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Investigation of the potential use of concentrating solar thermal technology for essential oil extraction and techno-economical comparison of renewable and conventional energy sources

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ABSTRACT

Distillation of essential oils is one of the processes that demand significant amounts of saturated steam. Majority of distillation processes are carried out using conventional energy sources requiring significant quantities of electrical energy. In addition, conventional steam distillation contributes significantly to the carbon dioxide emissions, thus harming the environment. The challenges mentioned can be resolved by concentrating solar thermal (CST) technologies in medium temperature level (80-240 °C) since wide range of agro-based processes operate well within this temperature range. Most of the industrial solar plants in South Africa use the flat plate and evacuated tube collectors with temperature below 100ºC, which is ideal for only low temperature process applications. Therefore, CST technologies would be vital for the survival of the already cost-burdened agro-based industries. There are several CST technologies, however, the suitable ones for industrial process heat are parabolic trough collector (PTC), linear fresnel collector (LFC) and parabolic dish collector (PDC). Although CST technologies have a great potential, there are only few realized projects. In terms of the research conducted, particularly on the use of CST technology for steam distillation of essential oils, only few studies can be located. Therefore, this research seeks to investigate further about the potential use of CST technology for essential oil steam distillation.

The PTC was selected for this research, due to its maturity and long record of successful operation. The components of PTC were specified and sourced according to energy requirements of an existing gas-powered steam distillation and installed for steam distillation of citrus peels. For comparative analysis, conventional gas-powered steam distillation and laboratory steam distillation were conducted. The results showed that PTC can compete with fuel gas, and in some cases, the yields of essential oil were comparable with that of laboratory experiments, thus rendering the PTC sufficient for deployment in agro-based industrial applications. In the case of gas-powered steam distillation, the essential oil yields were 0.65, 0.44 and 1.17 % for orange, lemon and mandarin, respectively. For PTC, the yields were 0.67, 0.53 and 1.09 %, which showed to be in the expected ranges. Gas Chromatography results for PTC experiment showed the presence of key components (e.g. 90% limonene) in the essential oils. The PTC achieved an overall system efficiency of 54.99 %, which is significant, given the fact that some parts of the system were not thermally insulated, thus adding to other efficiency problems that the system had. Having considered a techno-economic review, it has been proven that PTC can economically be used for steam distillation of essential oils.