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Valorisation of Apple Pomace Pectin Through Tailored Acid Hydrolysis: Structural Characterisation and Application in Gummy Candies

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Abstract

Apple pomace is a major byproduct of the juice processing industry and an excellent sustainable source for pectin extraction. This study aimed to extract pectin from apple pomace utilising three different acids for hydrolysis: hydrochloric acid (HCl), citric acid (CA), and glucono-δ-lactone (GDL), and compare their efficacy with commercial apple pectin (CAP). The extracted pectins were characterised for extraction yield, colour, and antioxidant activity (ABTS assay). Subsequently, these pectins were utilised to formulate gels with varying sugar concentrations (40%, 50%, and 60%), which were evaluated for colour, texture, and rheological properties to determine the optimum formulation. Finally, the optimised pectin was utilised alongside commercial pectin to develop gummy candy model systems by incorporating three different structural agents: starch, gellan gum, and carrageenan, resulting in distinct formulations comprehensively analysed for their texture, rheology, and colour attributes. Extraction yield was significantly influenced by the acid type used in hydrolysis, with GDL achieving the highest yield (20.63%), outperforming HCl (18.37%) and CA (17.25%). GDL-extracted pectin also demonstrated superior antioxidant capacity (3.81 mM TE/mL) compared to HCl (3.59 mM TE/mL) and CA (3.56 mM TE/mL); notably, all acid extractions significantly outperformed CAP (2.61 mM TE/mL). Regarding colour, CA and GDL extractions yielded remarkably brighter pectins (L* of 91.15 and 87.13, respectively) than CAP (72.96) and HCl (68.00), indicating a purer quality. Textural and rheological analyses of the initial gels showed that increasing sugar from 40% to 60% drastically enhanced hardness and the storage modulus (G'), approaching a 1000 Pa threshold at 60% sugar. At this optimum level, GDL-extracted pectin gels achieved a well-structured hardness of 5.686 N, outperforming CAP (4.821 N) and CA (1.697 N) while exhibiting a highly stable, frequency-independent rheological profile. Consequently, the GDL-extracted pectin formulation was selected as the optimum matrix. For the final gummies, hydrocolloid incorporation dictated both mechanical and rheological profiles. Frequency sweeps demonstrated that G' remained consistently higher than G'' (loss modulus) in all samples, indicating stable viscoelastic networks with high moduli (G' > 10^4 Pa for carrageenan) and a predominantly solid-like character. Carrageenan formulations achieved the highest G' and hardness values for both commercial (6.31 N) and GDL-extracted (5.87 N) pectin systems, followed by gellan gum and starch, establishing a strong correlation between dynamic rheology and destructive testing. Furthermore, GDL-extracted pectin yielded superior brightness (L*) in gellan and carrageenan matrices compared to commercial counterparts. Overall, this study demonstrates that pectin extracted from apple

pomace using tailored acid hydrolysis, particularly GDL, holds great potential as a functional, antioxidant-rich, and structural ingredient in confectionery products.

Keywords: Apple pomace, Pectin extraction, Acid hydrolysis, Glucono-δ-lactone, Pectin gel, Gummy candy, Rheology

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