Antioxidant activity of extracts from ultrasound-assisted extraction of *Morinda citrifolia* and synergism with α-tocopherol

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*Morinda citrifolia* L. (Rubiaceae) has been used as folk medicine for centuries throughout the world. In this study, ultrasound-assisted extraction (UAE) technique was developed for the fast extraction of bioactive compounds from *M. citrifolia*. The experiments were carried out using face-centered central composite design with four independent variables. The optimum combination of ethanol concentration, solid-to-solvent ratio and amplitude and duty cycle of ultrasound was achieved after numerical optimization for the maximum yields (total phenolic content and total flavonoid content) and antioxidant activities (ABTS radical-scavenging capacity and DPPH radical-scavenging capacity). The reduced quadratic models developed for the experimental data were found adequate to describe the relationship between the extraction conditions with $p$ values $< 0.05$ and $R^2$ values above 99%. The optimum extraction conditions were as follows: ethanol concentration, 66%; solid-to-solvent ratio, 4:100 g/mL; amplitude, 21.6% and duty cycle, 0.9 W/s. These extraction conditions were tested and validated experimentally; the differences were found insignificant ($p > 0.05$) between the experimental and predicted values for all four responses. The antioxidant interactions between *M. citrifolia* extract (ME) from ultrasound treatment and α-tocopherol was investigated using isobolographic analysis. All combinations of ME to α-tocopherol (1/5, 1/3, 1/2, 2/3, 4/5) had varying effects on the antioxidant activity with fraction 2/3 being synergistic as assessed by using ABTS radical-scavenging capacity and DPPH radical-scavenging capacity. The fraction of 2/3 allowed decrease of 4.4 and 6.0 folds, respectively in the amounts of ME and α-tocopherol needed to achieve desire antioxidant activity.