Liquid Impregnation into Plant Food Materials Promoted by High Hydrostatic Pressure

(高圧処理によって促進される植物食品素材への液体含浸)

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Abstract

Liquid impregnation can enhance sensory and nutritional qualities of plant food products, and conventional liquid impregnations improve mass transfer of water and solute into plant food materials. However, impregnation processes may damage cell membrane and tissue, which deteriorate the quality of products. It is necessary to find an alternative process to promote impregnation, while minimizing quality loss. Besides, quantitative methods are necessary to evaluate impregnation efficacy, cell membrane, and tissue damages for optimization of the impregnation processes.

In this study, high hydrostatic pressure (HHP) treatment was applied to promote the liquid impregnation into plant food materials. Apple and carrot were selected as typical fruit and vegetable materials with porous and nonporous structures, respectively. The effect of HHP treatment, and combined use of vacuum heat sealing (VHS), subsequent storage, and HHP treatment on the apple and carrot impregnations was investigated to explore their feasibilities regarding sufficient impregnation and suppression of the cell membrane and tissue damages. The results can be summarized as follows.

(1). Quantitative methods for impregnated plant food materials were established. Impregnation efficacy was quantified as impregnation ratio by image analysis, color (yellow, green, blue, or red) and concentration (apple: 0-0.15 %; carrot: 0-5.0 %) of pigment solutions have been optimized for distinguishing color difference. It was recommended to use 0.05 % red and 3.0 % blue pigment solutions for apple and carrot, respectively. Cell membrane damage was quantitatively evaluated as size of Cole-Cole circular arc (SCA) by electrical impedance spectroscopy (EIS). Water mobility and distribution have been quantified as relaxation time and area fraction by low-field nuclear magnetic resonance (LF-NMR). Tissue damage was evaluated by texture analysis. The

methods established in this study were applied thereafter.

(3). Apple was impregnated with 0.05 % red pigment solution by vacuum heat sealing (VHS) and/or HHP treatment (100-600 MPa, 25 °C, 5 min). Effect of storage after VHS on the impregnation efficacy was also studied. Impregnation of apple was sufficiently achieved by a combination of VHS and 100 MPa treatment, while minimizing the cell membrane and texture damages. HHP treatment achieved 100 % impregnation regardless of storage time after VHS. VHS and subsequent HHP treatments significantly damaged the cell membrane of apple. Meanwhile, the cell membrane damages between VHS and VHS+100 MPa samples were comparable. Probably due to water uptake after impregnation, relaxation times of semibound water (T_{22}) and free water (T_{23}) were significantly increased after VHS and VHS+100 MPa. As for the texture analysis, breaking strain (deformability) significantly increased after VHS+HHP treatment (200-600 MPa), indicating further damage resulting in increased deformability as compared with that after VHS and VHS+100 MPa treatment.

(4). Carrot was impregnated with 3.0 % blue pigment solution by vacuum heat sealing (VHS) and/or HHP treatment (100-600 MPa, 25 °C, 5 min). After optimal impregnation (i.e., VHS, storage for 120 min, and 100 MPa), the impregnation ratio reached 100 %, while the parameters for damages of cell membrane and tissue were comparable with those of fresh carrot. HHP treatment significantly improved the impregnation efficacy, where the impregnation ratio of VHS+S_0+100 MPa (98.6 ± 0.9 %) was drastically higher than that of VHS+S_0 (28.9 ± 6.6 %). The SCA_n of VHS+100 MPa sample was almost comparable with that of fresh control samples, and the SCA_n was significantly reduced by HHP treatments at 150-600 MPa. As for the texture analysis, normalized breaking stress and strain of 100 MPa-treated samples were almost comparable with those of control samples. Further severe texture damages were observed at 200 MPa and higher.

These results suggest that a combination of VHS, storage time for 120 min, and HHP treatment can be applied to process high-quality apple and carrot for sufficient impregnation, with cell membrane and tissue damages being minimized. In addition, quantitative methods for the impregnated products were established and can be applied to apple and carrot, which have distinct structural features. It may be of further interest to study HHP-assisted liquid impregnation by using other fruits and vegetables for optimizing their impregnation efficacy, cell membrane damage, and texture deteriorations.

Key words: Plant food materials; Impregnation; high hydrostatic pressure; Electrical impedance spectroscopy; Low-field nuclear magnetic resonance.