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Fractional-Order Based Control Strategies for Essential Oil Extraction Process

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Abstract

Essential oil extraction through steam distillation is widely recognized as a preferred technique in the industry due to its practicality and cost-effectiveness. Despite its advantages, the high process temperatures associated with distillation can lead to the formation of unwanted chemical compositions in the essential oils. To address this challenge, significant research has been directed towards developing advanced control techniques to enhance the extraction process by means of regulating the operational temperature. Traditional PID controllers are often used, but it has limitations, prompting to the exploration of more sophisticated methods such as advanced PID, Fuzzy-based controller, and Model Predictive Control (MPC). This paper delves into the potential of various fractional-order based controllers, including fractional-order PID (FOPID), Internal Model PID Controller with Fractional-order filter (IMC-PID FOF), and CRONE towards improving the control performance. Evaluations based on output response, control signal behaviours in response to step inputs, setpoint changes, and disturbance tests indicate that IMC-PID-FOF achieves the best control performance across all test conditions, followed by CRONE-2 and FOPID. The yield from C. nardus extracted under controlled steam temperature at 85°C had shown some alterations from the uncontrolled condition in terms of colour, refractive index and major chemical compounds. However, the composition is greater than the range stipulated by the standard ISO 3849:2003.

1. Introduction

Commercialized volatile substances that are obtained from aromatic plants can be divided into essential oil, concretes, resinoids, absolutes, and pomades [1]. These substances are naturally synthesized in one or more parts of the plants such as in flowers, leaves, barks, roots and seeds. Essential oil is a complex mixture of hydrocarbons, oxygenated compounds and waxes [2]. Among all, the oxygenated compounds are the principal constituents that give distinctive odour to the plants.

Essential oil can be found in oil form at room temperature but it is different in both chemical and physical properties from fixed oil. Essential oil is volatile and has high refractive index (more than 1). It is soluble in ether, alcohol, and organic solvent [3]. Essential oil is colorless or lightly colored but they become darker when exposed to air or light. Its quality can be deteriorated by heat, oxygen or moisture and hence, it should be stored in a cool and dry place in a tightly closed amber container. Essential oils are used in wide applications especially in consumer goods, pharmaceutical, perfumery and even insecticides. Although they contained lots of chemical compounds, the one that provide the distinctive features of the oil are generally composed of only one or two major compounds. An example of aromatic grass is Cymbopogon genus which comprises of about 180 species. They are rich in geraniol, geranyl acetate, citral, citronellal, and citronellol which are used commonly in pharmaceutical and household products [4].

Almost every component of essential oils has been shown to be unstable at high temperatures. There is an abundance of research available that discusses how temperature affects the extraction rate, kinetics, and quality of the extracted oil wherein all of which are impacted by the chemical contents recovered during the process [5-7]. Essential oils are commonly acquired using extraction methods which can be classified generally into expression, distillation, enfluerage, and solvent extraction. Distillation is the most common method in essential oil production [8] where the essential oil was released from raw material using substantial amount of heat.

Theoretically, hydro-steam distillation is better than hydro distillation but, this technique is often referred to as hydro distillation. A comparative study was conducted by Perović et al. [9] for lavender oil extraction. The study concluded that, hydro-steam distillation technique produced higher oil yield with greater ester content compared to steam distillation.

The advanced extraction techniques such as Supercritical fluid extraction (SFE)[8] and accelerated solvent extraction (ASE) have the advantages in terms of yield volume and faster kinetic compared to traditional methods. The innovation was done to provide rapid cell rupture at low temperature with minimal interface with water to prevent hydrolysis. However, these extraction methods are very costly compared to distillation. A comprehensive review on the essential oil extraction technique can be referred in [10].

Hence, research on advanced control technique to facilitate low temperature extraction using distillation method is really necessary. Kasuan et al. [11] applied Fuzzy Model Reference Learning Control (FMRLC) technique on a hydro-steam distillation process to regulate steam temperature at 85ºC during the extraction process. Muhammad et al. performed the same task but using hybrid fuzzy-PD plus PID and Model Predictive Control (MPC) [12] on an induction-based hydro-steam distillation plant. The same approach was implemented by Yusoff et al. [13] on a hydro-diffusion steam distillation technique. The control efforts were generally able to maintain the temperature at a desired level during hydro-steam and hydro-diffusion distillation process accordingly. In their research, essential oil extractions were performed below 100ºC for kaffir lime peels extraction in order to improve its quality. Quyen et al. [14] suggested that optimal extraction temperature for kaffir lime is at 85ºC where most major compounds were recovered while some was missing during unregulated temperature.

In general, some improvement in major compounds recovery was obtained even if the percentage is not consistent [15-16]. On the other hand, Tajjudin et al. [17] had reported similar finding using Fuzzy Fractional-order PI (FOPI) controller for a steam distillation system. Comparatively, Fuzzy FOPI can regulate the temperature better with less control action than the Fuzzy PI controller.

Currently, fractional-order controller has becoming more popular among researchers. Fractional-order controller was first introduced in 1960 along with the evolution of computing era. A fractional-order synthesis-based controller was later on proposed by Alain Oustaloup's whom introduced a Non-Integer Order Robust Control (CRONE) [18-21]. The motivation of CRONE design was to achieve constant phase (iso-damping) condition to give more tolerance to the gain and process parameter variations. Some modifications have been made to the first-generation CRONE and the second-generation CRONE was created to allow for fractional-order controller of complex number and nonlinear system.

In 1999, Podlubny [22] had proposed a generalization of PID terms into fractional-order PID (FOPID). Since then, FOPID control was applied to many applications and processes which produced better performances compared to the PID. Besides PID, fractional-order theory had also been applied to Internal Model Control PID(IMC-PID). IMC-PID was proposed by Morari and co-workers in the 1980s [23-25]. The IMC-PID with fractional-order filter (IMC-PID-FOF) controller is then proposed by Maâmar and Rachid [26]. This controller allows more variables to be adjusted, including not only the three PID gains, but also a fractional-order operators for derivative, α and the closed-loop time constant, τc in the fractional-order filter.

This paper summarized the findings of fractional-order based control strategies discussed above when implemented on a steam distillation essential oil extraction process. The controllers include CRONE-2, FOPID, and IMC-PID-FOF. Each controller employed different control strategies to fulfil the design requirements. Hence, a comparative study between those controllers is interesting to be carried out. The analysis was done by simulation using MATLAB/Simulink software based on a process model obtained experimentally.

Next section discusses an overview of the steam distillation process and controller design approaches considered in this study. Section III discusses and compares the simulation results of the proposed techniques. Finally, the conclusions from this research findings will be drawn in the last section with some future recommendations for improvement.

2. Research Methodology

2.1 Steam Distillation Model

This research developed a hydro-steam distillation plant to demonstrate the fractional-order based controller. The plant consists of a stainless-steel distillation tank, a condenser, and an oil separator. The distillation plant was developed from a stainless-steel tank with a capacity of up to 30 litres. The tank was connected to a condenser to cools down the steam and converted it into pure essential oil. Two temperature sensors of type RTD PT-100 were installed to measure the steam temperature and water temperature. The steam was generated by an electrical heater immersed in 10 litres of water at the bottom part of the tank. A perforated tray was upraised over the water to hold the plant materials. Schematic diagram of the design is shown in Figure 1.

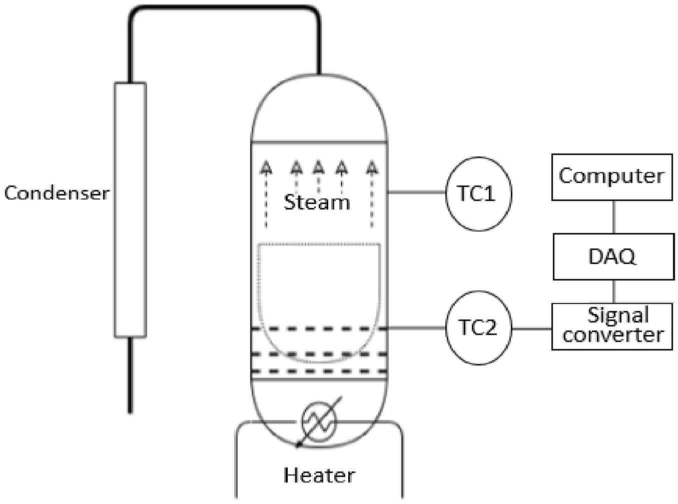


Fig. 1 *Schematic diagram of steam distillation essential oil extraction process*

Preliminary experiment using step test was performed to obtained the process reaction curve for model estimation. This method provides a simple and fast approach to determine an approximated linear process model such as a first-order plus time-delay (FOPDT) model. Process reaction curve was acquired by applying a change in the process input during open-loop and recording the process output. The process reaction curve of the steam temperature between 80ºC to 100 ºC is shown in Figure 2.

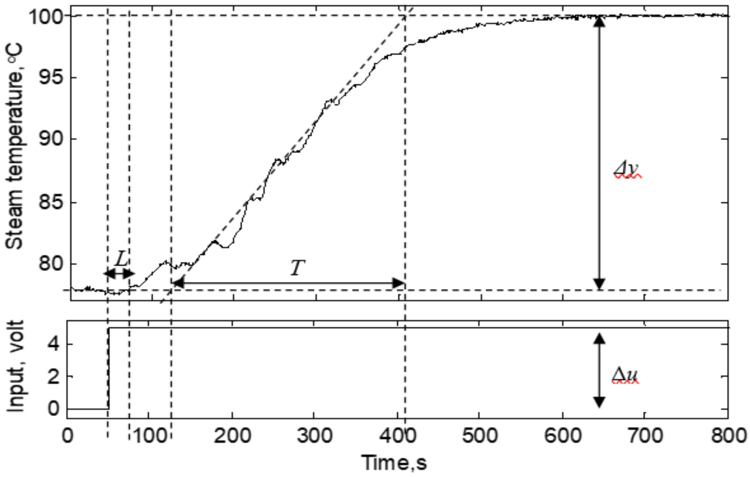


Fig. 2 *Schematic diagram of steam distillation essential oil extraction process temperature*

From the process reaction curve, K was determined as 4.5, T is 280 seconds, and L is 25 seconds. Hence, FOPDT model representation for the steam temperature is given in (1) with best fit of 68.47%.

$$G_1(s) = \frac{4.5}{280s + 1} e^{-25s} \tag{1}$$

2.2 Fractional-order PID (FOPID) Controller Design

The FOPID equation is defined in (2) where it consisted of proportional gain, K_p, integral gain, *Ki* and derivative gain, K_d. There are two extra parameters which are λ and μ that represent fractional-order integral and fractional-order derivative respectively.

$$G_{FOPID}(s) = K_P + \frac{K_i}{S^{\lambda}} + K_d S^{\mu} \tag{2}$$

The control space of FOPID controller is shown in Figure 3. When λ and μ are 0, the controller becomes a P controller, when λ or μ becomes 0, the controller becomes a PI or PD controller respectively. When λ and μ = 1, the controller becomes a PID. On the same manner, if λ and μ were set to any value between 0 and 1, the FOPID controller can be constituted to behave within these control space.

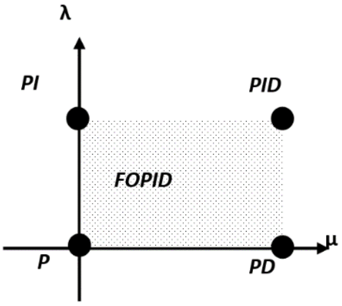


Fig. 3 *Fractional-order PID control space*

FOPID contains more parameter compared to PID. Thus, make it more complicated to tune. In this research, FOMCON Toolbox was used to tune the FOPID controller. FOMCON is a new fractional-order modelling and control tuning toolbox for MATLAB that was introduced around 2015 [27]. To tune the FOPID controller for steam temperature process, the phase margins were set to 84° for the design specification to achieve almost zero overshoot. Other settings required is the frequency range that was set to [0.0001,1000] rad/sec and approximate fractional-order, *N* was set to 5. As a result, the FOPID controller was obtained as given by (3). From the equation, we see that FOMCON has optimized both fractional-orders to 0.5, K_p = 1,07, *Ki* = 0.013 and K_d = 1.44.

$$G_{FOPID}(s) = 1.07 + \frac{0.013}{S^{0.5}} + 1.44S^{0.5} \tag{3}$$

2.3 IMC-PID-FOF Controller Design

The IMC-PID derivation with fractional-order filter will be discussed in this section. The concept of this model is to have an integer-order PID that is cascaded to a fractional-order filter to satisfy the closed-loop requirements of the system.

Earlier on, Rivera et al. [23] had derived the IMC-PID algorithm based on the block diagram shown in Figure 4. From the figure, we have a plant described by $g_p(s)$. In order to estimate the effect of external disturbances to the plant, a branch consisting of the plant model, $\widetilde{g_p}(s)$ was included. Instead of providing actual output to the feedback, this structure feedback the disturbance effect to the internal model controller, *q(s)* instead. So, IMC-PID is theoretically produced a robust control output.

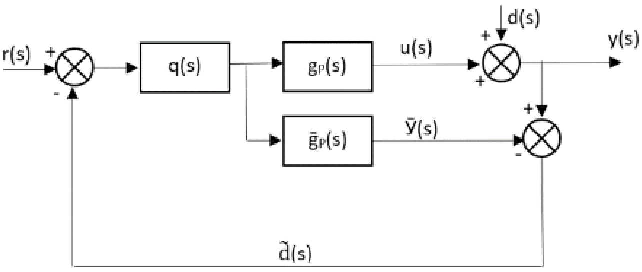


Fig. 4 *IMC control structure*

Simplifying the block diagram above, yields an equation for q(s) given in (4) where $\bar{g}_{p-}^{-1}(s)$ is an invertible element of $g_p(s)$ while f(s)= $\frac{1}{\lambda s+1}$ is a filter with λ as a time constant. In the IMC-PID, λ is the only tuning parameter that determine the closed-loop speed performance [24].

$$q(s)=\bar{g}_{p-}^{-1}(s)f(s) \tag{4}$$

In the same manner, the IMC-PID-FOF algorithm is given in (5) where $G_c(s)$ is the IMC-PID equation, Kc is the controller gain, τ_i is the integral time, τ_d is the derivative time and h(s) is the fractional-order filter equation.

$$G_C(s) = K_c\left[1+\frac{1}{\tau_i s}+\tau_d\, s\right].h(s) \tag{5}$$

The PID parameter can be calculated using equation (6) to (8) accordingly with τ_p is the process time constant, θ is the process time-delay and k_p is the process gain. Details on the derivation of IMC-PID-FOF algorithm can be referred to the research initiated by Ma'amar and Rachid [26].

$$K_C = \frac{2\tau_P+\theta}{k_P\theta} \tag{6}$$

$$\tau_i = \frac{2\tau_P+\theta}{2} \tag{7}$$

$$\tau_d = \frac{\tau_P\theta}{2\tau_P+\theta} \tag{8}$$

Adapting to the IMC-PID, Ma'amar and Rachid's had improvised the algorithm by introducing a fractional-order filter to the PID. The fractional-order filter takes the form of a simple first-order function as shown in (9) with a closed-loop time constant of τ_c and a fractional-order defined by α. The value of τ_c and α are related to the desired phase margin, φ_m and phase cross-over frequency, ω_{cg} represented by (10) and (11).

$$h(s) = \frac{1}{(1+\tau_c s^{\alpha+1})} \tag{9}$$

$$\tau_c = \frac{1}{\omega_{cg}{}^{\alpha+1}} \tag{10}$$

$$\alpha = \frac{\pi-\varphi_m}{\frac{\pi}{2}} \tag{11}$$

Hence, the desired design specifications including overshoot and settling time can be fulfilled. For this research, desired phase margin was set to 84° (1% overshoot) and phase cross-over frequency was set to 1.04 rad/sec to obtain the fastest response without overshoot.

2.4 CRONE-2 Controller Design

Non-Integer Order Robust Control (CRONE) was introduced by Alain Oustaloup in 1991 [18], marked the beginning of fractional-order system applications in dynamic control systems. CRONE is a control methodology specifically designed for achieving robustness in systems with uncertain dynamics. It utilizes a frequency domain approach within a typical unity feedback configuration to enhance the system's ability to maintain performance despite variations or uncertainties in the plant's behavior. The transfer function of a second-generation CRONE (CRONE-2) was obtained through derivation of an ideal Bode transfer function of an open loop system defined by (12) where ω_{cg} is gain crossover frequency and n is the system's order.

$$\beta(s) = \left[\frac{\omega_{cg}}{s}\right]^n \tag{12}$$

When the open-loop gain crossover frequency lies within a specific range, the plant's frequency response becomes asymptotic. This results in a relatively constant phase margin, which remains close to the crossover frequency. This behavior helps ensure a stable and predictable system response across that frequency range. Next, a band limited integrator, and a low pass filter was added to manage the level of control effort and steady state error. Hence, the new open loop transfer function, becomes,

$$C_F(s) = C_0\left(\frac{\omega_i}{s}\right)^{n_i}\left(\frac{1+\frac{s}{\omega_l}}{1+\frac{s}{\omega_h}}\right)^{n}\frac{1}{\left(1+\frac{s}{\omega_F}\right)^{n_F}} \tag{13}$$

Where C_0 is the gain multiplied to the integral frequency, ω_i with order of integral, n_i , and an Oustaloup's recursive approximation with corner frequency $[\omega_l, \omega_h]$ with fractional order, n. The low pass filter parameter was added such as frequency, ω_F and order of low pass filter, n_F. The fractional order, n is set around the gain crossover frequency ω_{cg}, and C$_0$ is a constant value to get the crossover frequency at ω_{cg}. The frequency response of the CRONE controller will be appear as shown in Figure 5 if all the criterion were met. The phase plot has an iso-damping properties over a large frequency range that will ensure system's robustness towards parameter variations.

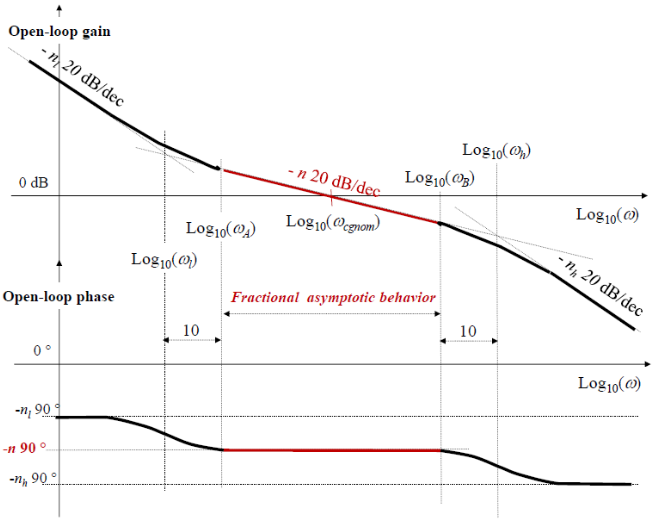


Fig. 5 *Frequency response of CRONE controller*

3. Results and Discussion

3.1 Controllers Evaluation

The performance of the FOPID-FOMCON, IMC-PID FOF, and CRONE-2 controllers was evaluated through three types of tests: step response, set point change, and load disturbance. During the step response test, each controller was analyzed based on rise time, settling time, and overshoot. Figure 6 presents the comparison of step responses for all the controllers.

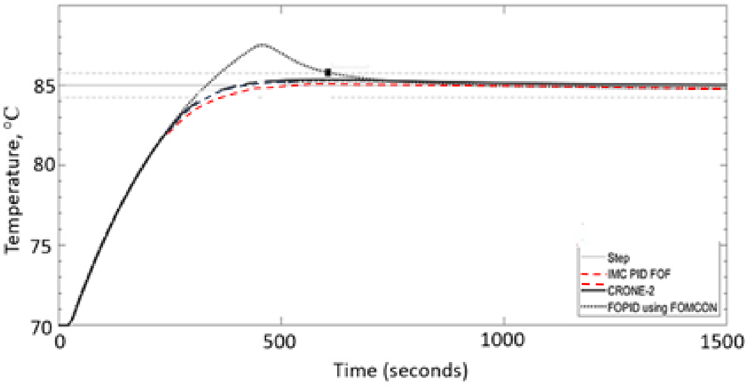


Fig. 6 *Output response for all controllers during step test*

As shown in the figure, the CRONE-2 controller, with a desired phase margin of 84° (resulting in 1% overshoot), achieved the best step response, with a settling time of 407.5 seconds. This is 11 percent faster than the IMC-PID-FOF controller and 48 percent faster than the FOPID controller. The performances of the IMC-PID-FOF and CRONE-2 controllers are nearly identical since both were designed with similar criteria, focusing on phase margin and phase crossover frequency. In contrast, the FOPID controller did not adhere to specific design requirements beyond minimizing error, which impacted its overall performance.

Figure 7 illustrates the comparison of control signals for various controllers during a step test. Notably, the CRONE-2 and IMC PID-FOF controllers demonstrate greater efficiency, requiring less effort compared to the FOPID controller. These controllers are able to accurately estimate the necessary control signal without over-actuating the process, thereby preventing any excessive overshoot in magnitude.

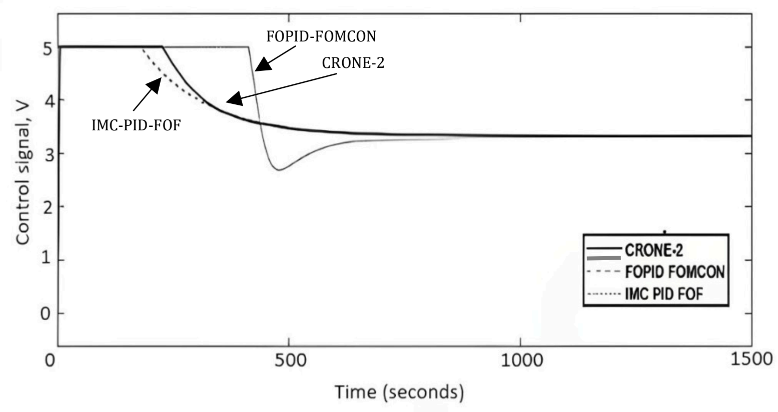


Fig. 7 *Control signal for all controllers during step test*

The performance results from the step response test are summarized in Table 1. The data clearly show that both the IMC-PID-FOF and CRONE-2 controllers achieve 0% overshoot, indicating their effectiveness in maintaining stability without exceeding the desired output. In contrast, the FOPID controller does not achieve the same level of performance, as it does not completely eliminate overshoot.

Table 1 *Evaluation during step response test*

Controller	Rise time, (sec)	Overshoot (%)	Settling time, (sec)
IMC-PID-FOF	277	0	454.8
CRONE-2	275	0	407.5
FOPID	272	18.67	604.3

Figure 8 illustrates the output response of all the controllers during a setpoint change, where the setpoint was increased by 5°C at 1000 seconds. The setpoint change test is essential because it evaluates how well each controller can adapt to changes in the desired system output. This test helps to determine the controller's ability to accurately and efficiently track a new target value without significant delay, overshoot, or steady-state error.

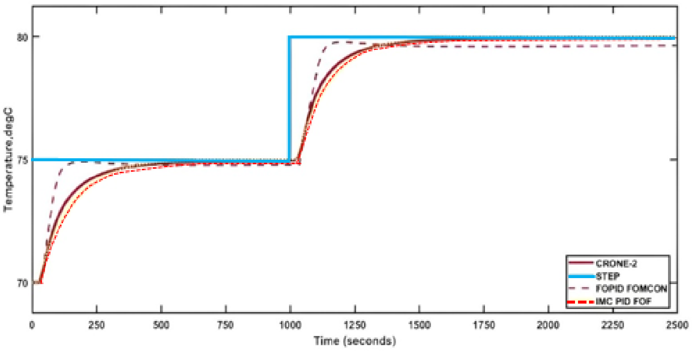


Fig. 8 *Output response for all controllers during step change*

According to the results, all controllers successfully adjusted the output to meet the new setpoint, with the exception of the FOPID controller, which displayed some steady-state error in its output. This indicates that while most controllers effectively handled the setpoint change, the FOPID controller struggled to maintain accuracy, leading to a persistent error in achieving the desired output.

Figure 9 displays the control signals for all the controllers during the setpoint change. As shown, the FOPID controller requires the highest control signal, followed by the CRONE-2 and IMC-PID-FOF controllers. This indicates that the FOPID controller demands more effort to adjust the output to the new setpoint compared to the other two controllers.

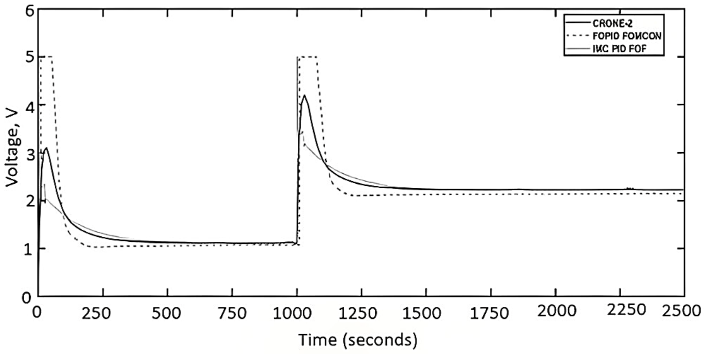


Fig. 9 *Control signal for all controllers during step change*

Next, a load disturbance test was conducted to evaluate the controllers' performance under real-world conditions where disturbances can cause fluctuations in temperature. This test is crucial because it simulates unexpected changes or disturbances in the system, which can lead to an increase or decrease in temperature. By assessing how quickly and effectively each controller can restore the system to its desired state, we can determine the robustness and reliability of the controllers in maintaining stable operation.

During the test, disturbance signals were introduced at t = 1000 seconds and t = 1500 seconds. Figures 10 and 11 show the output response and the corresponding control signals during the load disturbance test. The results indicate that the IMC-PID-FOF and CRONE-2 controllers provided the best response. Both controllers successfully recovered the system to the desired temperature within 300 seconds, without overshoot and with minimal control effort. This demonstrates their effectiveness in handling disturbances while maintaining system stability, making them well-suited for real-world applications where disturbances are common.

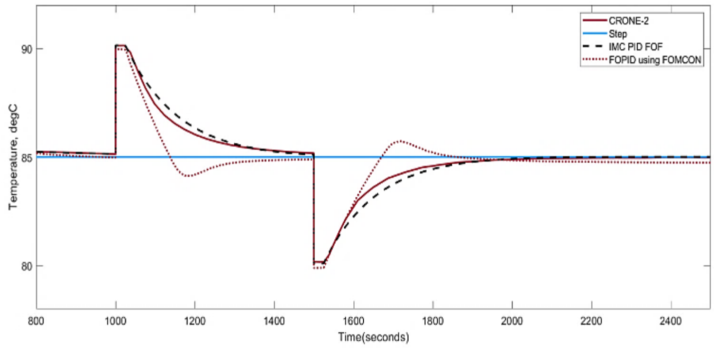


Fig. 10 *Output response for all controllers during load disturbance test*

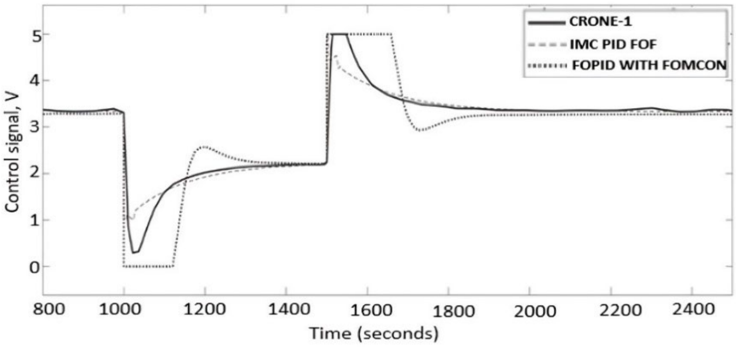


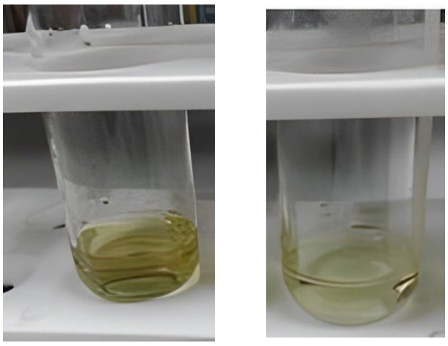
Fig. 11 *Control signal for all controllers during load disturbance test*

3.2 Quality Assessment of Citronella Oil

An examination of citronella oil extracted at 85°C and 100°C using the suggested hydro-steam distillation plant is provided in this section. Essential oil samples were obtained by extraction of Cymbopogon nardus leaves which were harvested in July 2012 from Malaysia Agricultural Research Development Institute (MARDI) in Kuala Linggi. The leaves were transported to the extraction facility and extracted a day later. Sample of 700g of leaves were chopped and arranged vertically inside the tank for optimum distillation for 3 hours. The oil that was yield will be dried with sodium anhydrous and stored in amber container under refrigeration before further analysis.

The essential oil which is commercially known as citronella oil will be tested based on three quality assessment tests which are its colour, refractive index measurement, and GC-MS analysis. Refractive index measures physical attributes of the essential oil and is defined as a ratio of the sine of angle of incidence to the sine of angle of refraction when a ray of light passes from air into the essential oil. The measurement was done using ATAGO refractometer unit.

Chemical components of citronella oil were analysed using gas chromatography- mass spectrometry (GC-MS) model Shimadzu GC-2010 Plus coupled with mass detector Agilent 7890A/5975C and HP-5MS capillary column. The analyses were performed by certified personnel at Forest Research Institute Malaysia (FRIM). GC-MS analysis was carried out at initial temperature of 60°C for 10 minutes and increasing 3°C for every minute until the column temperature achieved 230°C. Figure 12 shows the citronella oil extracted at 85°C and 100°C.



(a) **(b)**

Fig. 12 *Citronella Oil Extracted at (a) 100°C; (b) 85 °C*

Figure 12 shows that the oil extracted at 85°C had a pale-yellow appearance, but the oil extracted at 100°C had a darker brownish appearance. The physical characteristics of the two samples revealed their disparities. Remarkable variations are also apparent from the refractive index data provided in Table 2. In contrast to the oil extracted at 100°C (1.4747), the index for the oil extracted at 85°C was lower. A lower refractive index between essential oils typically indicates that the oil has a lower density or is less optically dense compared to others. They may have a higher concentration of lighter molecules, which can affect their overall optical density. This may imply to different chemical compositions or levels of purity [28].

Table 2 *Refractive Index of Citronella Oil*

Temperature (°C)	Refractive Index
100	1.4747
85	1.4710

Even though both sets of data were below the BS ISO 3849:2003 threshold of 1.479 to 1.490, this data further demonstrated the variation in citronella properties that were extracted at various temperatures. The chemical components of citronella oil that were identified by extraction at 85°C and 100°C and acquired from the chromatograms are listed in Table 3.

Table 3 *Chemical compositions of Citronella oil extracted at 85°C and 100°C*

No.	Compound	85°C Area (%)	100°C Area (%)
1	Limonene	0.17	2.67
2	Linalool	0.24	0.32
3	**Citronellal***	25.24	34.91
4	**Citronellol***	13.47	9.97
5	**Geraniol***	21.78	16.64
6	Citronellyl acetate	2.60	1.99
7	Eugenol	1.03	0.95
8	Geranyl butanoate	3.17	-
9	Geranyl acetate	-	2.49
10	β-elemene	2.22	1.65
11	α-humulene	0.17	-
12	Germacrene D	3.74	2.34
13	Germacrene A	-	1.28
14	γ-cadinene	0.37	0.24
15	Elemol	5.73	8.47
16	Germacrene D-4-ol	5.50	5.23
17	γ-eudesmol	0.40	0.67
18	α-cadinol	1.57	1.57
	Total	87.4	91.69

Additionally, 16 compounds representing citronellal (25.24%), citronellol (13.47%), and geraniol (21.78%) were discovered in citronella oil extracted at 85°C. However, the overall percentage of identified compounds was somewhat lower, at 87.4%. The same primary chemicals were found in both samples, however there were differences in their compositions according to the extraction temperature. Additionally, 16 compounds, or 91.69% of the identified compounds, were found in citronella oil extracted at 100°C. Citronellal (34.91%), citronellol (9.97%), and geraniol (16.64%) were the main constituents. This composition deviated from Nakahara et al. [30], Setiawati et al. [31], and Chan et al. [32], but it was in accordance with C. nardus extracts and comparable to earlier reports by Abena et al. [33] and Koba et al. [34]. However, the sample's composition was much greater than the ranges given by ISO 3849:2003 for geraniol (3.0% - 8.5%), citronellol (4.0% - 7.0%), and citronellal (7.0% – 11.5%). Table 4 provides a summary of the comparison.

Table 4 *Percentage comparison of major compounds in Citronella oil*

References	Plant origin	Citronellal (%)	Citronellol (%)	Geraniol (%)
ISO 3849:2003 [29]	-	7.0 -11.5	4.0 – 7.0	3.0 – 8.5
Nakahara et al. [30]	Bangkok	5.8	4.6	35.7
Setiawati et al. [31]	Indonesia	35.97	10.03	-
Chan et al. [32]	Penang	49.0	14.2	30.0
Abena et al. [33]	Benin	41.3	9.2	23.4
Aabena et al. [33]	Congo	37.5	7.5	29.4
Koba et al. [34]	Togo	35.5	10.7	27.9

Conclusions

A comparative study was conducted on fractional-order based controllers, including FOPID, Internal Model Controller with Fractional-Order Filter (IMC-PID FOF), and the second generation of CRONE (CRONE-2). Overall, all controllers demonstrated good performance and were effective in maintaining the temperature at the desired level across various robustness test conditions. However, the IMC-PID-FOF controller consistently delivered the best control output across all test conditions, followed by CRONE-2 and then FOPID.

Interestingly, the yield from C. nardus extracted under controlled steam temperature at 85°C exhibited some differences from the uncontrolled condition in terms of color, refractive index, and major chemical compounds. Despite these variations, the composition exceeded the range stipulated by the ISO 3849:2003 standard. These findings are consistent with those reported by other researchers in the field, suggesting that precise temperature control during extraction can significantly impact the quality of the essential oil.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows ***Led the research, conceptualized the study, conduct research on FOPID and essential oil extraction***: Mazidah Tajjudin; ***conduct research on CRONE-2***: Nor syafikah pezol; ***conduct research on IMC-PID-FOF***: Siti Nur Hasinah Johari; ***contribute to the data collection, review of existing research and identifying gaps***: Haslizamri Md Shariff; ***helped analysis and interpretation of results***: Mohd Hezri Fazalul Rahiman. *All authors reviewed the results and approved the final version of the manuscript.*

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