisture evaporation pan was compared with the traditional method. Three well experienced female labors in traditional *Kithu*l treacle production were involved in both *Kithul* treacle production methods. The newly developed pressure- controlled pan was operated under 0.2 atm (Economically achievable minimum pressure) with two fuel sources as firewood and LP gas. In the traditional *Kithul* production method, firewood and LP gas is the mostly being used fuel sources. Therefore, both, the traditional method and newly developed device were separately tested with firewood and LP gas. Three replicates were carried out for each fuel source.

Time taken to initiate the evaporation of moisture, time taken to remove the moisture and time taken to complete the entire process were recorded at each trail. As well as, amount of consumed fire wood and consumed LP gas was measured.

$$\text{Amount of consumed LP gas} = \text{Weight of the gas cylinder before starting the process} - \text{Weight of the gas cylinder after the process}$$

Collected data were analyzed using Statistical Analyzing Software (SAS). To compare this newly introduced method with the traditional method, two sample T-test was used under 95% confidence level.

3. Results and Discussion

Plate 1 shows the developed vacuum type pan evaporator for *Kithul* treacle and jaggery production. Plate 2, 3, 4 and 5 show moisture removal system, pressure controlling system, stirring system and sample observing system respectively.

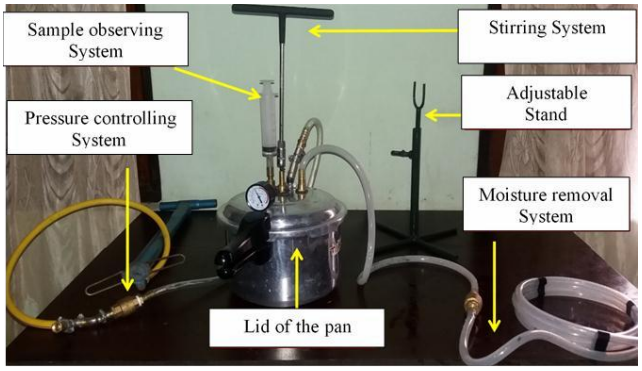

Plate 1: Developed vacuum type pan evaporator

Plate 2: Moisture removal system

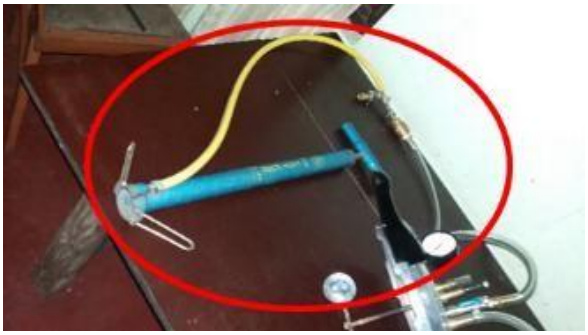

Plate 3: Pressure controlling system

Plate 4: Stirring system

Plate 5: Sample observing Unit

3.1.Specification of the developed vacuum type pan evaporator

Specifications of the vacuum type pan evaporator are shown in table 1.

Table 1: Specifications of the developed vacuum type pan evaporator

Specifications	
Capacity of the container	8 L (sap)
Total length of the pressure controlling unit	200 cm
Minimum achievable pressure inside the container	0.2 atm

In the traditional method, 6000 ml of sap is consumed to produce 750 ml of treacle. Therefore, sap to treacle conversion ratio was recorded as 8:1.

3.2.Performance evaluation of the devices

Desired pressure value was 0.2 atm and 61°C was the optimum boiling temperature of the water at aforementioned pressure.

3.3.Comparison of traditional and newly introduced method

Traditional and newly introduced methods were compared at each step of boiling with two different energy sources and three replications of each method were carried out. Results are shown in following table 2.

According to the results (Table 2), newly introduced method for *Kithul* treacle production consumes less time and fuel than the traditionalmethod.

Time saving in following parameters such as; average time taken to initiate moisture removing process, average time taken to overall moisture removing process, average time taken to complete entire process have significant different ($p<0.05$) when compared with traditional method. Average energy consumption also revealed significant ($p<0.05$) lower in new method. As the vacuum type pan evaporator can evaporate the moisture of sap under very low boiling point (61^0 C), both time and energy have been saved.

Table 2: Treacle production process with firewood as energy source from traditional and newly developed method.

Parameter	Traditional Method	Vacuum type pan evaporator	Percentage of reduction (%)
Average time taken to initiate moisture removing process (min)	11	6.5	40
Average time taken to overall moisture removing process (min)	191	138	27.7
Average time taken to complete entire process (min)	233	176	24.5
Average Fire wood Consumption	7.09 kg	5.0 kg	29.5

Table 3: Treacle production process with LP gas as an energy source from traditional and newly developed method.

Parameter	Traditional method	Vacuum type pan evaporator	Percentage of reduction (%)
Average time taken to initiate moisture removing process (min)	8.5	5.0	41
Average time taken to overall moisture removing process (min)	121	75.5	37.6
Average time taken to complete entire process (min)	150	104	30.6
Average LP gas consumption (Weight loss of gas cylinder)	625 g	435 g	30.4

With respect to the aforementioned results newly introduced method save time rather than traditional method during treacle production process. All the parameters of new method showed significant difference ($p < 0.05$) respect to the traditional method.

3.4. Comparison of firewood and LP gas

Parameters of treacle production process with newly develop method were compared with Firewood and LP gas as energy sources. Results are shown in following table 4.

Table 4: Comparison of firewood and LP gas.

Parameter	LP Gas	Firewood
Average time taken to initiate moisture removing process (min)	5	6.5
Average time taken to overall moisture removing process(min)	75.5	138
Average time taken to complete entire process (min)	104	176

Results revealed that, average time taken to overall moisture removing process and average time taken to complete entire process showed significant ($p < 0.05$) lower value with LP gas as an energy source. There is no significant difference in average time taken to initiate the moisture removing process in both sources. Treacle production process with LP gas involves saving time and labor with newly developed method. Treacle production with the newly developed method revealed best performance with LP gas, which took only 01 hour and 44 minutes to convert sap into treacle.

During the evaluation process any injury was not recorded. As well as there was no any break down during of the evaporation pan. It highlighted that newly develop device was safe for the operator and mechanisms to work properly.

4. Conclusions

This newly introduced method shows considerably low time consumption and low energy consumption compared to traditional

method. Considering the energy source LP gas was the best source of heat which saves time and labor. When it is being used with LP gas, it saves time by 30.6% and energy by 30.4%. When it is used with firewood the corresponding figures are 24.5 % and 29.5 % respectively over the traditional method. It can be concluded that, these devices can be efficiently utilized using one operator with higher efficiency with less drudgery. Since all the working mechanisms are very simple, a special skill to operate the device is not required and women also can operate this device. The total production cost of the device was LKR. 9000.00 so that an initial investment for the purchasing of device is affordable and easy. Finally, new improved device can be recommended as an effective moisture removing method in *Kithul* treacle and jaggery production.

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