Smart Sensor Based Distillation For Fractionating Citronella Oil: Current Research Challenges

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Abstract. Citronella oil is one of the essential oils derived from the leaves and stem of lemongrass (*Cymbopogon nardus*). At present, most of the lemongrass oil industry in Indonesia is still in the form of upstream industries which only provide crude purified oils with low purity for export with a fairly low sales value. Technology in improving the purity of citronella oil needs innovation in following the development of the industrial revolution 4.0. This article presents an overview of the research opportunities in the development of distillation for fractionating citronella oil referring to automatically of optimization processes in the vacuum fractional distillation accompanied by inspect the quality of essential oil isolation where run in the line process based on smart sensors integrated in a computer program. The combination technique of quality control of essential oils in line process system which combined with the optimization technique of the vacuum fractional distillation process has not been studied by advanced researchers. Therefore, this study has a state of the art in process engineering and smart sensor-based quality control systems that can be developed for strengthen the Indonesian citronella oil industry.

Key words: Citronella Oil, Fractional Distillation, Smart Sensor

1. Introduction and Literature Review

The quality of essential oils, especially citronella oil, is determined by the purity factor. Currently, most of the citronella oil industry in Indonesia is still in the form of upstream industries which only provide crude purified oils with low purity for export with a fairly low sale value. The quality of citronella oil is determined by the main components in it, namely the content of citronellal, geraniol and citronellol [1].

The citronella oil processing industry in Indonesia is not new, but recently the problem of productivity and quality is still a challenge that needs to be resolved. Distillation of citronella oil by farmers still uses simple technology or traditional equipment so that the essential oil produced is poor in both productivity and quality [1].

The active component of citronella oil can be obtained through the fractional distillation method. Redistilation can increase purity, then distillate is collected when the temperature changes. Research on the process of fractionation distillation has been widely developed such as fractionation distillation for citronellal isolation by pressure reduction distillation methods[2] [3].

Optimization of the vacuum fractionation distillation process through determination of the reflux ratio and digital instrumentation [3] [4] [5]. To simplify the vacuum fractional distillation process of essential oil, a pressure and temperature control system is carried out using a Programmable Logic

Controller (PLC) and through a computer equipped with Winpro-ladder software with the aim that the system can work automatically [6]. However, the analysis of active component fractions of citronella oil has been operated outside the system. It was analyzed (both separate and combined) by using a gas chromatography-mass spectrometry /GC-MS tool and refractometer [3] [7], FTIR and GCMS [8], NIRs spectra [9], low field NMR and GCMS [10]. Furthermore, studies which have been developed in the process of refining essential oil have not fully worked on an automated system and have not utilized information and communication technology.

Although laboratory analysis tools are able to meet the utilities of the characterization of essential oil products, they have weaknesses both economically and operating conditions. Some of the disadvantages of using laboratory equipment include high costs, time-consuming, not user friendly, immobility, and the results of the analysis are not real time.

Non-laboratory analysis of essential oils has been developed by several researchers. The voltammetric method for determining the main constituent elements of Carlina acaulis L. essential oil [11] as the best results were obtained using a boron-doped diamond electrode (BDDE). Electronic nose method for classification of essential oil compositions [12] that an electronic nose (EN) system was designed based on metal oxide semiconductor (MOS) sensors, and trained to identify the categories to which samples of essential oils could be classified. The EN can be used for classification of essential oil composition in Rosa damascena Mill. An error-correcting output codes (ECOC) classifier as a multi class model for support vector machines (SVM) was considered and the classification accuracy was increased to 99%.

There are many challenges pertaining to distillation process of fractionation of citronella oil from farmers of Indonesia. The requirement of essential oil farmers in the future, to improve the quality of essential oils through fractionation distillation, needs technology support both process optimization and inspect quality control that is fast method, easy, low-cost and real time. Moreover, they can produce citronella oil products not only meet with Indonesian National Standards (SNI) but also achieve export quality products. The next section presents a comprehensive analysis of challenges to isolate the citronella oil which more purity as a single component and the research opportunities in smart sensor based distillation for Fractionating Citronella Oil for strengthening it.

2. Current Research Challenges in Smart Sensor Based Distillation For Fractionating Citronella Oil

Along with the requirement of the development of the industrial revolution 4.0 which will run now, it is necessary to breakthrough technological innovation combined with the use of information technology based on the internet of things and sensor systems as control of the production process. Current sensor technology trends have shifted towards Integrated Circuit sensors in the form of micro systems, smart sensors, nano sensors, and others [13].

Sensors for the automation of a process have been widely used so that analytical instruments become more in-line, allowing the operation of appropriate process automation. Industry can integrate smart instruments into the automation system [14]. Smart sensor can be made by combining a sensor, an analogue interface circuit, an analogue to digital converter (ADC) and a bus interface in one housing. Whereas, to make an integrated smart sensor need important elements per node among them : one or more sensors, amplifiers, a chopper and multiplexers, an AD converter, buffers, a bus interface, addresses, and control and power management [15]. Smart sensor is a basic sensing element with embedded intelligence. Sensor signals are fed to the microprocessor, which processes data and provides informative output to external users [16]. The study of process and quality control in smart sensor system based citronella oil fractionation distillation is supported by 4 main studies, namely the essential oil isolation process, process control, quality control, and sensor systems. Nested relationship between these four factors are shown in Figure 1.
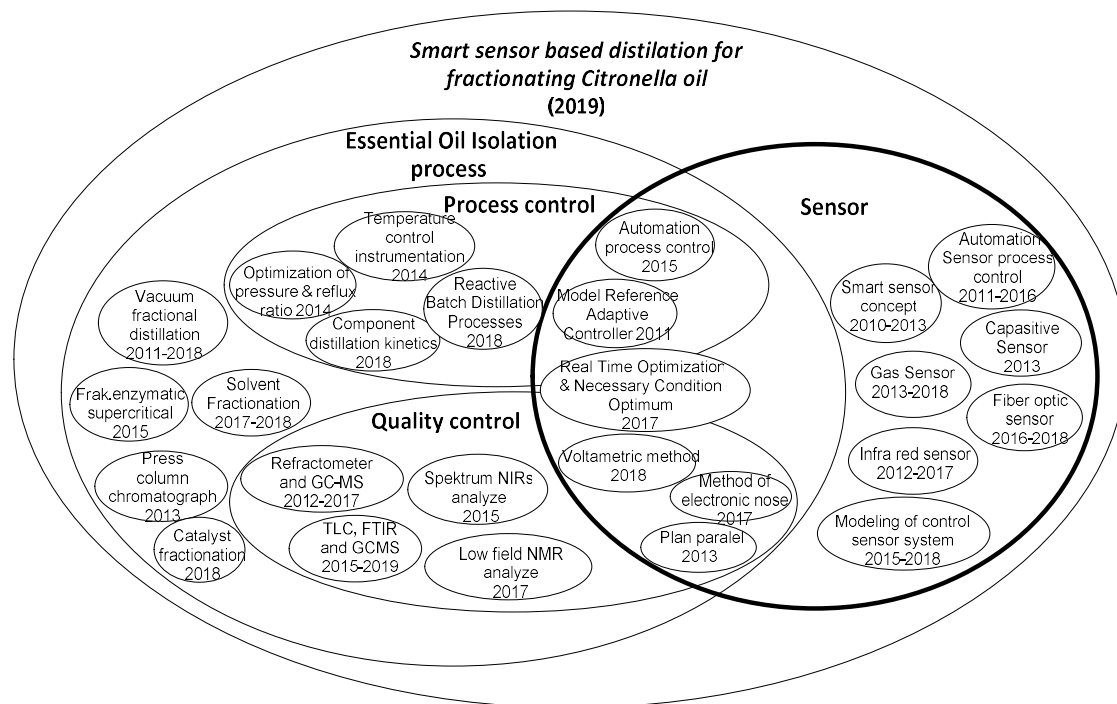
Figure 1. Nested relationship of factors smart sensor based distillation for fractionating citronella oil

The sensor system can be used to support a condition of the process of refining essential oils. Efforts to simplify the method of characterizing citronella oil have been carried out by previous researchers through NIRs, which are based on the results of molecular vibrations. Characteristics of fragrant citronella oil NIRs around the wave number 4540 cm-1. The second derivative signal from the transreflectance spectrum is related to the content of a compound [9]. In addition, efforts to determine the content of essential oil chemical compounds can be done with a gas sensor or known as an electronic nose to analyze odor patterns, which are designed based on metal oxide semiconductor (MOS) which is very potential for use in the industry [12]. Authenticity analysis of citrus essential oils by combination of HPLC-UV-MS on oxygenated heterocyclic components [17].

Intelligent sensor-based process control methods and approaches that also study the use of sensors for the characterization of essential oils and how to interpret data that can be computerized based on Comparison and Ranking of studies that have been conducted by previous researchers. The selection of adaptive infrared sensors in the optimization process of oleic acid esterification with glycerol in real time with the optimization of the esterification process using self-optimization (SO) was developed with a classification process combined with Necessary Condition Optimum (NCO) as an adaptive gradient selection, supported by a medium scale laboratory long-wave infrared (IR-intermediate) sensors, and measuring system optimization indicators proposed in the batch process. Business Process Modelling and Notation (BPMN 2.0) was built to describe SO work flow tasks in collaboration with NCO as an abstraction for the conceptual phase. Next, Stateflow modeling was deployed to simulate three gradient-based adaptive control states combined with support vector machine classification (SVM) and Arduino microcontrollers for implementation [18]. Combination of patchouli-fluorescence oil transmittance imaging system. This system consists of fluorescence-induced front ultraviolet light (365 nm) and a white LED-based backlighting imaging system that successively captures fluorescence and oil transmittance characteristics in the visible region. From the images

taken, features are extracted and analyzed using Principle Component Analysis (PCA) to identify important image features for origin discrimination [19][20].

Data mining techniques on the classification of essential oils using 6 different algorithms for classification (Decision Tree, Random Forest, Nearest Neighbors algorithm, Support Vector Machines, Neural Network and Naïve Bayes classifier), then the results of essential oils are grouped into 4 classes. The most successful classification is obtained by using the Decision Tree algorithm. This result can be used to support decision making in the production of Juniper berry essential oils [21].

Based on review that has been carried out in the present condition, the study of vacuum fractional distillation of citronella oil has a research gap that has not yet filled by previous researchers, namely in the process control slot accompanied by quality testing in line (real time) using a smart sensor system, that is, the sensor system which is assembled in addition to controlling the operation of the process automatically can also provide information on the quality of essential oils that are produced in real time. The automatic system of essential oil fractionation distillation process has the potential to be able to increase the productivity of citronella oil efficiently and environmentally friendly, the application of smart sensor systems that support process performance can be informative in facilitating process control and the quality of citronella oil produced. Therefore, that the strengthening of local resource-based agro-industry can be realized through process technology innovations development.

3. Conclusions

The low quality of citronella oil produced in Indonesia is a major problem that has not been resolved to date. Most of the essential oil processing technology still uses simple technology and limited production capacity so that it needs to strengthen agro-industry through technological innovations that can increase the productivity of citronella oil produced by farmers and increase the purity of its constituent components. Along with the development of the 4.0 revolution the strengthening of the agro-industrial sector needs to take advantage of information and communication technology in order that the role of technological innovation that is developed not only optimizes the production process but also utilizes modern technology by involving the internet of things and sensor systems. The challenge of the current research is how to optimize the process of fractionation distillation in producing fractions of the components that make up the purer citronella oil. Furthermore, the ideal smart sensor system model design so that the process conditions able to run automatically and be able to provide quality data information in real time by referring to methods that are easy, fast, and low in cost.

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