Essential Oil Extraction: Being Green and Emerging Technologies

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The essential oil extraction industry responds for a significant role as a raw material supplier to the cosmetics, pharmaceutical, and cleaning product segments. These oils are produced mainly via steam distillation in small businesses, applying systems with broad opportunities when technology is concerned. This paper aims to present the technological features to optimize extraction effectiveness (yield) and energy consumption. The answer to the question in the title involves improvement proposals to green extraction and the impact on business. This study is the continuation of the one previously published in the number 3/2021 of this Journal, entitled "Essential Oil Steam Distillation: Manufacturing 4.0".
Keywords: Essential Oil. Yield. Technology. Green Extraction.

Introduction

The essential oils (EO) extraction industry is, in general terms, supported by production systems with significant potential for technological upgrades [1]. These processes are characterized by yield uncertainties: the variability coming from the raw materials (herbs), in addition to undetected and uncorrected operational occurrences, due to the lack of basic instrumentation and control. In general, the essential oil extraction process operates in multipurpose plants, in batches, with a broad range of feedstock (leaves, branches, roots, flowers, and bark). In addition, they present variation in process cycles [2], energy, and time waste, thus with direct effects on productivity and quality, compromising the expected results. The steam distillation method is, unquestionably, the most frequently used within extraction industries [3,4].

This work presents a comparative frame between the current situation and a scenario of technologically improved processes. It is based on emerging technologies that may achieve a direct positive impact on sustainability indicators. As far as technology is concerned, the proper use of sensors and controllers [5,6], data acquisition, data treatment, followed by intelligent modeling [7] (for instance, with digital twins [8]), have the purpose of improving the steam distillation process. The detection of undesired occurrences and their correction, in the steam flow through the vegetable bed, is brought with promising proposals to optimize the extraction process toward green extraction.

Yield and extraction duration are indicators of the process performance. When optimized, these factors deliver both energy and water minimum consumption for effective production. Besides, digging down into the production chain, maximum yield requires a reduced planted area for the same produced quantity of essential oil. Therefore, it reduces all the agricultural needs and environmental impacts.

<u>Essential Oils</u>

Essential oils are a complex chemical mixture. Produced by secondary plant metabolic systems, they are responsible for communication with other plants, animals, attracting or repelling them, as they can be beneficial or malefic for the organism, respectively, and protection against fungi and other microorganisms. With broad use in several industries, their importance is highlighted by their customer industries: cosmetics, pharmaceutical, home care, and food preservatives [9-11].

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The Technological Scenario of the EO Industry

The vast majority of the worldwide EO volume is produced via steam distillation. Many other methods such as organic solvents, cold pressing, micro-wave assisted, ultrasound-assisted, carbon dioxide in a critical state, and others, with small-expression, are also found in industry, academic research, and product development areas. Nevertheless, when steam distillation is concerned, the lack of technology leads to high energy consumption, risk of poor quality, and yield loss, all due to process control and monitoring weaknesses.

According to Chemat [12], process intensification is a clear path toward green extraction with direct benefits on other business' areas as customer service, product quality, and operational costs.

Figure 1 presents the process that applies the conventional concept. Hydrosol is the odorized water obtained from the separation after condensation.

Simply explaining the process, steam is generated and flows through the plant material carrying the essential oil. Afterward, it is condensed and separated from the hydrosol. The sketch shown in Figure 1 shows the cases when the EO is lighter than the hydrosol. Just for context, some few EO's are heavier than the hydrosol.

Materials and Methods

The path to reach the purpose of the present work consists of an ordered comparison between the current state, the basic process shown in Figure 1, and the proposed concept, with technological upgrades, as the spinal column of this paper. Among the countless possibilities, we considered a few in this comparison due to their overall process effectiveness.

The sensors, controllers, data acquisition and analysis, and intelligent modeling are tools to improve the steam distillation process. Table 1 exposes the core of the propositions to process improvements and, in consequence, sustainable performance (green extraction). PLC (Programmable Logic Controller) is the first element of process control. SCADA (Supervisory Control and Data Acquisition) is the human-

Figure 1. Essential oil conventional steam distillation process.

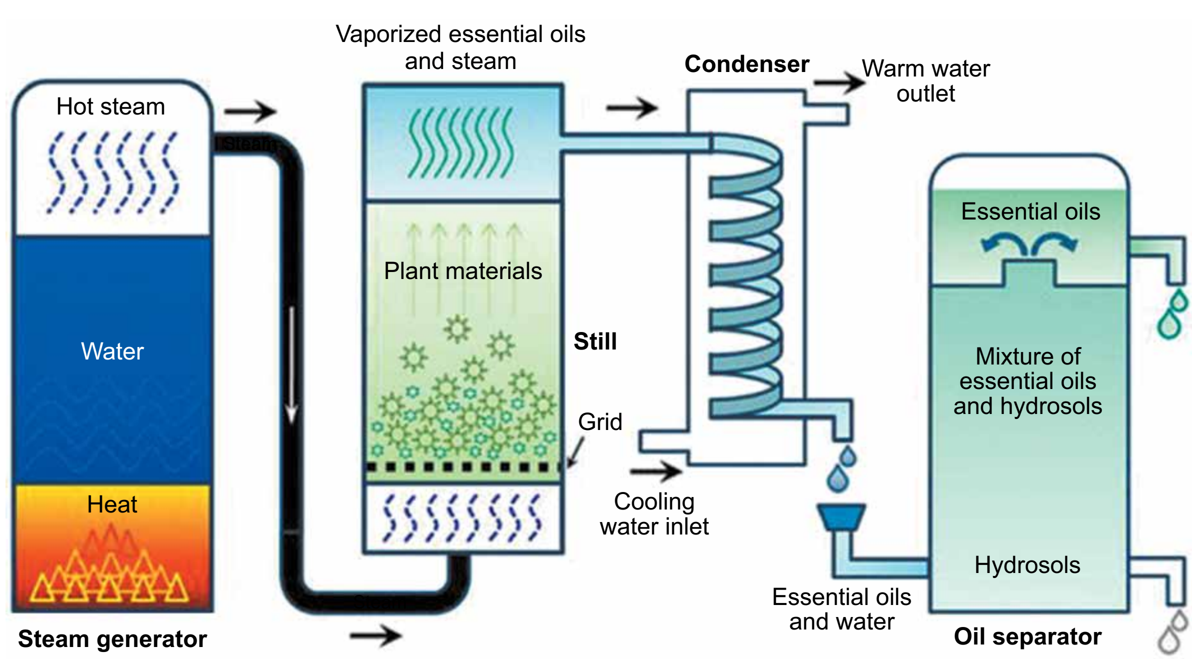


Table 1. Comparison between current and proposed situations.

	Current Status	Proposed Status
Sensors	Few sensors, local indication	Sensors transmitting data to PLC, SCADA and A.I.
Data Acquisition	No automatic data acquisition. Only handwritten logbook with final yield and process duration information.	All data are from sensors, operator inputs, duration between main events, and outputs are logged to allow correlations.
Data Treatment	None	Statistical analysis and search for promise correlations.
Modeling (A.I.)	None	Correlations allow the systematic improvement of process parameters coming from A.I.

machine interface and the center of the data acquisition system. The AI (Artificial Intelligence) is embodied in a model, searching correlations and proposing optimized process parameters [13].

The process diagrams display the differences between a conventional extraction plant, without sensors/controls, and the one instrumented to detect deviations, allowing proper control, correlations, and, consequently, process parameters optimization (Figure 2).

In this optimized proposition, conventional temperature sensors (transmitters) should be installed (Figure 3). In this conception, the thermocouples were inserted internally into the raw material bed to detect fluctuations in temperature at the points where they should be the same (or just slightly different). These differences indicate that the steam is flowing through preferential paths, named channeling by the authors. When these undesired process phenomena occur, they affect yield and quality: two indicators with primary and secondary consequences over the environmental performance.

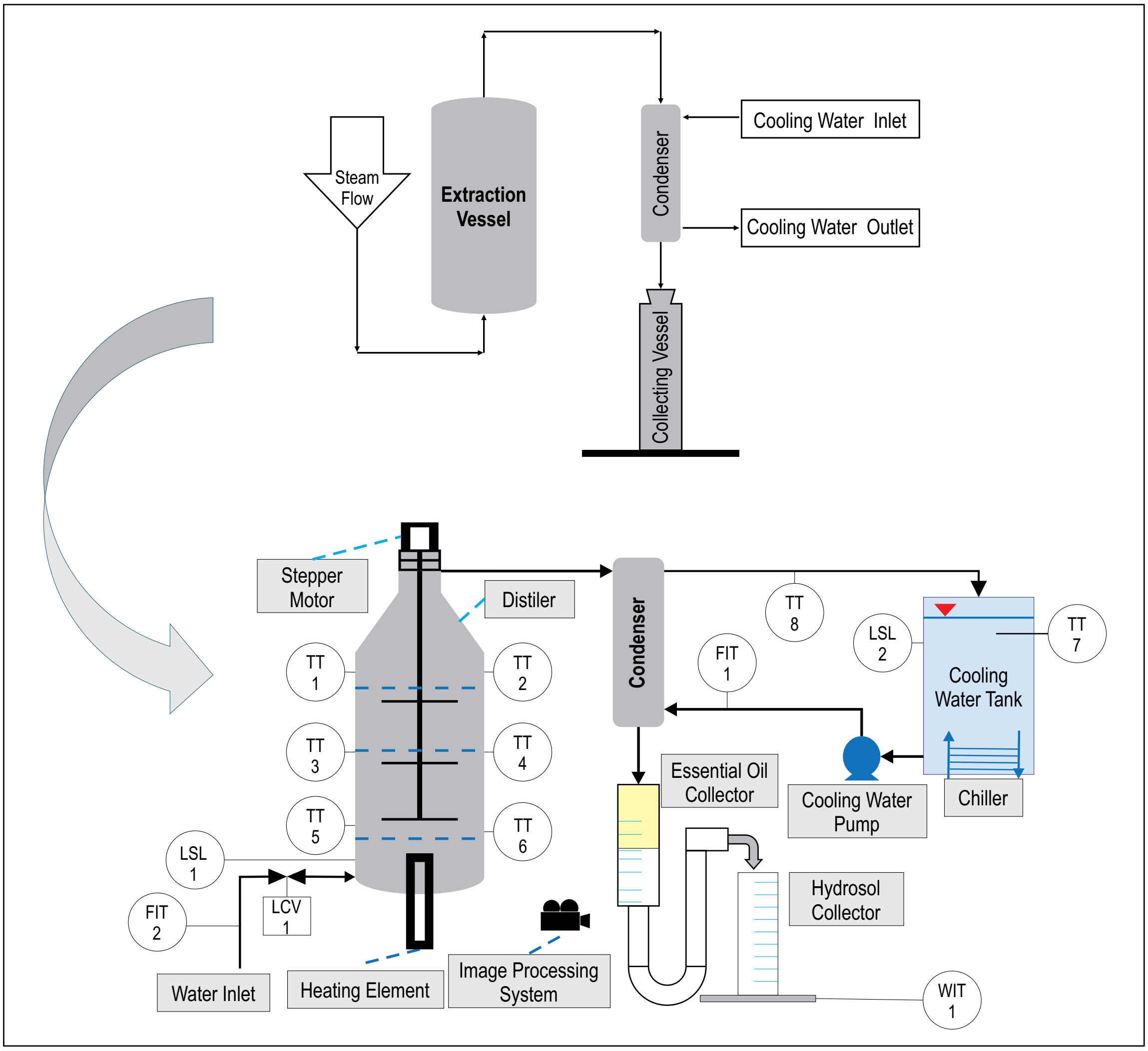
The image processing system intends to detect the progress of the extraction curve (Figure 4) and determine the economic end-of-extraction, being t1 within the ramp of maximum slope, t2 the economic end-of-extraction time, and t3 the time usually used in the industry. The period between t2 and t3 shows where is the waste of energy, water, and capacity: a clear impact on the operation's overall effectiveness, including environmental care. Also, it shows the risk of product degradation, due to overexposure to high temperatures, can occur.

All correlation possibilities among yield, hydrosol weight, cooling water temperatures, and other factors like channeling correction via stepper driver action (frequency of action, duration, and magnitude of the movement) are possible due to the applied technology. The data acquisition and the data treatment indicate, batch after batch, better parameters, toward the optimized ones with modeling [7], for instance with a digital twin [8]. It means that monitoring, controlling, and providing optimized process parameters can effectively contribute to an eco-friendly operation.

Results and Discussion

The main results can be placed as a promising proposition for the essential oil industry as a technological path toward a continuous improvement production process. The prospects coming from the affirmation: "being green with technology" are clear: manufacturing facilities market development, without the properly applied technology, is impacted, reduced if none

Figure 2. Comparison between conventional and technologically developed processes.



FIT: Flow Indicator and Transmitter; LCV: Level Control Valve; LSL: Level Switch Low; TT: Temperature Transmiter; WIT: Weight indicator/transmitter

when competitiveness is at the stake. The structure production (extraction, lacks control, monitoring, and continuous optimization parameters) can compromise the strategic business dimensions. Then, technology embeds opportunities for the essential oil business, with an impact on sustainability performance.

Conclusion

It is almost impossible to establish a standard solution to fit all needs in the essential oil industry. It is, indeed, not a case of “one size fits all”. However, this paper is an invitation to researchers for further studies on the subject with evident beneficial consequences to a greener world.

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Figure 3. Channeling.

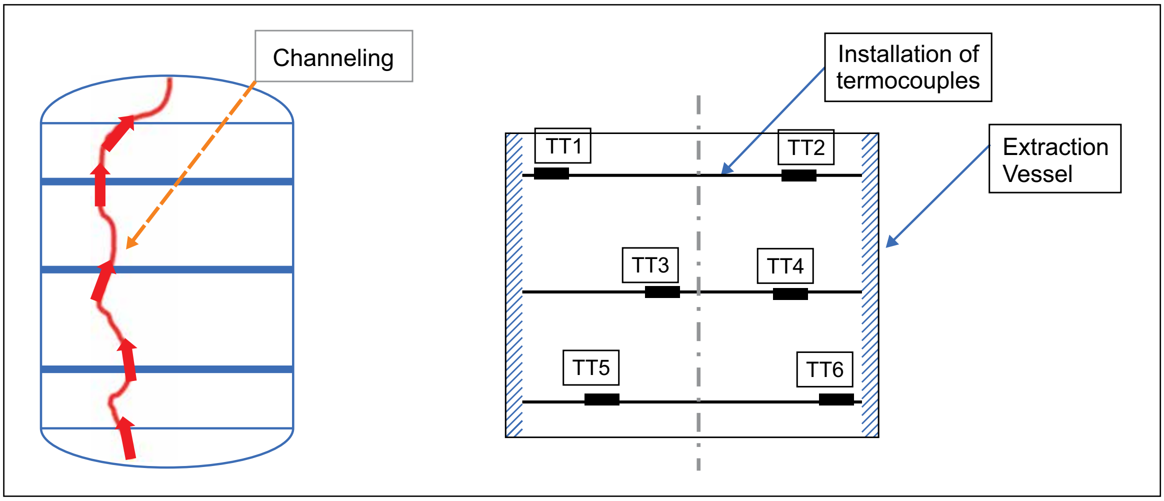
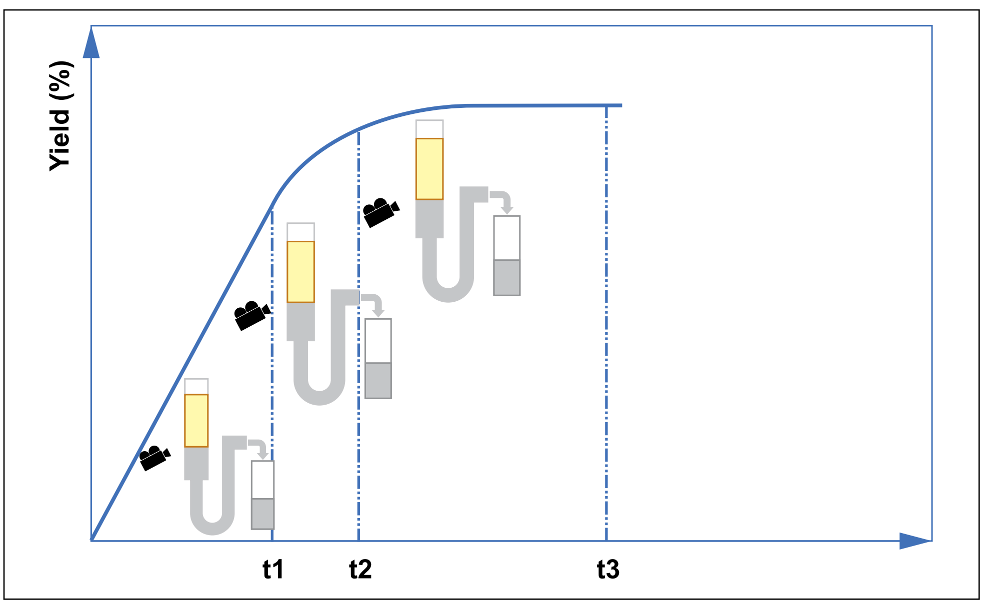


Figure 4. Optimum yield, optimum extraction time.



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