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Thermal efficiency analysis of a discontinuous distiller for *Ocotea quixos* from Amazon Region of Ecuador

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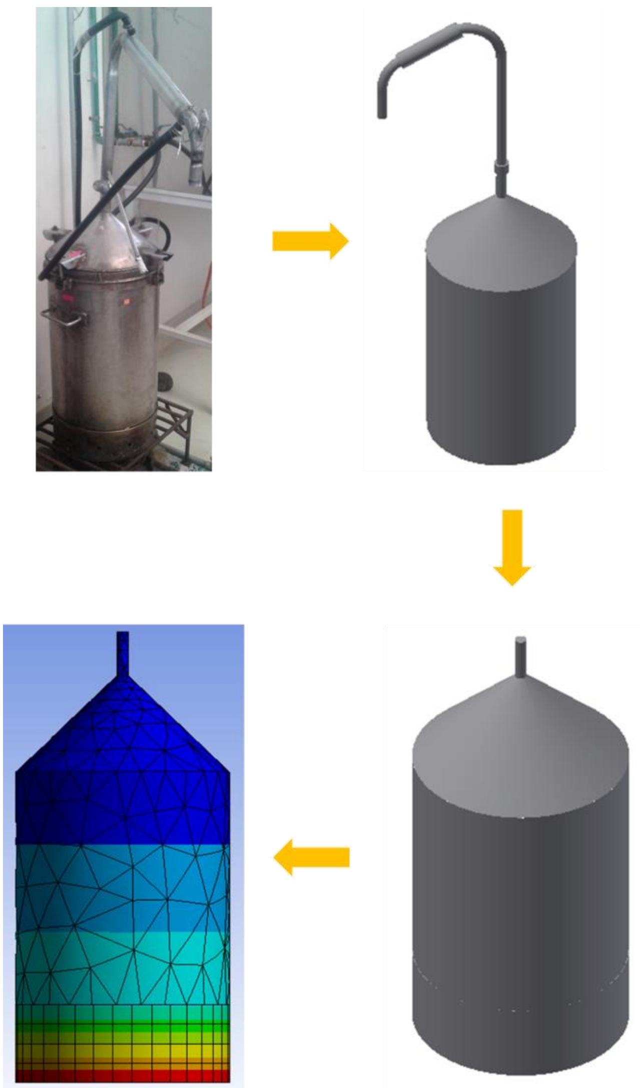
Graphical Abstract



Abstract.

Temperature gradient in any process of transformation of matter is parameter that can affect the efficiency of the equipment. Bearing in mind this antecedent, we have simulated temperature behaviour in a discontinuous distiller for obtaining of essential oil by steam distillation. The thermal analysis was accomplished taking into consideration the typical raw material from Amazon Region of Ecuador as Ocotea quixos*, which have different physical and thermal properties as shape and specific heat respectively. The temperature gradient is affected for raw material mash, due to that the mash behave as thermal insulator and vary temperature distribution inside of the distiller by depending thickness of the mash, which is directly proportional to the raw material mass. The thermal analysis was done by finite elements, where we varied mash thickness with the respective specific heat of the raw material aforementioned and found range of thickness where temperature distribution is uniform inside of the distiller. Thereby, we determined with the aid of engineering program the amount of optimal raw material to increase output of essential oil inasmuch as with uniform temperature distribution the rate of heat and mass transfer increase.*

Introduction

Finite element method was used initially to analyze structure machines problems. Nowadays, this method is widely used to solve engineering problem as analysis of solids and structures, heat transfer, and fluids behavior. In the Figure 1, finite elements analysis process is summarized, which entails knowledge about physical problem, mathematical model, prototype design and redesign to fulfill boundary conditions [1].

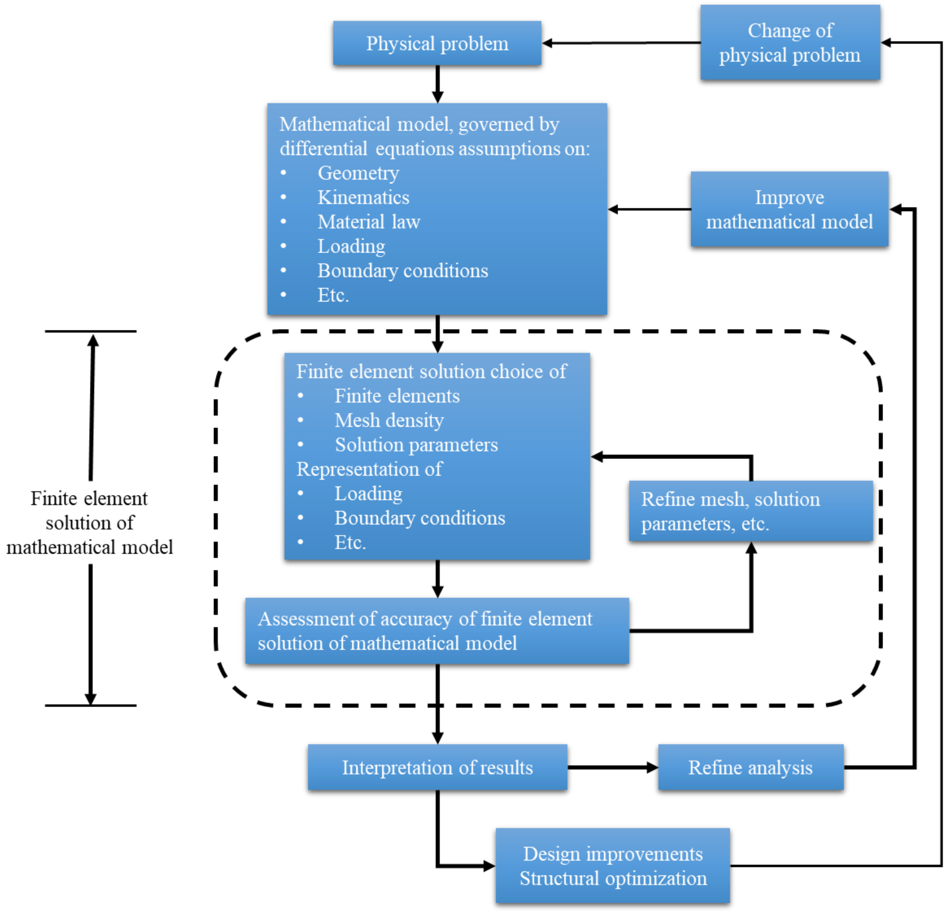


Figure 1. Finite element analysis (Bathe, 2014)

The distillation is a unit operation, where interfere the principles of heat and mass transfer in the interaction between liquid and vapor phases. In binary mixtures, transfer of material is achieved in conditions of constant temperature and pressure meaning isothermal and isobaric process [2]. Hence, if temperature gradient is uniform the efficiency of process increases. Thereby, temperature gradient can be analyzed by finite element.

To the *Lauraceae* Family belongs *Ocotea* quixos, which is used to extract essential oil for its properties antioxidant and anti-inflammatory. *Ocotea quixos* leaf is composed of several components as polysaccharides, lignin, reducing sugars, etc. Wherein cellulose represent 67.11% of the leaf [3]-[5].

Materials and Methods

A. Physical Problem Definition

The actual discontinuous distiller for craft processes from Universidad Estatal Amazónica was designed for volumetric capacity of 4 kg for *Ocotea quixos*. Bearing in mind, this antecedent we analyzed volumetric capacity of the distiller, to determine how is behaviour of temperature gradient in the vapor phase to be isothermal process.

To determine data, we used experimental data and measurements of actual equipment (Table 1). Moreover, *Ocotea quixos* leaf is 67.11% of cellulose, meaning that thermal conductivity is established by cellulose, which behaves as thermal insulator in the equipment. Thereby, electrical circuit method for heat transfer is determined for cellulose (*ocotea quixos*) and mixture vapor and essential oil, where thermal conductivity is water in vapor phase (Figure 2).

Table 1. Summary of experimental data

Room Temperature (°C)	24
Initial Temperature (°C)	100
Final Temperature (°C)	94
Thermal conductivity (cellulose) (W/m K) [6]	0.0035
Thermal conductivity (vapor) (W/m K) [7]	0.0246

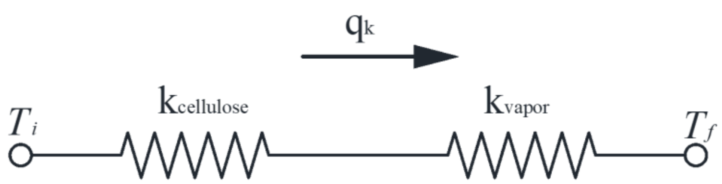


Figure 2. Thermal Circuit of distiller, where T_i is initial temperature, T_f is final temperature, q_k is heat flux in function of thermal conductivity, $k_{cellulose}$ is thermal conductivity of the cellulose, k_{vapor} is thermal conductivity of the vapor.

B. Geometry Definition

To define geometry, we took as reference equipment measurements and volumetric capacity of distiller (Figure 3), due to maximum capacity of the equipment is 4 kg that to represent to 500 mm of the height of Ocotea quixos.

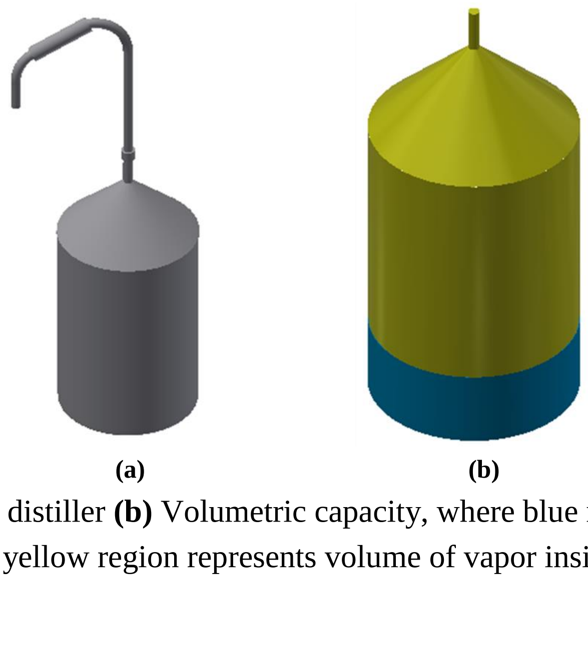
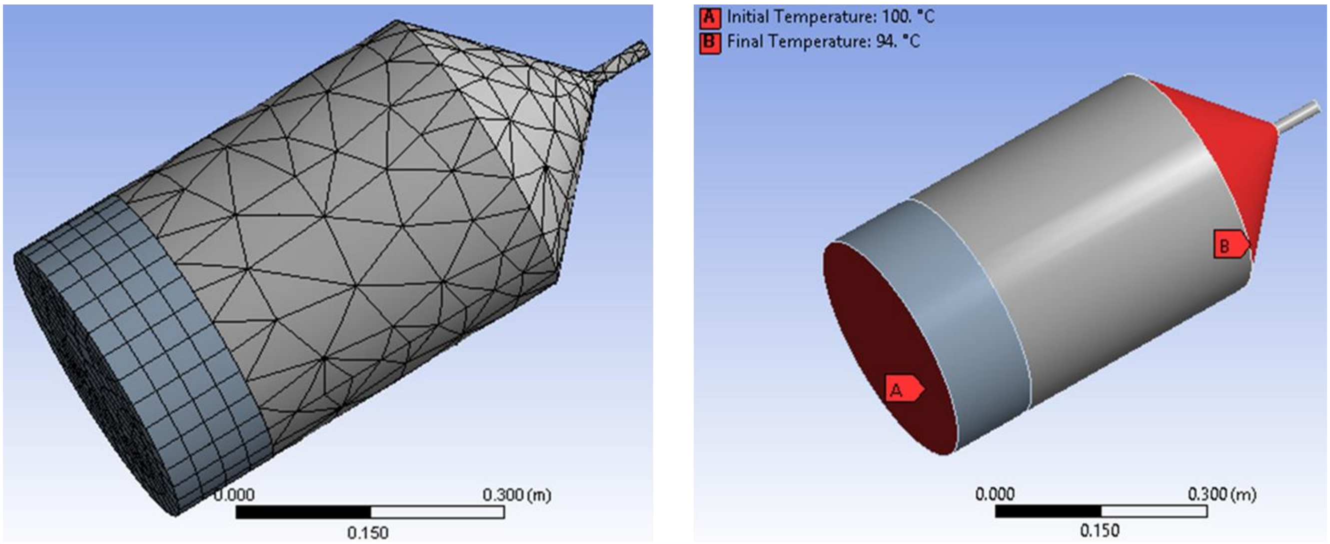


Figure 3. (a) CAD of the distiller **(b)** Volumetric capacity, where blue region represents 1 kg of *Ocotea quixos* and yellow region represents volume of vapor inside of the distiller.

C. Working and Boundary Conditions

Considering the experimental data mentioned in the Table 1, we defined the boundary conditions, material law and mash density (Figure 4).



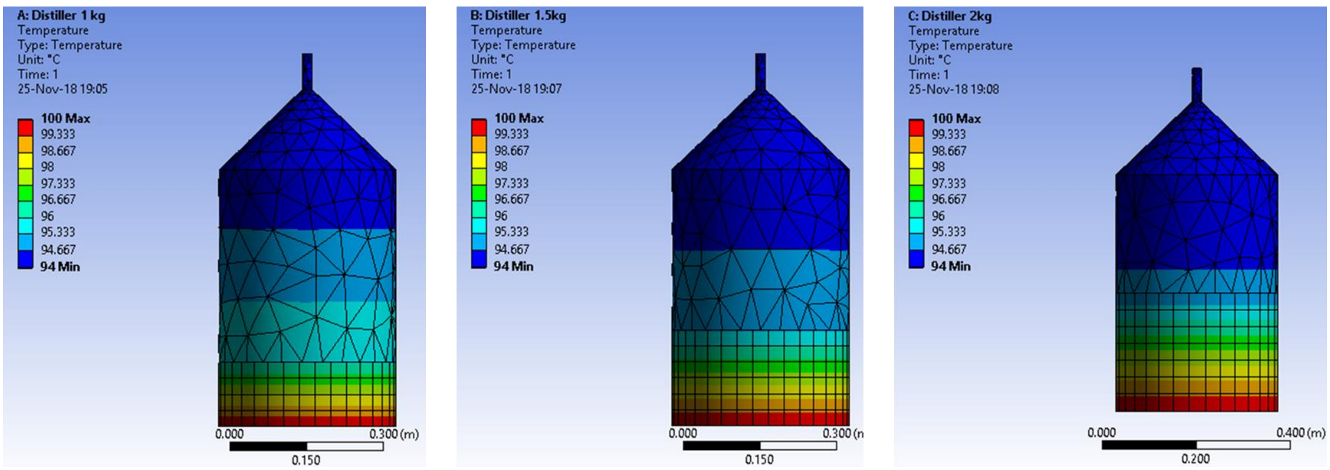
(a) **(b)**

Figure 4. **(a)** Definition of the material properties, connections and mesh **(b)** Definition of the working conditions.

To analyze the current physical problem, we found that the temperature of the water below of the Ocotea quixos mash was constant due to the initial temperature is 100 °C (water temperature inside of distiller).

Results and Discussion

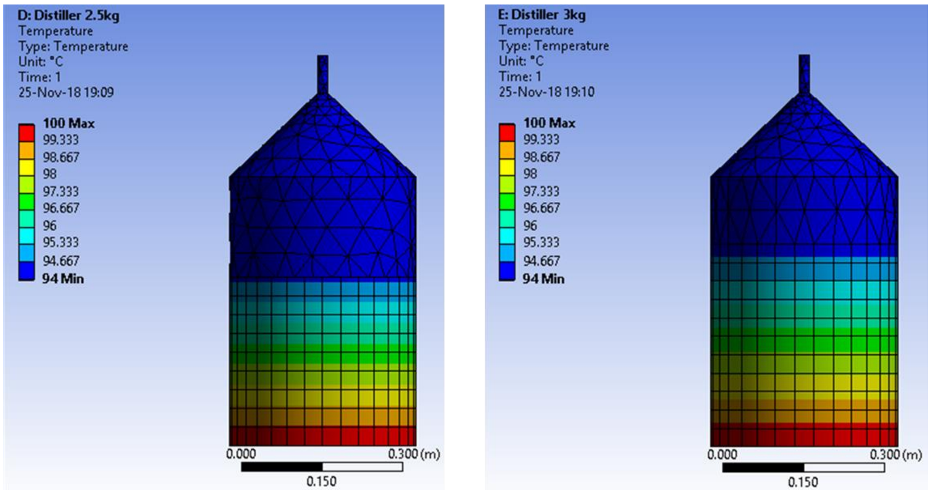
Temperature gradient was analyzed by finite elements. Whence Ocotea quixos mash is considered as thermal insulator with thermal conductivity of cellulose equal to 0.0035 (W/mK). Moreover, distiller is used for craft process and for this reason we analyzed for 5 different capacity of equipment and we found how temperature gradient vary inside of distiller.



(a) **(b)** **(c)**

Figure 5. Volumetric capacity was defined with following conditions **(a)** 1 kg of Ocotea quixos **(b)** 1.5 kg Ocotea quixos **(c)** 2 kg of Octea quixos

In the Figure 5 and Figure 6, we observed how vary temperature gradient behaviour if we vary mash height, as 4 kg represents to 500 mm we analyzed for 1 (kg), 1.5 (kg), 2 (kg), 2.5 (kg) and 3 (kg) where the height are 125 (mm), 187.5 (mm), 250 (mm), 312,5 (mm) and 375 mm respectively. Whence, we found that if mash range is between 1 (kg) and 2 (kg) the temperature gradient do not keep constant and to harm to the thermal efficiency due to that distillation is isothermal process. Finally in the Figure 6, we found that mash range is between 2.5 (kg) and 3 (kg) the temperature is constant in the vapor phase.



(a) **(b)**

Figure 6. Volumetric capacity was defined with following conditions **(a)** 2.5 kg of Ocotea quixos **(b)** 3 kg Ocotea quixos

Conclusions

In this work, we analyzed the temperature gradient of a discontinuous distiller for Ocotea quixos, where we found that if mash range vary between 2.5 (kg) and 3 (kg) the temperature inside of distiller is constant, which allows to keep the conditions of an isothermal process and so thermal efficiency is constant. Thereby, if artisans want results in the production of essential oil of Ocotea quixos, we recommended that the mash must be between range of 2.5 (kg) and 3 (kg) to keep efficiency of the process.

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