CHAPTER 7

CONCLUSION AND RECOMMENDATION

7.1 Conclusion

This thesis presents a comprehensive exploration of optimizing bacterial cellulose (BC) production using kombucha fermentation technology based on Thai tea, followed by structural modification and application in jelly candy as a nutraceutical or functional food model.

7.1.1 Pre-Optimization of Bacterial Cellulose Production: Investigating Key Factors Affecting Yield and Properties

The research successfully optimized BC yield by leveraging different Thai tea substrates, additives, and carbon source combinations. Among the four tea types examined, Thai Red Tea (RTC) and *Assamica* Black Tea (BTC) demonstrated the highest BC production, with yields of 168.00 ± 2.93 g/L and 158.56 ± 3.96 g/L, respectively. Yield was further improved through the use of additives, particularly ethanol (RTC-EtOH), which produced 218.36 ± 12.85 g/L of BC. Among carbon source combinations, sucrose-glucose (RTC-SGlu) resulted in the highest BC yield at 259.54 ± 8.92 g/L, outperforming sucrose-dextrose (RTC-SD), although the difference was not statistically significant.

Subsequently, essential cultivation parameters, including initial pH, harvesting period, tea concentration, and cultivation method, were systematically studied. Optimal BC yield was obtained at an unadjusted initial pH of ~5.20, a tea concentration of 2%, and biweekly harvesting over four weeks in each separated experiment. Static cultivation proved most effective for producing uniform, dense BC pellicles, while shaking conditions enhanced water-holding capacity (WHC).

7.1.2 Optimization of Bacterial Cellulose Production from Thai Red Tea Kombucha Using Central Composite Design in Response Surface Methodology

Further statistical optimization through response surface methodology (RSM) developed a highly efficient formulation (RTC-V1) comprising 7.97% 9w/v) sucrose, 2.03% (w/v) glucose, 1.41% (w/v) tea, and 1.56% (v/v) ethanol, achieving a remarkable wet BC yield of 621.71 ± 24.06 g/L, representing a 238% increase compared to the RTC-SGlu sample. The optimized BC displayed desirable physical and chemical properties, including well-defined nanofiber morphology, high crystallinity, thermal stability, and strong mechanical performance.

7.1.3 Impact of High-Pressure Microfluidization Treatment on The Properties of Bacterial Cellulose Derived from Thai Red Tea Kombucha

To improve BC versatility, high-pressure microfluidization (HPM) was applied to reduce fiber size and tailor material properties. Treatment at 10,000 psi for 10 to 20 cycles effectively reduced fiber diameters from 37 nm to approximately 25 nm and decreased WHC from 96.58 ± 13.91 g/g to about 31 g/g. These modifications were confirmed through SEM, XRD, and TGA analyses, establishing HPM as a practical tool for producing bacterial cellulose nanofibrils (BCNFs) with controlled structural and functional characteristics.

7.1.4 Effects of Bacterial Cellulose Nanofibrils on Jelly Candy Properties and Bioactive Compound Profiles During Simulated Digestion

In the final phase, microfluidic-treated bacterial cellulose nanofibrils (BCNF) were incorporated into jelly candy (JC) to evaluate their effects on texture and bioactive compound bioaccessibility. BCNF did not affect appearance but reduced color a* and b* values as treatment cycles and concentration increased. Texture analysis showed BCNF increased hardness, gumminess, and chewiness while reducing adhesiveness, cohesiveness, and resilience; the BCH20 formula (5 g BCNF) achieved the best texture balance.

During digestion simulation, JC with vitamin E and BCNF (JC-VEBC) showed minimal or no release of active compounds, indicating limited bioaccessibility, whereas the sample without BCNF (JC-VENBC) exhibited the highest total phenolic content and better antioxidant release. The consistently low flavonoid levels across samples likely reflect low concentrations, suggesting more sensitive analytical methods are needed to confirm their presence. BCNF protected antioxidant activity in the vitamin C formulation (JC-VCBC) better than its non-BCNF counterpart (JC-VCNBC), but no antioxidant release was observed in JC-VEBC, possibly due to protective interactions. BCNF provided limited antioxidant protection in jelly candies containing butterfly pea flower powder (BF) and tomato extract (TOM). Overall, microfluidic BCNF influences texture and modulates bioaccessibility depending on the bioactive ingredient.

7.2 Recommendations

Building on the successful optimization of bacterial cellulose (BC) production from Thai red tea kombucha fermentation and its structural modification through high-pressure microfluidization, several avenues are recommended to advance research and application:

1) Scale-Up of Bacterial Cellulose Production

To meet future industrial needs, it is recommended that the optimized bacterial cellulose (BC) production process developed in this study be scaled up to pilot or industrial levels. The key parameters established—namely fermentation duration, substrate composition, and harvesting intervals—should be further validated under larger-scale conditions to ensure consistent yield, quality, and reproducibility. For effective scale-up, the implementation of real-time monitoring and process control strategies is also strongly advised.

2) Expanding Functional Food Applications and Bioactive Delivery

Future research should explore the interactions between bacterial cellulose (BC) nanofibrils and various bioactive ingredients—such as vitamins, antioxidants, and plant-based extracts—within different food matrices. This includes potential applications in beverages, gummies, dairy-based products, and other functional food systems. Understanding how BC influences the stability, release behavior, and bioaccessibility of these compounds during processing and digestion will be crucial for the development of targeted, health-promoting foods with enhanced nutritional value and consumer appeal.

3) In Vivo Evaluation of Digestibility and Health Benefits

Although in vitro digestion studies offered valuable preliminary insights into the effects of BC nanofibrils (BCNF) on bioaccessibility, in vivo studies are strongly recommended to validate these findings under physiological conditions. Such studies are essential to further evaluate the digestibility, safety, and health impacts of BC-enriched foods. They will also help clarify how BC interacts within the digestive system, its effect on nutrient absorption, and its potential role in modulating gut health. Ultimately, this will support the evidence-based development of BC as a functional ingredient in nutraceutical and health-oriented food products.

4) Product Development and Consumer Acceptance

Further research into the sensory attributes—particularly texture and mouthfeel—shelf-life stability, and consumer acceptance of bacterial cellulose (BC)-containing products is essential to ensure successful market introduction. Understanding consumer preferences, especially among target groups such as children, the elderly, and health-conscious individuals, will guide the development of formulations that meet their expectations. Additionally, expanding BC applications beyond jelly candy into diverse food formats, including functional beverages, dairy alternatives, and bakery products, can significantly broaden its commercial potential in the functional and health food markets.