Enhancement of biomass and calcium carbonate biomineralization of Chlorella vulgaris through Plackett–Burman screening and Box–Behnken optimization approach

ABSTRACT

The biosynthesis of calcium carbonate ($CaCO_3$) minerals through a metabolic process known as microbially induced calcium carbonate precipitation (MICP) between diverse microorganisms, and organic/inorganic compounds within their immediate microenvironment, gives rise to a cementitious biomaterial that may emerge as a promissory alternative to conventional cement. Among photosynthetic microalgae, Chlorella vulgaris has been identified as one of the species capable of undergoing such activity in nature. In this study, response surface technique was employed to ascertain the optimum condition for the enhancement of biomass and $CaCO_3$ precipitation of C. vulgaris when cultured in Blue-Green (BG)-11 aquaculture medium. Preliminary screening via Plackett–Burman Design showed that sodium nitrate ($NaNO_3$), sodium acetate, and urea have a significant effect on both target responses ($p < 0.05$). Further refinement was conducted using Box–Behnken Design based on these three factors. The highest production of 1.517 g/L C. vulgaris biomass and 1.143 g/L of $CaCO_3$ precipitates was achieved with a final recipe comprising of 8.74 mM of $NaNO_3$, 61.40 mM of sodium acetate and 0.143 g/L of urea, respectively. Moreover, polymorphism analyses on the collected minerals through morphological examination via scanning electron microscopy and crystallographic elucidation by X-ray diffraction indicated to predominantly calcite crystalline structure.

Keyword: Chlorella vulgaris; Box–Behnken design; Plackett–Burman design; Biomass; Calcium carbonate; Biomineralization; Response surface methodology