

Evaluation of potential multiscale mechanism of ultrasound-assisted mass transfer in porous medium: experiment and modeling on this intensified process

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Enhancement effect of ultrasound on mass transfer has been widely demonstrated and applied to extraction of bioactive compounds from natural plants, and this phenomenon was commonly attributed to cavitation damage presently. The purpose of this study is to propose a multiscale mechanism to supplement the theory of ultrasound-assisted extraction. Green coffee beans (GCB) were chosen as the experimental material to investigate the interactions of ultrasound and micropores on extraction as its internal structure would burst under overheating. First, the influences of ultrasound power, particle size and extraction time on total phenolics yield of GCB were studied by single factor experiment and response surface method. Afterwards, the property changes of roasted coffee beans (RCB) were comprehensively compared including pore morphology and phytochemicals contents (caffeine, trigonelline, chlorogenic acid and caffeic acid). Then the extraction yields (expressed as the percentage of total content) of GCB, RCB-120 μ m and RCB-180 μ m were measured along with 30 min. The differences of extraction rate and mass transfer rate between each group were compared by coefficients of empirical kinetic equations. Besides, the effects of porous characteristic on extraction at different particle sizes and ultrasound power were also determined. From the point of view of extraction yield, these results indicated that the mass transfer rate of RCB was significantly higher than that of GCB and this phenomenon became more prominent with ultrasound-assisted, which means not only the sonoporation but also the synergistic effect between ultrasound and porous medium could facilitate the mass transfer during extraction. At last, the multiphysics simulation was applied to modeling the distributions of sound pressure and flow field within the macro extraction system at different ultrasound conditions. Based on these, the dilute solution diffusion of mediums with different porosity could be also visualized to reveal and validate the multiscale mechanism of ultrasound-assisted mass transfer in porous medium. Overall, this work proposed a potential explanation of ultrasound-assisted extraction, and this finding could not only supplement the deep theory but also inspire other processings which rely on mass transfer. Notably, the confined cavitation and slippage flow on gas-liquid-solid interfaces at microscale induced by ultrasound still need further investigation.