CHAPTER 5 CONCLUSION

5.1 Conclusion

This research successfully developed a realistic Monte Carlo simulation model using PHITS to analyze the distribution of 10 MeV electron doses in ellipsoidal dragon fruit for phytosanitary applications. The systematic validation of the scanning horn electron beam source model against Riso Aluminum Wedge experimental data established a foundation of confidence with average deviations below 10%, well within the acceptable limits specified by ISO/ASTM 51649 standards.

The depth-dose profile analysis revealed that electron penetration characteristics in dragon fruit are primarily governed by beam energy and material density rather than geometric factors. The practical range (R_p) demonstrated remarkable consistency across different fruit sizes with mean 6.20 ± 0.16 cm and RSD 2.6%, confirming that the continuous slowing down approximation accurately predicts electron behavior in water-equivalent media. The double-sided irradiation configuration proved highly effective in achieving dose uniformity, with DUR values ranging from 1.15 to 1.32, representing improvement over single-sided irradiation where the mean DUR is 5.80. These values substantially exceed the requirements of international phytosanitary standards, which specify a maximum DUR of 2.5.

The statistical evaluation comparing simulation results with experimental measurements from BRIN revealed position-dependent accuracy. The middle position demonstrated excellent agreement with a mean relative deviation of 10.52%, with paired t-test showing no statistically significant difference (p = 0.1513). In contrast, surface positions exhibited larger deviations with values 30.12% for top and 33.67% for bottom with statistically significant differences (p < 0.001), primarily due to the homogeneous material assumption failing to account for density variations between skin and flesh.

The significant deviation between simulated and experimental surface doses can be partially attributed to the homogeneous material assumption failing to account for dragon fruit's distinctive scaled skin structure, which enhances electron backscattering at the surface and fundamentally alters the dose distribution pattern compared to smooth homogeneous models.

The D_{min} achieved in simulations with mean 380.97 ± 12.22 Gy, approached the recommended minimum dose for controlling *Bactrocera dorsalis* in dragon fruit. For the D_{max} with mean 470.34 ± 8.99 Gy remained well below the 1000 Gy threshold associated with quality degradation. This operational window demonstrates the feasibility of electron beam irradiation for preserving both treatment efficacy and product quality.

This research contributes significantly to the field of food irradiation physics by establishing PHITS as a reliable simulation tool for complex geometrical commodities, providing validated 3D dose distribution data essential for industrial process optimization. The methodology bridges the gap between theoretical radiation physics and practical phytosanitary applications, enhancing the credibility of computational approaches for regulatory acceptance in food safety protocols.

5.2 Suggestion

Based on the findings of this study, the following suggestions are proposed for future research:

1. Develop a more realistic geometric model by incorporating internal structures such as seeds and skin, and consider packaging effects by modeling the complete phytosanitary process including the product box and conveyor system.
2. Develop a more realistic geometric model with accurate density and composition variations between skin, flesh, and seeds.