SIMULATION OF ELECTRON DOSE DISTRIBUTION FOR DRAGON FRUIT PHYTOSANITARY USING ELLIPSOID MODEL WITH PARTICLE AND HEAVY ION TRANSPORT CODE SYSTEM

BACHELOR'S THESIS

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SIMULASI DISTRIBUSI DOSIS ELEKTRON UNTUK FITOSANITARI BUAH NAGA MENGGUNAKAN MODEL ELIPSOID DENGAN *PARTICLE AND HEAVY ION TRANSPORT CODE SYSTEM*

ABSTRAK

Penelitian ini bertujuan mengembangkan model simulasi Monte Carlo menggunakan *Particle and Heavy Ion Transport Code System* (PHITS) untuk menganalisis distribusi dosis elektron 10 MeV pada model elipsoid buah naga serta memvalidasi akurasi prediksi dosis melalui perbandingan posisi spesifik yaitu atas, tengah, bawah, serta evaluasi statistik terhadap data eksperimen. Simulasi dilakukan pada sembilan variasi ukuran buah naga dengan kombinasi tiga diameter vertikal yaitu (7,0; 7,4; 7,7) cm dan tiga kisaran massa (300, 350, 400) g dalam konfigurasi *double-sided irradiation*. Model *scanning horn* divalidasi menggunakan data eksperimental *Riso Aluminum Wedge* dengan deviasi rata-rata 2,55%. Hasil simulasi menunjukkan bahwa penyinaran dua sisi menghasilkan distribusi dosis yang seragam dengan nilai *Dose Uniformity Ratio* (DUR) berkisar antara 1,15 hingga 1,32. Seluruh nilai DUR berada di bawah batas maksimum 2,5 yang ditetapkan oleh ISO/ASTM 51649 untuk proses fitosanitari sehingga memenuhi kriteria keseragaman dosis yang dipersyaratkan. Rata-rata D_{min} 380,97 ± 12,22 Gy mendekati ambang batas fitosanitari 400 Gy yang direkomendasikan untuk inaktivasi *Bactrocera dorsalis*, sementara rata-rata D_{max} 470,34 ± 8,99 Gy berada di bawah ambang degradasi kualitas buah. Validasi statistik komprehensif dilakukan meliputi analisis Bland-Altman, uji-t berpasangan, dan perhitungan deviasi relatif. Hasilnya menunjukkan kesesuaian yang baik antara simulasi dan pengukuran eksperimen menggunakan dosimeter alanin pada posisi pusat geometri dengan deviasi relatif rata-rata 10,52% (p=0,1513). Namun pada posisi permukaan atas dan bawah ditemukan bias sistematik berupa underestimasi dosis sebesar (30-34)% (p<0,001) yang disebabkan oleh asumsi homogenitas material yang tidak menangkap efek *backscattering* elektron pada permukaan antara udara dengan jaringan buah.

Kata kunci: buah naga, distribusi dosis, *DUR*, fitosanitari, PHITS

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ABSTRACT

This study aims to develop a Monte Carlo simulation model using the Particle and Heavy Ion Transport Code System (PHITS) to analyze the distribution of 10 MeV electron doses in a dragon fruit ellipsoid model and to validate the accuracy of dose predictions by comparing specific positions, specifically top, middle, and bottom, as well as statistical evaluation of experimental data. Simulations were performed on nine variations of dragon fruit sizes with combination of three vertical diameters, consisting of (7.0, 7.4, 7.7) cm, and three mass ranges (300, 350, 400) g in two-sided irradiation configuration. The scanning horn model was validated using Riso Aluminum Wedge experimental data with mean deviation is 2.55%. The simulation results showed that two-sided irradiation produced uniform dose distribution with a Dose Uniformity Ratio (DUR) value ranging from 1.15 to 1.32. All DUR values were below the maximum limit of 2.5 set by ISO/ASTM 51649 for phytosanitary processes, thus meeting the required dose uniformity criteria. The average D_{min} 380.97 ± 12.22 approximated the 400 Gy generic phytosanitary threshold recommended for Bactrocera dorsalis inactivation, while the average D_{max} 470.34 ± 8.99 Gy is below the fruit quality degradation threshold. Comprehensive statistical validation was performed, including Bland-Altman analysis, paired t-tests, and relative deviation calculations. The results showed good agreement between the simulation and experimental measurements using alanine dosimeters at the geometric center with average relative deviation of 10.52% ($p=0.1513$). However, at the top and bottom surface positions, systematic bias in the form of dose underestimation (30-34) % ($p<0.001$) was found, caused by the assumption of material homogeneity that did not capture the backscattering effect of electrons at the interface between the air and the fruit tissue.

Keywords: dragon fruit, dose distribution, DUR, phytosanitary, PHITS