Impact of lipid co-isolation and processing strategies on the yield and foaming functionality of soybean okara protein isolates

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Soybean okara, the insoluble residue from soy drink and tofu production, represents a protein source that promotes circularity in the food system if effectively valorized. However, its valorization is hampered by a low protein extractability. To overcome this, processing strategies that allow efficient recovery of functional proteins are required. This study investigated particle size reduction, hexane defatting, and ultrasound-assisted protein isolation (extraction at pH 9.0, precipitation at pH 4.5), either alone or in combination, with the aim to improve the yield, purity, and foaming functionality of okara protein isolates. By comparing produced isolates with varying protein purity and lipid content, insights were gained into the role of co-isolated lipids in hampering the foamability of okara proteins.

Without using processing strategies, protein recovery from okara was less than 10%. An ultrasound-assisted process (2.5 W/mL for 5 min) produced isolates with a recovery of 35% and purity of 45 g/100 g DW (dry weight). However, these isolates exhibited a poor foamability of less than 20% at 5.0 mg protein/mL (pH 7.0). This was hypothesized to be due to the aggregated state of the proteins and/or lipid co-isolation. Therefore, okara particle size reduction by ball milling was applied to further improve the protein recovery and to increase the lipid removal efficiency. Indeed, the lipid removal efficiency of hexane defatting increased from 45% for non-ball-milled okara to 70% for ball-milled okara, likely due to disruption of cellular structures, as microscopically observed. Ball milling also improved the protein recovery using the ultrasound-assisted isolation process from 25% to 43% for defatted okara. Moreover, with or without hexane defatting, isolates from ball-milled okara differed in purity (75 g/100 g DW and 45 g/100 g DW, respectively), reflecting different extents of lipid co-isolation. Foamability at 5.0 mg protein/mL (pH 7.0) was more than 3-fold higher for higher-purity isolates compared to low-purity isolates (70% and <20%, respectively), while protein aggregation states in terms of non-covalent and disulfide bond mediated interactions remained largely similar. This indicates that lipid co-isolation, rather than protein aggregation, is the primary cause of the impaired foaming functionality of okara protein isolates, likely via anti-foaming effects. Foaming data were further supported by analysis of protein adsorption dynamics and dilatational rheology at the air-water interfaces.

In summary, our findings demonstrate that reducing lipid co-isolation enhances the purity and foaming performance of okara protein isolates. These insights are of great relevance for both academic and industrial applications. Future research should focus on unraveling the mechanisms by which co-isolated lipids destabilize protein-based foams.

Keywords:
soybean okara, soy protein, ball milling, defatting, ultrasound, lipid, protein aggregates, foam