UNIVERSITI TEKNOLOGI MARA

STEAM TEMPERATURE CONTROL OF HYDRO-STEAM DISTILLATION PROCESS USING SELF-TUNING FUZZY FRACTIONAL-ORDER PI CONTROLLER

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

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ABSTRACT

Essential oil is the volatile extracts of botanical material and it is being used to promote health and human well-being because of its therapeutic effect. Essential oil is commercially extracted using distillation method which requires heat in order to break the oil glands during the process. Unfortunately, the oil quality obtained using this method is uncertain because chemical compounds in the oil are exposed to decomposition or transformation at high temperature. Hence, this research proposed a novel approach of closed-loop temperature control using a new self-tuning fuzzy fractional-order PI (FOPI) controller to realize low temperature essential oil extraction for a hydro-steam distillation process. The controller will regulate the steam temperature at a desired level to protect the oil from excessive heat. FOPI control technique is still at its infancy but the efficiency of the controller had been acknowledged by many researchers globally. FOPI controller is a generalized form of PI controller whereby it provides more degree of freedom that can guarantee better performances relative to the integer-order PI with the same controller parameters. Unfortunately, this characteristic leads to a more complex tuning methodology. Self-tuning capability of fuzzy rules was found to facilitate this issue satisfactorily using only information about the output error and rate of the output error. The control performances were evaluated on a hydro-steam distillation process under set point change and load disturbance tests. The proposed controller was found to produce less overshoot and better steady-state response under both conditions compared to PI, FOPI, self-tuning fuzzy PI, and self-tuning PID pole-placement controllers. Essential oil quality assessment was also performed on citronella oil samples that were extracted at 85°C and 100 °C. Some differences had been observed in the sample extracted at lower temperature which produced lower refractive index and lower composition in citronellal but higher composition in citronellol and geraniol based on Gas chromatography – Mass spectrometry (GC-MS) analysis. This results show that the improvement proposed in this research is feasible towards improving the quality of essential oil extracted using hydro-steam distillation process.

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May my humble findings be a contribution to community.

CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND OF STUDIES

Essential oils are complex mixtures of volatile substances mainly derived from aromatic plants. They are primarily used in flavor, fragrance, food, cosmetics, perfumery, toiletry and pharmaceutical industries [1][2]. Unlike fixed oils, essential oils are volatile and blessed with therapeutic effects originated from the presence of chemical constituents such as hydrocarbons, alcohols, acids, and esters. The properties of essential oil are unique and can be distinguished by the composition of these chemical constituents.

The composition of chemical constituents present in essential oil can be affected by many external factors such as cultivation, region, altitude where the plant was grown, and time of harvest [3]. Moreover, temperature during the extraction process also has important impact and was identified as the major influence on the essential oil quality [4]–[7]. This is due to the fact that temperature can alter the composition of essential oil because most of chemical constituents are unstable at high temperature. Hence, to obtain the best quality of oil, essential oil extraction must be done at lower temperature which is normally less than 100°C [8], [9].

Quality of essential oil can be determined based on its chemical compositions. Even though essential oils have great number of chemical compounds, only few are considered as major compounds which were important during quality inspection [10]. Standards quality criterions for commercial essential oils had been established and are governed by international and national standard authorities such as British Standard (BS), International Standards Organization (ISO), Essential Oil Association of USA (EOA), and Food Chemicals Codex (FCC) and must be abide by commercial essential oil producers.

Generally, essential oil was extracted using distillation method. There are varieties of distillation methods available, but the most common methods used in the industries are hydro distillation, hydro-steam distillation and steam distillation. Distillation process separates the chemical constituents according to its boiling point