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Appropriate technology application of traditional clove oil production: effort to upgrade quality

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KEYWORDS

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Clove oil
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ABSTRACT

In East Java, the production of clove leaf oil refinement is developed by businesses owned by rural people. The processing operation is simple and start-up investment is low. The clove leaf oil manufacturing procedure uses old leaves that fall naturally in the dry season, these are found to be better preserved, mature and environmentally friendly. East Java rural distillers use a single boiler for steam, water and raw materials in order for the investment costs to remain low. This study aimed to research the use of appropriate technology for the clove leaf distillation process and how to increase clove oil both in yield and quality. Two different tests were conducted; introducing a leaf crusher as a raw material and replace the old chamber material with stainless steel. There are three grades of raw materials; rough leaves, smooth leaves, and non-crushed leaves. After the clove leaves were crushed, they are distilled in the new stainless steel boiler with an aim to compare the oil yield and quality. The result from the crushed leaves treatment indicates there are different volume condensates produced from the same volume of raw materials, 128.2 litres from smooth grade and 117.2 litres from rough grade leaves. The highest percentage of clove oil (15.07%) results from rough grade crushed leaves. By replacing the chamber material with stainless steel positively affects the brightness of the clove oil. In conclusion, these two tests, to improve appropriate technology for clove oil production, can increase both yield and oil brightness, and subsequently improve the competitive advantage and future aspiration of the product.

Introduction

Clove (*Syzgium aromaticum* L.) is an aromatic plant from the Myrtaceae plant family. Clove trees can grow between ten and twenty metres tall with large oval leaves and red flowers. The colour of the bud is pale and gradually turns to green; the bud becomes red once it has blossomed. Clove is ready for harvest once it is between 1.5 to 2 cm (Hussain et al., 2017). The main material of clove oil production in small enterprises are dry leaves that fall naturally when the dry season period occurs around clove trees. This raw material is available for only 6 months in a year. In the Ponorogo Regency, clove leaves are abundant during dry season but decrease drastically in the rainy season (Arizona and Lamusa., 2016). Consequently, distillers gather as many clove leaves as possible and store them carefully to be used for production when the rainy season arrives. In the rainy season, only a few of the distillers exist, who produce oil, due to a lack of supply of clove leaves.

In the Ponorogo Regency, traditional clove leaf production is considered environmentally friendly. According to Thomas and Dhueti (2001) To maintain environmental ecosystems such as forests or plantations, there is a need for efforts from the surrounding community. In spite of the cheap price raw material, it does not cause any damage to the tree nor to the clove bud production rate. The community can utilize agricultural or plantation products while at the same time preserving forests or gardens by replanting trees around them. From the plantation it can produce fruit, wood and leaves (McGinley and Finnegan,

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2003). Furthermore, this production process does not produce unsafe wastewater that can negatively affect the environment. As a traditional production method, distillers only operate when the raw material is available naturally. There is no enforcement to achieve a particular target for production rate. Although it produces solid waste, distillers utilize this solid waste as both a wood stove material and a fertilizer. Therefore, it can be concluded that the traditional clove leaves distillation is a sustainable production system. Sustainability is maintaining or improving the material and social conditions for human health and the environment over time without exceeding the ecological capabilities that support them (Sikdar, 2003) and sustainability metrics that are quantifiable and applicable to a specific process i.e. material intensity (non-renewable resources of raw materials, solvents/unit mass of products), energy intensity (non-renewable energy/unit mass of products), potential environmental impact (pollutants and potential chemical risk (toxic emissions/unit mass of products) (Demirel, 2004; 2006; 2013). Clove leaves yield approximately 1 to 4% and contain between 70% to 80% of eugenol (Mittal et al., 2014). As the clove oil price depends on the amount of eugenol present in the clove leaf, this clove oil from the Ngebel regency is regarded as expensive. There are 3 types of essential oils that can be produced from the clove tree namely clove flower oil, clove twig oil and clove leaf oil. Each of them has a distinctive flavor and chemical composition. Genetics, climate, soil and cultivation techniques affect some secondary substances like essential oil (Tsusaka et al., 2017).

An essential oil is defined as the product obtained by hydro distillation, steam distillation, dry distillation or by a suitable mechanical process without the heating of a plant or some parts of it (Miguel, 2010). A high level of eugenol present in essential oil indicates strong biological activity as well as anti-microbial activity (Marchese et al., 2019; Panchevska et al., 2017).

As an effort to increase distillation yield, crushing is required in the small enterprises distillation process, reason being that in the existing distillation the leaves are put directly into the kettle without pre-treatment. Crushing allows the evaporation of essential oils located in the oil gland between cells in order to evaporate more easily. As a research conducted by Talati (2017), over the years a number of machines have been designed to either crush the peel of a citrus fruit or crush the whole fruit and then separate the oil from the juice and The term expression refers to any physical process in which the essential oil glands in the peel are crushed or broken to release the oil. Furthermore, crushing also reduces the size and volume of the leaves in the distillation chamber so there is more space in the upper part of the kettle. When the distillation chamber reaches its maximum capacity of raw materials, the oil distillation process is unable to fully function. In the previous study using clove buds, extraction result increases by crushing the buds or reducing the size of a particle. The oil distillation process produces higher amounts of oil when buds are crushed (Mostafa et al., 2004; Reverchon and Marrone, 1997). However, the eugenol content in clove oil also increases along with the particle size. Hence, one should take the size of the particle into account in extracting any materials that evaporate very easily and to avoid impurities such as chopped ash and dust (Guan et al., 2007).

This study aims to research the use of appropriate technology in the clove leaves distillation process to increase clove oil both in yield between three grades materials (rough, smooth, and non-crushed) and effect of oil quality (eugenol and brightness) between iron boiler and stainless steel boiler to improve appropriate technology for Small and Medium Enterprise (SME) clove oil production can increase both yield and oil brightness, and subsequently improve the competitive advantage and future aspiration of the product

Research Methods

The research was divided into three steps, i.e. crushing step, distillation process, and identifies the oil quality. The materials used in crushing step were crusher which has comb shape blade and powered by diesel engine 7 HP, three pulley (1000 rpm, 1600 rpm, 1900 rpm), and Galvanized Square Mesh (10x10). The rough leaves could not pass through the sieves whereas the smooth leaves could pass through thesieves, shown in Figure 1. Each treatment of crushing was 3 times repetition.

The second step was the distillation process. The materials were 500 kg of dry clove leaves, distillation and condensation unit. The three grades of crushing included rough leaves, smooth leaves, and non-crushed leaves and were distilled in the different batch process. It also requires 350 litres of water during a five hour period. The distillation unit is built from stainless steel with an aim to monitor the oil quality. The first stage of condensation flows out after 20 minutes. In this study, the measurements are conducted five times over a five hour period, i.e. every hour. The overall distillation time of one batch was completed in 5 hours.

(a) (b)

Figure 1. a. Smooth aggregate leaves, b. Rough aggregate Leaves

The third step was identified the oil quality (i.e. eugenol and brightness) by comparing an iron boiler and a stainless steel boiler. Each testing was 3 times repetition.

Results and Discussion

Crushing Yield

The speed of the pulley directly affects the crushing productivity and the size of the leaves. The crusher runs for 5 minutes at each speed of the pulley i.e. 1000 rpm, 1600 rpm, 1900 rpm. The three levels of treatment of crushing operation result in different crushing yields as shown in Figure 2. The highest percentage of smooth crushed leaves (50.06 %) is obtained from 1000 rpm operation, whilst the highest percentage of rough crushed leaves (37.66 %) is obtained from 1900 rpm operation.

The process of leaf crushing aims to open tissue culture to make it easier for oil to flow when distilled in the boiler. The lower rotating operation produces the higher amounts of smooth crushed leaves, otherwise used for rough crushed leaves. It is because the lower rotating operation allows the leaves a longer detention time in the crusher chamber. The intensity of blades cutting the leaves is increased when they spend longer in the crusher chamber. Downsizing by applying mechanical forces to reduce the size of commodity aims to produce an easier processing of products. It is much easier to control processes such as sterilization, dehydration, or freezing in sorted food units, and they are also better suited to mechanized operations such as size reduction, pitting, or peeling (Grandison, 2011). A higher operating speed produces a faster speed for the leaves to pass the chamber. It signifies that there is only low intensity for the blades to cut the clove leaves, hence 1900 rpm operations result in the highest rough crushed leaves.

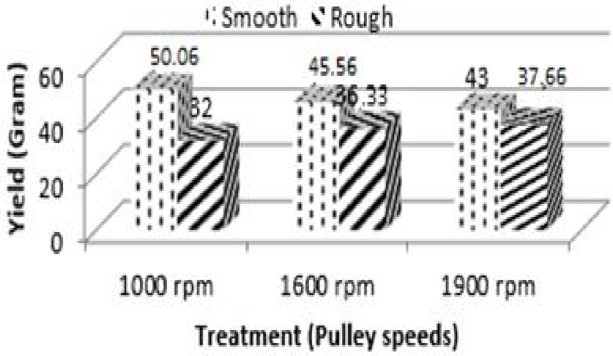

Figure 2. Crushing yield

Product Losses

During the process of crushing, the product loss occurs due to an open section whereby the leaves flow out. The average figures of product loss from three speeds replicating measurement is shown in Figure 3. The highest product loss occurs at 1900 rpm operation and the lowest product loss occurs at 1000 rpm.

The product loss occurs as a side effect of the crusher operation when downsizing clove leaf commodities (Figure 3). The product loss percentage is caused by several factors, including the gap between the hopper and the blade, turbulence force inside the machine chamber and inappropriate raw material conditions. These factors cause some crushed leaves to flow out from the crusher chamber and not into the provided storage. As a result of the high percentage of product loss, the crusher needs to be improved to minimize this impact. For increasing crusher performance, (Harwood and Ramon, 2000) there is a proposal using a metal hammer and grating with small holes to achieve higher yields.

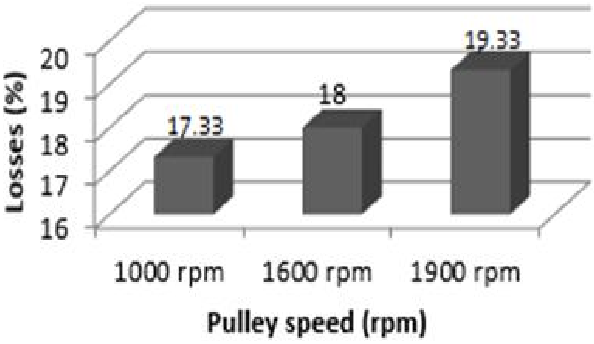

Figure 3. Product losses

Condensate

The three treatments of raw material of non-crushed, smooth crushed and rough crushed clove leaves are distilled in different batch processes. The condensate, as a result of the water and steam distillation method, is a mixture of oil and water which flows out from the condenser. The condensate is collected and measured every hour during a whole process of a five hour period. Figure 4 shows the measurement results of the hourly condensate volume.

The effectiveness of leaf crushing is known by compare the respective yield of each leaf size grade. The measurement of yield is done by collected condensate at the end of the condensation pipe. The condensate is a mixture between water and clove oil as the product. It occurs as evaporation that changes the phase of a substance (Catrawedarma, 2008). In this case, condensation is the changing of a substance from steam into a liquid or the opposite of evaporation process. Each batch distillation process takes 5 hours. Every hour the condensate is collected and measured to find the volume, as per data shown in Figure 4. The essential oil of the plant will be effective extracted at a boiling point as high as 200°C (Dean, 2014). However, the oil vapour is produced closer to 100°C to avoid a low essential oil quality , which can be caused by structure damage, and the distillation is performed at a temperature below the essential oil boiling point.

The amounts of condensate which flows out each hour determines the overall yield of distillation. Yield of clove oil, in percentage, is a comparison between condensate mass and the total mass of plants or parts of plants being distilled (Al Hilphy, 2015).

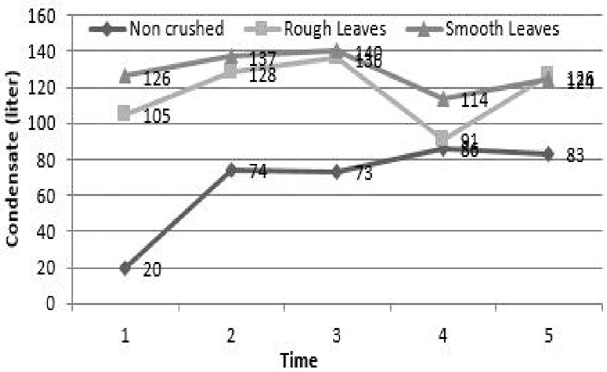

Figure 4. Condensate

Oil Yield

Based on the condensate results, the oil yield can be used to evaluate the raw materials grade and which leaf size produces the highest oil yield. The highest percentage is 33.4% for rough crushed leaves on the third hour. Figure 5 shows the oil yield collected every hour during the 5 hour distillation process.

In this study, the treatments are of three different grades of crushed leaves and the hourly condensates shown in Figure 5. The highest result is obtained from the rough crushed leaves, while the non-crushed leaves show the lowest results compared to the smooth crushed leaves. This illustrates that in the distillation process there is a tendency that smaller clove leaves will produce higher essential oil. Based on Harunsyah and Yunus (2012) the essential oil of an aromatic plant is surrounded by oil glands or granular hair, hence crushed clove leaves oil is easier to evaporate and extract. Actually, essential oil can be extracted from an unbroken plant partly due to hydro fusion, but the process requires more time due to the stronger barrier for oil to evaporate. As a result, non-crushed leaves produce a lower oil output compared to smooth and rough crushed leaves. Moreover, smooth crushed leaves do not produce the largest amount of oil because they are too small and there is a powder like substance which makes it difficult to mix with water creating a blocking effect to produce oil.

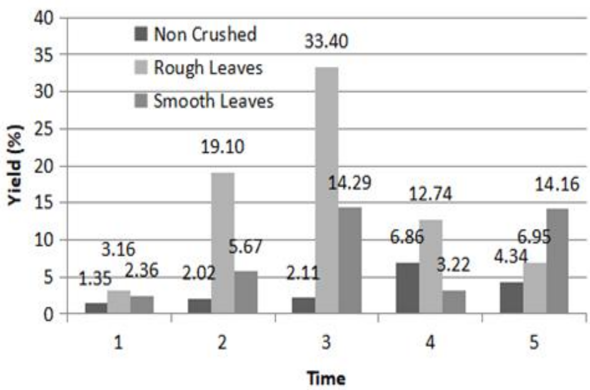

Figure 5. Oil yield

Brightness and Eugenol of Clove Leaf Oil

The brightness of clove oil distilled using the stainless steel boiler depicts the achieved aims of replace the old iron boiler with a new stainless steel boiler. The stainless-steel boiler produces clove leaf oil brighter than leaves distilled using the iron boiler. Table 1 shows clove oil brightness produced using stainless steel at 0.090A, meaning it is brighter than 0.130A. The stainless steel boiler produces clearer oil because it is non-corrosive which does not contaminate the clove oil.

Table 1. Cloves leaf characteristics

	Iron Boiler	Stainless Steel Boiler
Brightness	0.130A	0.090A
Eugenol	78.25%	77.08%

Furthermore, iron is corrosive and soluble in clove oil, hence becomes a contaminant, making it turbid. Figure 6 shows the different colour of the oils produced, the dark oils are distilled using the iron boiler and the clear oil is produced by the stainless steel boiler. Eugenol (4-allyl-2-methoxyphenol) is an important major constituent of clove oil that is usually present is about 90%-95% (Kamatou et al., 2012).

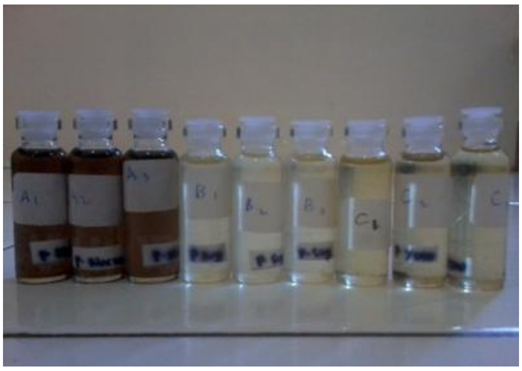

Figure 6. Sample of clove oils

The dark brown oil indicates there is a soluble rust in the oil. As eugenol is easy to evaporate, it has a disadvantage for distilling small chopped leaves because it allows the weight compounds, such as chopped ash and dust, to disturb the distillation process (Guan et al., 2007). In this study, eugenol components are not affected by the crushing leaves or the stainless steel boiler.

Conclusion

Rough grade could increase the clove oil yields. It reaches the highest yield of 15.07% during the five hour distillation process, whilst the yield from non-crushed leaves is significantly lower at 3.33%. The stainlesssteel boiler produces brighter clove leaf oil compared to oil distilled using the iron boiler. In conclusion, these two different tests to improve appropriate technology for clove oil production can increase both the yield and oil brightness. Furthermore, it can improve the competitive advantages and future outlook of the product.

Conflict of interest

Authors declare that there is no conflict of interest.

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