

Effect of peppermint oil nano-emulsion on surface wettability of vegetables

Dalluchawan Kalantagaphan^a, Kanithaporn Vangnai^a, Pitirat Klintham^b, Sasitorn Tongchitpakdee^a

^a Department of Food Science and Technology, Faculty of Agro-Industry, Kasetsart University, Bangkok 10900, Thailand

^b School of Integrated Science, Kasetsart University, Bangkok 10900, Thailand

Abstract

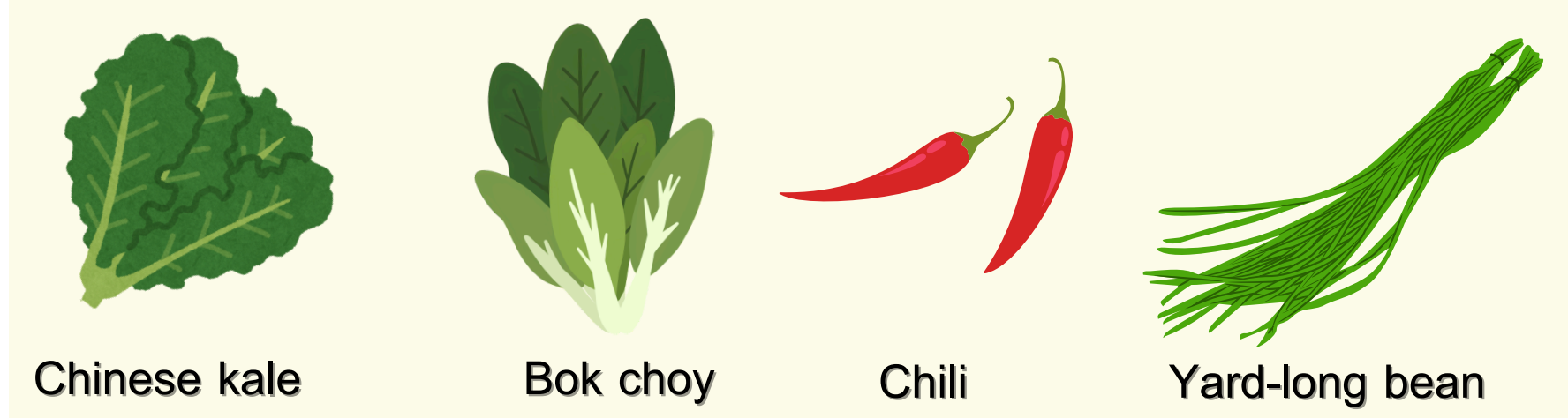
Surface wettability is critical to vegetable washing efficiency, as it determines the spreading of washing solutions on plant surfaces. This study evaluated the effect of peppermint oil nanoemulsion (PON) on the wettability of yard long bean, bok choy, Chinese kale, and red chili. Vegetables were washed with filtered water, surfactant solution, or PON, and wettability was assessed by static contact angle measurement. PON exhibited a mean droplet size of 241 ± 6.58 nm, low PDI (0.158), and high zeta potential (-39.33 mV), indicating good stability. Both vegetable type and washing formulation significantly affected contact angle values ($p < 0.05$). Surfactant-containing treatments reduced contact angles compared with water, while PON achieved greater reductions (13–56%) than surfactant alone, particularly in bok choy and Chinese kale. These results demonstrate that PON enhances surface wettability and may improve washing performance in fresh produce systems.

1 Introduction

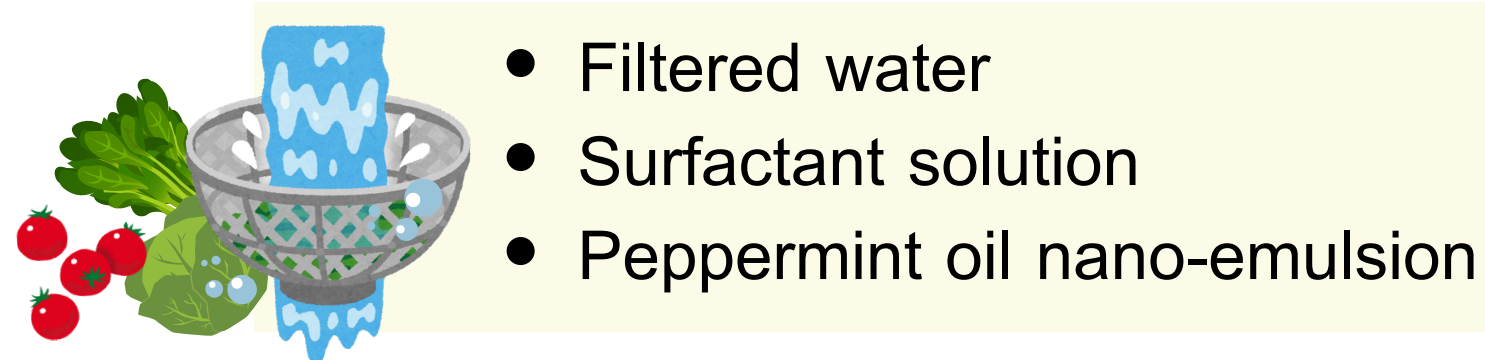
Washing efficiency of fresh vegetables depends on surface wettability, which is influenced by surface roughness and epicuticular wax composition. Surfactants improve wetting, while essential oils may interact with lipid based surface components; however, their combined effects remain limited. This study evaluated the effects of vegetable type and washing formulation on surface wettability using contact angle measurement.

2 Materials and Methods

Vegetables



Washing process



Contact angle

- Wettability determination measure by contact angle

Contact angle measurement

Table. 1 Contact angle (°) of vegetable surfaces with different types of washing solution

Vegetable	Filtered water	Surfactant solution	Peppermint oil nanoemulsion
Yard long bean	78.74±7.03a	67.16±4.76b	58.38±6.08b
Bok choy	77.37±4.85a	70.03±2.47b	33.76±6.89c
Chinese kale	104.01±5.32a	90.11±8.62a	76.33±5.11b
Chili	80.50±9.60a	77.42±9.93ab	70.11±3.78b

a-b Different superscript letters within the same row indicate significant difference ($p < 0.05$)

Peppermint oil nanoemulsion reduces contact angles by enhancing the spreading and wetting of aqueous solutions, particularly in combination with surfactants. Previous studies have shown that incorporating essential oils into washing solutions lowers surface tension and improves liquid dispersion on plant surfaces. These effects are attributed to reduced intermolecular forces at the liquid-surface interface, resulting in improved wettability [2].

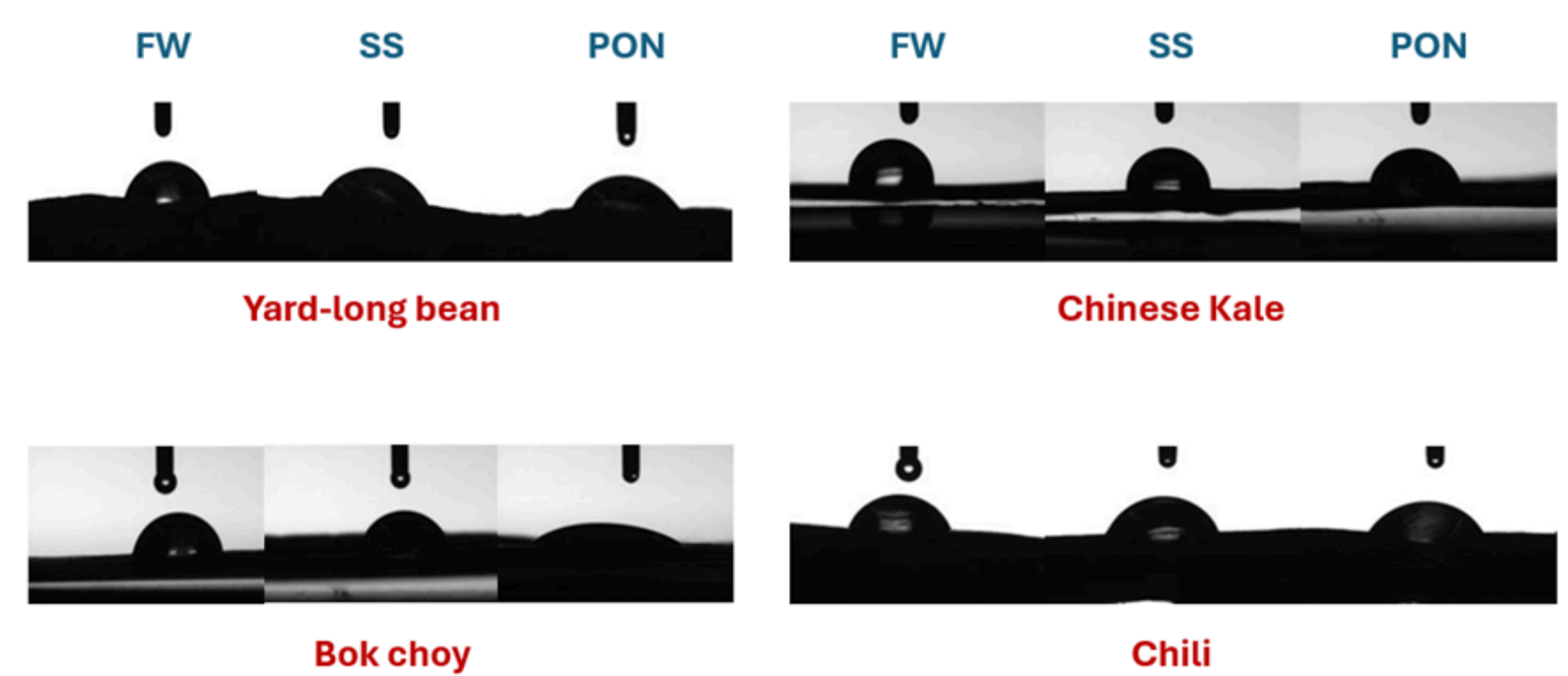


Fig. 2 Contact angle photo of different vegetables after washing with peppermint oil nanoemulsion (PON), Surfactant control (SS) and Filtered water (FW)

The hydrophobic nature of epicuticular wax is associated with higher contact angles, limiting the spreading of aqueous solutions on plant surfaces. The composition and microstructure of wax layers, such as tubular or platelet formations, enhance surface hydrophobicity. This explains the limited wettability improvement observed in Chinese kale and highlights the importance of considering surface wax characteristics when designing washing protocols [3].

3 Results and Discussion

Peppermint oil nano emulsion

- Mean droplet size: 241 ± 6.58 nm
- Polydispersity index (PDI): 0.158
- Zeta potential: -39.33 mV

Optical microscopy (1000×) showed that peppermint oil droplets were spherical, finely dispersed, and uniformly distributed in the aqueous phase, with sizes below $10 \mu\text{m}$. No phase separation or sedimentation was observed after 5 days of storage, indicating good physical stability [1].

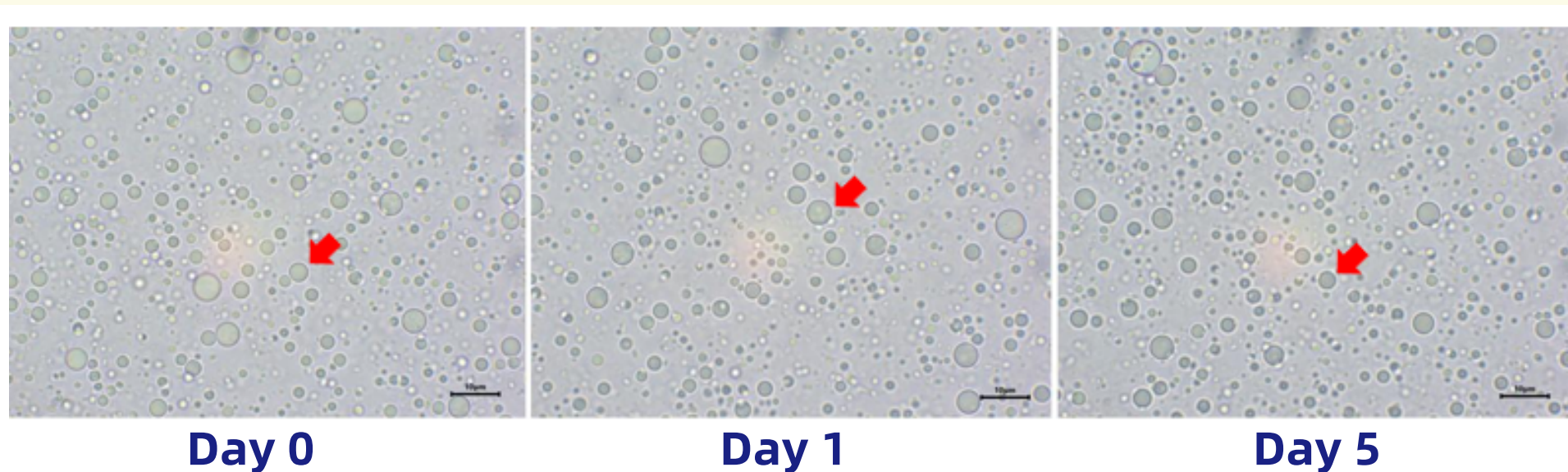


Fig. 1 Optical microscopy (1000×) images showing the morphology of peppermint oil droplets suspended in the aqueous solution on day 0, 1, and 5 after preparation

4 Conclusions

- Surface wettability depends on vegetable surface properties and washing formulation.
- Peppermint oil nanoemulsion (PON) reduced contact angles more than water or surfactant alone by lowering interfacial tension.
- Vegetables with less dense wax layers showed better wettability, while Chinese kale remained hydrophobic.
- Results highlight the role of surface morphology and the potential of essential oil nanoemulsions for improved vegetable washing.

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