Synergistic effect between silver nanoparticles produced by green synthesis and lemongrass essential oil (*Cymbopogon citratus* (DC)) against *Candida albicans*

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INTRODUCTION

Nanotechnology is a field of science that is expanding and bringing together diverse fields, such as biology, engineering, physics, chemistry and materials science. Particles with sizes ranging from 1 to 100 nm are also studied as part of this field, in which scientific advances in the control of the physical and chemical properties thereof could revolutionize the treatment of various diseases. Essential oils (EO) and silver nanoparticles (AgNP) are from different class of substances. However, both has been studied due to its bactericidal, fungicidal and virucidal properties. The purpose of work was evaluate the synergistic activity of lemongrass (*Cymbopogon citratus*) essential oil associated with silver nanoparticles (AgNP) against *C. albicans*.

MATERIALS AND METHODS

The essential oil was extracted from the leaves (*Cymbopogon citratus*), while the AgNP were synthesized, purified and characterized by using non-toxic compounds (glucose, ribose and SDS) (green synthesis). For this study, 20 strains of *C. albicans* were seeded, purified and identified. Synergism between the lemongrass oil and the AgNP was evaluated by the disk diffusion protocol on Mueller-Hinton agar, supplemented with 2% glucose and 0.05% methylene blue.

RESULTS AND DISCUSSION

The AgNPs had a diameter of 73.64 ± 43.54 nm (Fig. 2(a, b)) for those produced from glucose and $126.1 \text{ nm} \pm 66.08$ nm (mean $\pm$ SD) for the route using ribose (Fig. 2(c, d)). The main constituents of the essential oil were geranial, neral and β -myrcene (Fig. 3). The AgNP prepared from glucose (G) and ribose (R) brought about an increase in the fungal growth inhibition area of 100% and 53%, respectively, compared to the oil used alone (Fig. 4) and Table 1.

Figure 1. Mode of action AgNP + EO

Figure 2. DLS (a), SEM (b) of AgNP-G. DLS (c), SEM (d) of AgNP-R.

RESULTS AND DISCUSSION

Figure 3. (a) The actual image of the *Cymbopogon citratus* plant used in the extraction of essential oil. (b) Essential oil obtained after extraction. (c) Graphical representation of the chemical structure of major constituents.

Figure 4. Potato agar plates with strain of *C. albicans* (left) and (right). Effect of essential oil (EO) and AgNP against *C. albicans*. 1. EO alone; 2. EO + AgNP-R; 3. EO + AgNP-G; 4. AgNP-G alone; 5. AgNP-R alone.

Yeasts (n)	Halo (mm) /geometric mean					Increased fold area ($\times 100$)	
	A	B		C		(B ² -A ²)/A ²	(C ² -A ²)/A ²
<i>C. albicans</i> (20)	EO	AgNP-G+EO	AgNP-R+EO	AgNP-G	AgNP-R	100	53
	18.9	26.8 ^a	23.4 ^b	10.7	1.2		

Table 1. Antifungal activity of essential oil (10 μ L) alone, AgNP alone (25 μ L) and AgNP (25 μ L) plus essential oil (10 μ L). EO- essential oil; EO plus AgNP significant compared to EO alone ^a $p = 0.004$. ^b $p = 0.033$, respectively.

CONCLUSION

This synergistic effect can be attributed to different mechanisms of action of the EO and AgNP (Fig 1). EO acts by destabilizing cell membranes and AgNP inactivate enzymes, DNA and other cellular components and prevent *C. albicans* from replicating, leading to death of the yeast. The synergistic effect of AgNP against bacteria was evaluated, and the results prove the synergistic action with known antimicrobials. This new combination (lemongrass essential oil + AgNP) has potential to be used in the treatment of its and other fungal infections, and can be used as an alternative product from renewable source.