Innovation of Cooking Juice in Process Production of Red-Cane Sugar in Lawang Village of Agam District

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Abstract. Cane refining activities which produce red-cane sugar has traditionally been the primary source of income in Lawang villagers of Agam district since hundred years ago. Three main weaknesses found in the process traditionally conducted are lower evaporation rate caused in longer time production and need more fuel, lower product quality caused in lower price, and flue gas pollution. Heat transfer mechanisms involved as long as evaporation takes place in traditional cooking process of juice, namely conduction, convection, and radiation, are not well evaluated yet. Meanwhile, falling film evaporation is not found and gummy cakes formed and accumulated in the surface of basket made of woven bamboo placed in the juice pot. The influence of evaporator like device made of a series of diameters of aluminium circular plates to evaporation process has been studied in traditional cane refining in Lawang village. The device was introduced to the juice pot which significantly faster evaporation process, namely reached about 45% faster then what usually run by villagers. The influences of introduction of lids of aluminium plates as well as any variation in circular plates to faster evaporation process had also been studied. It showed that the numbers of circular plates in a series and introduction of lid of aluminium plate contributed dominantly to faster evaporation process till about 56.67% faster, while the incline of circular plates in a range of 0 to 20 degree and the existence of some holes in the inner plates for circulation of juice cooking are not significantly shorten the time needed for evaporation process. It was also found in this study that falling film evaporation occurred in the evaporator like device introduced that contributed to faster evaporation process. The special channel added at the outsider of circular plate could play a role to accumulate gummy cakes formed.

1. Introduction

ASEAN free trade era compels people tobe higher in efficiency and productivity, especially villagers in West Sumatera who are economically heavily dependent on micro and small enterprises. Many micro and small enterprises in West Sumatera use traditional stove having common characteristics that are wasteful fuel, need longer time for cooking, and unhygienic in production process [1]. Renewable energy from biomass is supplied and converted by traditional open combustion, which is very inefficient, in these stoves. Generally, the thermal efficiency of these local stove is lower than about 20% [2]. As tens of thousands of these traditional stove use firewood fuel then they should contribute to deforestation impact [1]. Multi Effect Evaporator application, in order to achieve a more efficient process in the sense of energy use, is also not introduced in these local stoves [3]. While, fire protection is not implemented [4].

Cane refining activities which produce red-cane sugar in West Sumatera are centred in Agam and Tanah Datar districts. Lawang is a village (nagari) in Agam district as the centre of red-cane sugar production. Headman of Lawang village said that there were about 300 cane refinings there. Less papers had
discussed traditional red-cane sugar production. The key process in production of red-cane sugar from the juice is to vaporize water to paste phase follows by cooling the paste to form mold crystals [5]. There are four sets of pot in the stove can be found in Lawang to vaporize the juice with the height of 40, 55, 70, and 85 cm respectively. The hot flue gas flows naturally from the combustion chamber at the first pot to the fourth one. It needs more or less 5 hours for cooking cane juice to get the first pot product of caramel ready to mold to become red-cane sugar. One pot of juice (around 50 kilograms of juice per pot) gives 7 to 9 kilograms of red-cane sugar. Three modes of operation for milling sugar juice are find in this Lawang village, namely buffalo-powered mill, motor to replace buffalo power mill, and engine-powered mill with product capacity reach around 40, 60, and 120 kilograms respectively.

This paper attempted to design and construct evaporator like devices introduced to the juice pot using aluminium plate material and to evaluate their contribution to faster evaporation process, minimizes fuel need, collecting gummy cakes formed, and shortening total time work needed.

2. Methods

This study consists of four main steps, namely field survey, design, construction, and introduction evaporator like device to cane juice pot in testing cooking process innovation. The field survey was conducted in Lawang village to collect dates about existing condition on cane refining process applied by villagers for state comparison need. The evaporator like devices were designed in the form of circular plates to enhance heat transfer and evaporation area. Then, they were constructed using aluminium plates material [6]. The influences of number of circular plates in a unit introduced to the juice pot, namely 4 and 9 circular plates, on their contribution to faster evaporation process, minimizes fuel need, and shortening total time work needed were to be evaluated. The height of the circular plate is set to about 45 cm above the initial level of juice in the pot and the biggest diameter one is 56 cm. The influences of the introduction of lid made of aluminium plates as well as any variation in circular plates, namely the thickness, the inclined of plates, and the existence of some holes in inner circular plates, were also be studied. Handmade special pocket in the outer of circular plate is also introduced to collect gummy caked formed as long as cooking process takes place. Combustion and the end of cooking process were determined as usually be done by villagers in cane refining. Cooking time equal to 5 hours to get the first pot product of caramel ready to mold to become red-cane sugar was set to be state comparison. Temperatures at any position in the stove were measured by infrared-thermometer [7]. All test are conducted in the first pot.

3. Results

Simple sketches of evaporator like device are given in Figure 1. Its construction introduced to the cane juice pot compared to the existing pot without evaporator like device belong to villager is given in Figure 2. Falling film takes place in evaporator like device and contributes to evaporation process. Meanwhile, gummy cakes formed as long as cooking process were accumulated at the outsider edge of circular plate. The results of cooking test of cane juice by introducing the evaporator like devices to juice pot are given in Table 1.

![Figure 1. Sketches of Evaporator like device; (a) top and (b) side views](image-url)
Figure 2. a) Evaporator like device introduced to cane juice pot and b) the existing one

Table 1. The Results of Cooking Test of Cane Juice by Introducing Evaporator Like Device to Juice Pot

| Parameters                        | Variation in distances between plates (0.7 mm thick), cm |
|-----------------------------------|-------------------------------------------------------|
|                                   | 4          | 9          | 9          | 9          |
| Cooking time in first pot, hours  | 2.75       | 3.15       | 3.15       | 3.80       |
| Evaporation rate, liters/hour     | 15         | 12         | 12         | 9          |
| Chamber temp. °C                  | 594        | 500        | 500        | 460        |
| Cooking juice temp. °C            | 96         | 93         | 93         | 90         |
| Outer circular plate temp. °C     | 47         | 42         | 42         | 37         |
| Outer chamber wall temp. °C       | 47         | 46         | 46         | 36.5       |
| Early juice temp. °C              | 24.3       | 24.3       | 24.3       | 24.3       |
| Environment temp. °C              | 20.6       | 20.6       | 20.6       | 20.6       |

3.1 Falling Film Phenomena

Falling film phenomena seems to occur on any variation of circular plates evaporator like device introduced to cane juice. This phenomena takes place on the surface of circular plate as the boiled juice is falling down it. It makes evaporation process going faster by addition of the mechanism of evaporation [Coulson, 2005]. As long as cooking takes place, the boiled juice molecules conducts a series of recirculation by flowing upward and falling down the circular plates. This re-circulation motion of boiled juice takes place by thermosyphon effect based on natural convection [Coulson, 2005] as well as capillary action which occurs because of intermolecular forces between the liquid and surrounding solid surfaces.

In the annular between circular plates the hot molecules will move upward while the cold ones will fall down. This re-circulation will going on and boiled juice move upward through annular then falling as the film of fluid on the outer surface of plate. The molecules of water vaporizes from the boiled juice as it both flowing upward in the annular and falling down the surface of plates. The closer the the distances between plates to make annular the more rapid re-circulation of boiled juice to occur and the faster evaporation process will going on.

Ignoring any variation on others parameters, the results of cooking test in Table 1 show that evaporation rate increase significantly to 15 liters/hour as variation in distances between circular plates equal to 4 cm compare to 12 liters/hour when distances between circular plates equal to 9 cm. The increase in evaporation rate due to closer circular plates which make the smaller annular where a series of recirculation of boiled juice takes place more rapidly. This phenomena is not found in traditional cooking and it perhaps plays the main role in shortening cooking time.
In traditionally cooking juice in Lawang village, re-circulation of the boiled juice flowing upward and falling down takes place by thermosyphon effect only on the surface of a basket made of woven bamboo placed in the first pot of cane juice. There is no capillary action exist here. The villagers placed the basket in their pot to prevent the squirt of juice as it boiled as well as to trap gummy cakes formed as long as cooking process takes place to control the dirt content of product of the red cane sugar. They did not take care of falling film phenomena. As an isolation material, woven bamboo certainly obstructs falling film evaporation to occur. Conversely, cooling effect happened to the boiled juice due to contact with the surface of basket which restrained the evaporation process to occur. Then evaporation process in traditional cooking due to vaporize of water to air from the boiling juice only without contribution of any surface area addition.

3.2 Number of Circular Plates and Holes in Inner Plates
The number of circular plates for each unit of evaporator like devices used is dictated by the distances between the circular plates which were set up to 4 and 9 cm. Consequently, the number of circular plates of the two units will be difference, one consists of 9 circular plates and the other one has 5 circular plates. As cooking time more or less 5 hours was taken to be state comparison then evaporator like devices made of aluminum plate 0.7 mm thick seem to give significant contribution to shorten cooking time as it enlarge the surface area for heat transfer and evaporation as well as for a series of re-circulation of boiled juice to occur [8].

The result of cooking test in Table 1 show that cooking time for 4 cm distance between circular plates in one unit was noted to become 2.75 hours and for 9 cm distance one it was noted to 3.15 hours. Then, the reduced cooking time is within the range of 23.33 to 45%. It is clear that the first unit gives better performance as it has larger total surface area with 9 circular plates where evaporation will takes place and the other one has only 5 circular plates.

The influence of the holes exist in inner circular plates were studied for 9 mm thick plates. The existences of some holes by diameter around 1.5 cm in each inner plates were aimed to serve the juice in order to move on horizontal and radial direction between annular in inner plates and to produce agitation effect. However, it seems that they give no contribution to evaporation process and to shorten cooking time. In addition, temperature drop in chamber from 500 to 460 °C followed by slightly reduced in cooking juice temperature, namely from 93 to 90 °C and caused cooking time 40 minutes longer. It can be seen in Table 1 for evaporator like device with 9 cm distance between circular plates that it needs cooking time of 3 hours and 50 minutes, or it is still 23.33% faster than state comparison. As firing in traditional chamber is conducted manually, and using mixing of biomass fuel of bagasse, bamboo, and firewood then temperature drop is often to occur.

Measurement of low temperature on the outer chamber wall as well as on the outer circular plate showed that heat loss through wall has relatively been very small. It means that much heat losses through hot flue gas flow in traditional cooking cane juice done by villagers [1]. Meanwhile, the temperature of the outer circular plate which was only reach 47 °C indicates that the plates was only heated by heat transfer from the boiled juice.

It is seemed that the mechanism of conduction of heat transfer from the pot to the circular plates was not exist as they were not be joint mechanically and to be separated by film of fluid of juice. Suppose it is heated by mechanism of conduction from the pot, its temperature certainly will higher than the temperature of boiled juice. Then, heat will be transferred from the plate to juice and evaporation process will take place faster.

Well design and construction of integrated pot and evaporator like device will make possible heating of the plates by conduction mechanism, namely heat from the flue gas in the chamber will be transferred to the pot as well as to the circular plates connected to the pot. This will certainly increase the temperature of the plates and make evaporation process will be going faster.

The boiled cooking juice temperature which was measured to be 96 °C or less showed that surface area of evaporation served by circular plates play a role for mass transfer of molecules of water from the juice body to the air. The larger surface area of evaporation the more rapid water evaporates from the juice, and less working time needed.
Comparison of cooking time with and without introduction of circular plates evaporator like device is given in Table 2. It is clear that introduction of circular plates are very helpful to reduce working time, and consequently to save fuel need significantly. Therefore, workers can either increase their product capacity or reduce their working time.

Table 2. Comparison of Cooking Time with and without Circulate Plates Evaporator Like Device

| Capacity, pots of juice | With circular plates, time | Without circular plates, time | Reduced time work, % |
|-------------------------|---------------------------|-------------------------------|----------------------|
| 10                      | 06.00-15.00               | 06.00-18.20                   | 27.03                |
| 7                       | 07.50-15.00               | 07.50-17.00                   | 21.82                |
| 6                       | 06.00-11.30               | 06.00-14.00                   | 31.25                |

3.3 The Thick of Plate and Mode of Lid

The influences of plate thick and modes of lids to cooking parameters’ values are given in Table 3. Plate thick slightly influences the cooking parameters values; cooking time with 0.7 mm thick plate of evaporator like device is 25 minutes faster than 0.9 mm thick one. It is 33.33% faster than cooking without evaporator like device. The identical value is 25% with 0.9 mm thick plate.

Table 3. The Influences of Plate Thick and Modes of Lids to Cooking Parameters

| Parameters                  | Plate thick (9 cm plates distance), mm | Mode of lid (9 cm plates distance, 0.7 mm thick) |
|-----------------------------|----------------------------------------|-----------------------------------------------|
|                             | 0.9                                    | 0.7                                           |
|                             | Large one hole lid                     | Small many holes lid                          |
| Cooking time, hours         | 3.75                                   | 3.3                                           | 2.15                             | 2.5                             |
| Evaporation rate, liter/hour| 10                                     | 12                                            | 18                               | 16                              |
| Chamber temp. °C            | 505                                    | 500                                           | 587                             | 574                             |
| Cooking juice temp. °C      | 91                                     | 93                                            | 97                              | 92                              |
| Outest circular plate temp. °C| 44                                     | 42                                            | 68                              | 65                              |
| Outer chamber wall temp. °C | 44                                     | 46                                            | 48                              | 46                              |
| Early juice temp. °C        | 24.3                                   | 24.3                                          | 24.3                            | 24.3                            |
| Environment temp. °C        | 20.6                                   | 20.6                                          | 20.6                            | 20.6                            |

The rate of heat transfer by conduction mechanism is influenced by the thick of plate [Coulson, 2005]. This finding is in consistence with the value of cooking juice temperature, where 0.7 mm thick plate gives slightly higher temperature than 0.9 mm one, namely 93 compare to 91 °C. However, the evaporator like device made of 0.7 mm thick of plate is lighter and not comfortable in used. The villager has recommended to use heavier one mode of 0.9 mm thick of plate.

The consistence value is also due to evaporation rate, where 0.7 mm thick plate gives the value of 12 liters/hour compared to 0.9 mm thick plate which gives 10 liters/hour. Introduction of lid on the evaporator like device influence significantly the performance of device, such as on cooking time, evaporation rate, cooking juice temperature, and the temperature of the outer circular plate. However, chamber temperature for this test are around 20% higher than averages.

Large centered one hole lid introduce on evaporator like device reduces cooking time to become 2 hours and 10 minutes, or 56.67% faster than what usually run by villagers. Meanwhile, small distributed many holes lid gives lower performance than the large centered one hole lid, where the cooking time reduce only to become 2 hours and 35 minutes, or 48.33% faster compare to what usually run by villagers.

The lid on top of evaporator like device prevent heat release freely, then it was accumulated in the device. Consequently, circular plate temperature and evaporation rate increase significantly [8]. For
large centered one hole lid as an example, circular plate temperature is 68 compare to 42 °C and evaporation rate is 18 comp are to 12 liters/hour.

3.4 The Incline of Circular Plate

The influences of the inclines of circular plate to cooking parameters’ value are given in Table 4. Generally, the incline in circular plate between 0 to 200 give no influence on cooking parameters value. Evaporation rate was relatively constant in 12 liters/hour. It can also means that falling film phenomena is not influence by the incline of circular plates. Slightly higher in cooking juice temperature triggered by higher temperature chamber was not accompanied by the increase in evaporation rate or cooking time. Cooking time even slightly longer for inclined plate than the vertical one. In contrast with higher difficulty in its construction, inclined circular plate evidently gives no contribution to reduce cooking time.

Table 4. The Incline of Circular Plate to Cooking Parameter

| Parameters                  | 0° inclined (9 cm plate distances, 0.7 mm thick) | 10° inclined (9 cm plate distances, 0.7 mm thick) | 20° inclined (9 cm plate distances, 0.7 mm thick) |
|-----------------------------|-------------------------------------------------|---------------------------------------------------|--------------------------------------------------|
| Cooking time, hours         | 3.33                                            | 3.67                                              | 3.65                                             |
| Evaporation rate, liters/hour | 12                                              | 12                                               | 12                                               |
| Chamber temp. °C            | 500                                             | 555                                              | 567                                              |
| Cooking juice temp. °C      | 93                                              | 96                                               | 96                                               |
| Outer circular plate temp. °C | 42                                              | 46                                               | 46                                               |
| Outer chamber wall temp. °C | 46                                              | 47                                               | 47                                               |
| Early juice temp. °C        | 24.3                                            | 24.3                                             | 24.3                                             |
| Environment temp. °C        | 20.6                                            | 20.6                                             | 20.6                                             |

3.5 Special Pocket to Collect Gummy Cakes Formed

Gummy cakes from organics and mineral contents formed in boiled juice occur as long as cooking process takes place. Replacing the basket made of bamboo by evaporator like device made of aluminum plates give impact on the increase of dirt content on product of red-cane sugar which reaches 7% or higher. The aluminum circular plates did not play role to trap the gummy cakes as could be done by basket made of woven bamboo. To collect the gummy cakes the evaporator like device needs to be equipped with special pocket.

So, the special aluminum pocket was placed around the circular plate to collect the gummy cakes formed has also been introduced in this evaporator like device. It should give the result as good as traditional cook used a basket made of bamboo except its construction is not qualified. Unfortunately, as handmade special pocket is not qualified in construction then the dirt content of red-cane sugar product found in this study is not less than about 5.4%. However, this device make the cooking process more comfortable as the worker is not used to collect the gummy cakes many times as long as the cooking process take place.

Indeed, the dirt content of high quality product of red-cane sugar is lower than 3%. It certainly needs some treatment to achieve this standard, namely to clean the cane from sand, dust, and others dirt sources and to filter cane juice before cooking. Unfortunelly vilagers is commonly not interest to do such treatment.
4. Conclusion

Innovation of cooking juice in process production of red-cane sugar in Lawang Agam district has been conducted by introducing evaporator like device made of aluminium plates in the first pot of stove. Falling film phenomena occur on any variation tested in this study and contributes to make faster the cooking process, to save fuel need, and to shorten total time work needed. Circular plate evaporator like device equipped with lid made of 0.7 mm thick aluminium plate introduced to the juice pot has successfully reduced cooking time till 56.67% faster than what had usually run by cane refinery workers in Lawang village. The distances between circular plates in one unit, and consequently numbers of circular plates in one unit, contribute significantly in reducing cooking time, namely 4 cm distance between circular plates reduces cooking time up to 45% and 9 cm one reduce 23.33%. The thick of aluminium plate gives difference results in reducing cooking time, namely 25% for 0.9 mm thick and 33.3% for 0.7 mm one. However, some holes made on the inner circular plates and the incline of circular plates give no contribution to shorten cooking time. Gummy cake formed as long as cooking process take place can be collected in special channel in the device to make the cooking process more comfortable.

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