Effect of ohmic pretreatment on tissue integrity and extraction yield of Chinese chives (Allium tuberosum) leaf oil

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Abstract
Chinese chives (Allium tuberosum Rottl.) are known for its antimicrobial and antioxidant properties. However, extract from Chinese chives was not commercially available due to very low extraction yield of the conventional method, steam distillation. This study focused on effect of ohmic pretreatment at different electric field strengths on tissue integrity and extraction yield of Chinese chives leaf oil. The field strength was varied at $E = 0, 25, 50, 75$ and $100$ V/cm. For all treatment, the cut-off temperature was fixed at $60 \degree C$. The tissue integrity was determined by an electrical conductivity disintegration index ($Z$) and viable staining using neutral red dye. It was found that as the field strength increased, $Z$ value increased indicating a higher degree of tissue damage. The highest degree of tissue damage ($Z \sim 0.8$) was obtained when $E \geq 75$ V/cm were applied. The viability test showed agreeable results to the $Z$ values. More red cells were observed at the lower field strength. At $E = 25$ V/cm, the amount of viable cells were comparable to the control (fresh tissue) while there was almost no viable cell left at $E \geq 75$ V/cm. When ohmic pretreatment at $E = 75$ V/cm was applied prior to 2.5 h of steam distillation, the extraction yield was increased from $0.12\pm0.01\%$ to $0.16\pm0.02\%$ by fresh leaf weight or about $33\%$. Thus, ohmic pretreatment was suggested to increase the permeability of any biological materials prior to extraction process in order to enhance the extraction yield.

Keywords: Chinese chives, Extraction yield, Ohmic, Tissue integrity, Viability staining.

Introduction
Chinese chives (Allium tuberosum) belongs to Allicaeae plant family and Allium species similar to garlic and onion. In Thailand, Chinese chives are generally used as food and medicine. The medicinal properties of Allium species are qualified by their rich content in sulfide compounds which are responsible for their antimicrobial and antioxidant properties (Mnayer et al., 2014). For Chinese chives plantation, fresh leaves were cut several times within the growing season (Yabuki et al., 2009). After 1 year, the Chinese chives were cut and discarded as agricultural by-products. To maximize the usefulness of Chines chives by-products, the Bang-Phae organic vegetable grower community enterprise group, Ratchaburi province, which is one of the largest Chinese chives growers in Thailand, is interested in producing the Chinese chives leaf oil from the by-products. The chives leaf oil has a potential to be used for food preservative and alternative to synthetic antioxidant (Mnayer et al., 2014).

The conventional methods for essential oil extraction from plant materials are hydrodistillation and steam distillation. Most of the small and medium essential oil producers employ these methods because of its simplicity. However, there are some disadvantages of the conventional methods which are long extraction time, low extraction yield and low energy efficiency. Moreover, many beneficial natural compounds are thermal unstable and degraded during thermal extraction (Kimbaris et al., 2006). Thus, advanced extraction techniques need to be explored in order to improve quality of the extract, extraction yield and enhance the extraction efficiency (Gavahiana et al., 2015).

Ohmic heating is one of the promising advanced technologies. During ohmic heating, heat is internally generated by the passage of alternating electrical current through a body such as a food