Biogenic Synthesis of Averrhoa bilimbi L. (Kamias) Flower Silver Nanoparticles and Their Mechanistic Induction of Apoptosis in HepG2 Cell Line: An Integrated in silico and in vitro Study

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Overexpression of BCL-2 and XIAP proteins inhibits caspase-mediated apoptosis in mutated cells, promoting survival and driving chemoresistance, leading to poor clinical prognosis, highlights the need for biogenic and low-toxicity interventions that reactivate programmed cell death. In silico bioactive compound investigation of drug potentiality, interaction of A. bilimbi (kamias) flower silver nanoparticles and in vitro evaluation of caspase-mediated apoptotic activity is the focus of this study. Simulations of molecular docking revealed that Galangin has the strongest binding affinity against the protein structures of BCL-2 and XIAP among other four ligands, indicating effective dual inhibitory property. Pharmacokinetic profiling further indicated a high predicted human intestinal absorption, optimal tissue distribution, high metabolic stability, low bioaccumulation risk, efficient excretion, non-mutagenic, and non-hepatoxic property, proving bioavailability and safety as potential anticancer agent. A. bilimbi AgNP extract exhibited a dose-dependent increase in fluorescence intensity and caspase-3 activation assert pro-apoptotic activity. The highest AgNP flower concentration tested (200 µg/mL) achieved approximately 75% of apoptotic induction relative to the Staurosporine, a commercial drug benchmark. One-way ANOVA and t-test were performed to compare the mean RFU values. Results reflect a $p<0.05$ between groups, confirming the effects of kamias flower AgNP extract. Collectively, these findings suggest that kamias flower AgNP exhibit significant potential as promising dual-target, biogenic nanotherapeutic candidate for cancer treatment. Further, in vivo validation is recommended to establish its efficacy and therapeutic potential in cancer therapies.

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