

Hospital mattresses: Thermal disinfection against bacteria, fungi and virus

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Abstract: Disinfection protocols for medical items play an important role in the prevention and control of healthcare-associated infections. Regarding mattresses, disinfection with chemical products only cleans the surface, leading to failures in the execution of final processes of cleaning. This study aims to evaluate the antimicrobial activity of ECOSTOVE® Thermal Chamber for the disinfection of hospital mattresses. Microbiological analyses were carried out under different experimental conditions, considering microbial viability, treatment time and position of inoculum on mattress. *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Candida albicans* and Chikungunya virus were inoculated at five pre-defined positions on the external and internal areas of hospital mattresses. Imprints were done using RODAC plates, before and after heat treatment to evaluate colony-forming unit and microbial viability. The percentage of microbial inhibition obtained by heat treatment of the ECOSTOVE varied between 83.1 to 100%. The best results were observed for the enveloped Chikungunya (100% inhibition) and *C. albicans* (between 97.6 and 100%), followed by *K. pneumoniae* (85.4-100%) and *S. aureus* (83.1-99.1%). Due to the significant antimicrobial activity of ECOSTOVE, it can be integrated into standard hospital hygiene and cleaning procedures as a promising strategy in the control of healthcare-associated infections.

Keywords: Hospital mattress; Microbial control; Cross infection; Thermal treatment.

1. Introduction

Healthcare-Associated Infections (HAIs) affect millions of patients around the world each year, being responsible for high mortality rate and high expenditure of health systems. According to the World Health Organization, for every 100 patients hospitalized in developed and developing countries, 7 and 10 patients, respectively, are most likely to acquire at least one HAI [1].

HAIs can be prevented, and research shows that well-executed prevention and control programs in health care establishments can reduce these infections by up to 70% [2]. In this context, the contamination of hospital environments, mainly surfaces close to patients such as mattresses, bed tables and wheelchairs, can be reduced with improvement in cleaning and disinfection processes, since these areas can be sources of cross contamination between patients, by the presence of nosocomial microorganisms [3, 4].

In relation to patient mattresses, standard hygiene protocols require their disinfection with detergents and 70% alcohol after patient is discharged [5]. Nevertheless, this cleaning only occurs on the external area of the mattress, at the waterproof cover. However, the cover can present damages invisible to the human eye, leading to internal contamination. This fact highlights the importance of inspecting waterproof covers for damages as a disinfection protocol [6].

Damaged and damp mattresses have been associated with hospital infections. Prior reports highlight that pathogens in the internal foam can migrate to mattress surface during use [7, 8]. Mattress degradation is associated with unavoidable damage from liquid disinfectants and friction during cleaning, in addition to impaired zippers and micro-cracks due to abrasion [8].

In the literature, the disinfection of hospital items of patient use, such as mattresses, based solely on thermal processes such as a heating chamber has not been described. Here, we report the use of ECOSTOVE® Thermal Chamber to control the spread of pathogens in hospital mattresses. The strategy presented significant results as regards microbial load reduction in hospital mattresses.

2. Material and methods

2.1 Study design

The study is microbiological research (qualitative- exploratory-descriptive design) on the antimicrobial activity of ECOSTOVE Thermal Chamber in disinfecting hospital mattresses. The microbiological tests were carried out under different experimental conditions, considering microbial variability, treatment time and position of inoculum on mattress.

The ECOSTOVE is a Brazilian company, located in the city of Salto, state of São Paulo. Initially, the company developed thermal chamber for the heat treatment of automotive seats and upholstery and is currently focused on the thermal disinfection of hospital mattresses.

2.2 Experimental conditions of ECOSTOVE Thermal Chamber

The ECOSTOVE Thermal Chamber features rigid structure with galvanized sheet walls, presenting 3.400 mm high by 2.200 mm wide, with a volume of 11.500 cm³. The chamber conducts hot air at a temperature between 40 °C to 120 °C, produced by the electric motor. The test was conducted according to the following criteria for treatment temperature and time: 70 °C for 1 h 30 min.

The ECOSTOVE Thermal Chamber (Figure 1) allows its installation in the hospital. This equipment allows the disinfection of up to 16 mattresses in the same process, and can be located in a covered area, following these dimensions: 3m wide X 3m deep and X 3.5 meters high.

2.3 Microbiological assays

All microbial tests, before and after heat treatment in the chamber, were conducted with mattresses with D23-23 kg cm⁻³ density and size of 90x60x10 cm - Polyurethane, covered with nappa leather. Neither cleaning nor chemical disinfection process were realized in the mattresses before testing.

The investigation was conducted for the following microorganisms: *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Candida albicans* and *Chikungunya* virus. The strains used belong to the collection of microorganisms (clinical isolates) from the microbiology laboratory of the São José do Rio Preto School of Medicine – FAMERP.

Two analysis groups were considered: treated (subjected to thermal treatment in the chamber) and control (without thermal treatment). For the inoculation of the bacterial and fungal strains, ten positions (quadrants of 10 cm²) were fixed on each mattress, five located

on the surface and five on the inside (Figure 2). For the inoculation of Chikungunya virus, two surface areas and two on the inside were considered, both in the control group and in the treated group.

For inoculation in the internal points of the mattresses, cuts of the size of the quadrant were made and then the inoculum were deposited in the internal part (mattress foam). The cutout quadrants were reinserted into the mattresses so that it was completely sealed.



Figure 1: Demonstration of the ECOSTOVE Thermal Chamber and the position of hospital mattresses inside the equipment.

The inoculum of the fungal and bacterial microorganisms was prepared with nephelometric parameters according to the Mc Farland Scale (0.5), corresponding to a concentration of 108 colony-forming unit (CFU ml⁻¹), with 30 µl distributed in each quadrant in the internal and external mattress areas. Two diametrically opposed areas were investigated, before and after heat treatment generated by ECOSTOVE Thermal Chamber, totaling 40 samples of bacteria and 20 of fungi. For all groups, after inoculation, an imprint was performed using RODAC plates (MCTA Agar – Laborclin, Paraná, Brazil) aimed at assessing microbial viability based on CFU cm⁻² values for microbial growth. The plates were incubated at 35±2°C, with analysis of colony growth after 24 hours.

The Chikungunya virus culture was performed in cell Vero monolayers with incubation at 37°C and 5% CO₂ for 3 days. Posteriorly, the virus inoculum was prepared from cell cultures at a concentration of 1-2x10⁶ plaque forming unit (PFU ml⁻¹), being 30 µl distributed in Eppendorf tubes. This inoculum remained inside the tubes and was fixed on the external and internal areas of the mattresses. As control, the tube test was immediately placed in ice followed by cell culture. In relation to the treated group, after heating, the Eppendorf tubes were removed from the target points on the mattress, introduced into ice and transported to the research laboratory. Considering virus tests they were analyzed in cell culture to determine viral load expressed as PFU ml⁻¹.

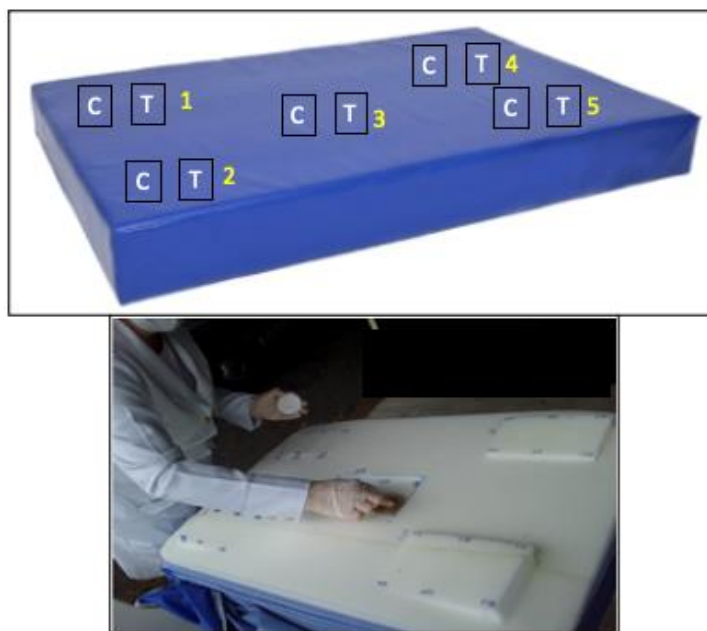


Figure 2: Demonstration of mattress areas submitted to microbiological investigation, surface and internal. Top image, control, and treated positions on the protective cover of the mattress. Bottom image, internal positions below the cover.

3. Results

The antimicrobial activities of ECOSTOVE Thermal Chamber against microorganisms were expressive, showing inhibition percentages between 83.1 and 100% when comparing the CFU between the control and treated groups. The best inhibition results were observed for Chikungunya virus followed by *C. albicans*, *K. pneumoniae* and *S. aureus*.

All variations observed in the number of CFU cm⁻² are shown in Table 1. Considering the original inoculum with a high load of microorganisms, 106 and 108 cells, microbial inhibition occurred independent of position on the mattress. The antimicrobial activity of the thermal chamber against *C. albicans* was above 97.6% inhibition, with intervals of 98.4 to 100% for internal areas, and 97.6 to 100% for external areas (Table 1).

For *K. pneumoniae*, with the exception of a sample with 85.4% inhibition, the others showed inhibition greater than 94%. In the internal and external areas of the mattress, the antimicrobial activity of the thermal chamber was remarkable, with inhibition values between 85.4 and 100% and 94.6 to 99.2%, respectively (Table 1). There was a reduction in the number of colony-forming units for *S. aureus* with percentages between 83.1% and 99.1%. The external areas had an inhibition of 95.7 to 99.1% and, for the internal areas, 83.1 to 98.8% (Table 1).

Considering the log values obtained before and after the heat treatment by ECOSTOVE Thermal Chamber, there was a reduction between 0.77-1.96 log CFU cm⁻² to the population of *S. aureus*, 0.83-2 log CFU cm⁻² to *K. pneumoniae*, and 1.72-1.84 log CFU cm⁻² to *C. albicans* in the surface areas of the mattresses. Reflecting inner areas of the mattresses, there was a reduction in the log values between 1.36-2 log CFU cm⁻², 1.26-2.11 log CFU cm⁻², and 1.61-1.95 log CFU cm⁻² to the populations of *S. aureus*, *K. pneumoniae*, and *C. albicans* respectively. Based on log values for all positions in the mattresses, the means were calculated and presented in the Figure 3 for *S. aureus*, *K. pneumoniae* and *C. albicans*, control and treated groups.

Table 1. Results of the microbiological tests for *S. aureus*, *K. pneumoniae* and *C. albicans*. Microbial growth expressed in CFU cm⁻², log reduction and percentage of inhibition, considering microorganism, sample positions on the mattresses and the time of sampling (before and after thermal treatment with ECOSTOVE thermal chamber).

| Microorganism | Positions | External Area | | | | Internal Area | | | | |
|----------------------|-----------|-------------------------|-------------------------|---|------------|-------------------------|-------------------------|---|------------|------|
| | | Control | Treated | Reduction | Inhibition | Control | Treated | Reduction | Inhibition | |
| | | (CFU cm ⁻²) | (CFU cm ⁻²) | (log ₁₀ CFU cm ⁻²) | (%) | (CFU cm ⁻²) | (CFU cm ⁻²) | (log ₁₀ CFU cm ⁻²) | (%) | |
| <i>S. aureus</i> | 1 | 90 | 2 | 1.65 | 97.8 | 1 | 115 | 5 | 1.36 | 95.7 |
| | 2 | 85 | 1 | 1.92 | 98.8 | 2 | 100 | 2 | 1.69 | 98.0 |
| | 3 | 100 | 7 | 1.15 | 93.0 | 3 | 99 | 1 | 1.99 | 99.0 |
| | 4 | 93 | 1 | 1.96 | 88.9 | 4 | 113 | 1 | 2 | 99.1 |
| | 5 | 89 | 15 | 0.77 | 83.1 | 5 | 130 | 3 | 1.63 | 97.7 |
| <i>K. pneumoniae</i> | 1 | 70 | 0 | 1.84 | 100 | 1 | 130 | 7 | 1.26 | 94.6 |
| | 2 | 92 | 1 | 1.96 | 98.9 | 2 | 128 | 2 | 1.80 | 98.4 |
| | 3 | 100 | 1 | 2 | 99.0 | 3 | 100 | 1 | 2 | 99.0 |
| | 4 | 89 | 0 | 1.94 | 100 | 4 | 122 | 4 | 1.48 | 96.7 |
| | 5 | 103 | 15 | 0.83 | 85.4 | 5 | 130 | 1 | 2.11 | 99.2 |
| <i>C. albicans</i> | 1 | 62 | 1 | 1.79 | 98.4 | 1 | 62 | 1 | 1.79 | 98.4 |
| | 2 | 70 | 1 | 1.84 | 98.6 | 2 | 83 | 2 | 1.61 | 97.6 |
| | 3 | 59 | 0 | 1.77 | 100 | 3 | 79 | 1 | 1.89 | 98.7 |
| | 4 | 65 | 0 | 1.81 | 100 | 4 | 90 | 0 | 1.95 | 100 |
| | 5 | 53 | 0 | 1.72 | 100 | 5 | 85 | 1 | 1.92 | 98.8 |

The results of the antiviral activity of ECOSTOVE thermal chamber against *Chikungunya* virus were exceptional, reaching 100% inhibition at all sampling points. In the surface and internal areas of the mattress, the viral load dropped from 2.75x10⁶ PFU ml⁻¹, 2.95x10⁶ PFU ml⁻¹, 1.62x10⁶ PFU ml⁻¹, and 1.6x10⁶ PFU ml⁻¹ to zero, after heat treatment (Figure 4).

4. Discussion and conclusion

During hospitalization, patients spend significant periods in contact with hospital mattresses, making them possible sources of nosocomial microorganisms. Although mattresses have a cover to protect the foam from body fluids, any surface damages such as cracks or damaged zippers, no matter how small, may allow fluids to enter the mattress [9].

Hospital protocols recommend that mattresses be cleaned after a patient is discharged and when occupied by same patient it should occur once a week. The cleaning process is done with chemical disinfectants associated with mechanical processes (friction) [5, 10]. The chemical product must not be extremely aggressive to avoid potential damage to the surface, requiring visual inspection of the mattresses to identify such damage. However, this cleaning process occurs only on the outside of the mattress, in addition to its malleable surface which can impair thorough cleaning, resulting in inefficient disinfection [6, 9].

Thus, procedures commonly used for terminal cleaning of mattresses may not allow complete disinfection, especially if the internal part is contaminated [11]. Resistant and non-resistant microorganisms have been identified on the cover and /or foam of hospital

mattresses, even after terminal cleaning [11, 12]. There are also reports of hospital infection outbreaks associated with pathogen transmission from mattresses [13, 14].

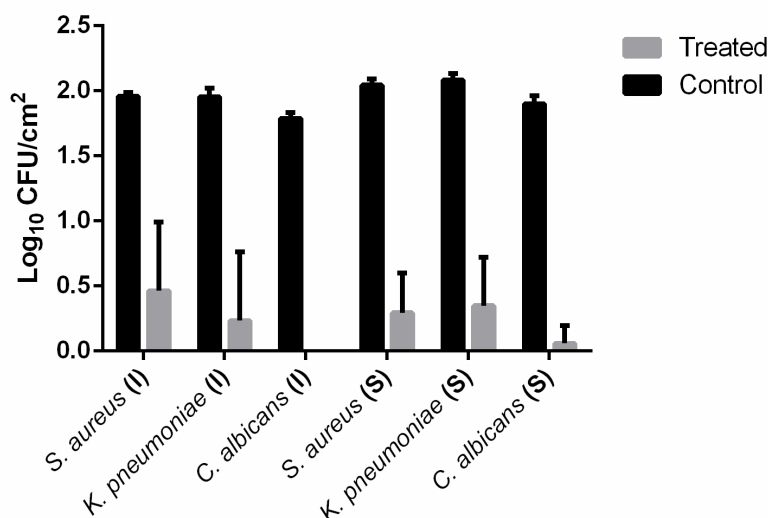


Figure 3: Results of the microbiological tests for *S. aureus*, *K. pneumoniae* and *C. albicans* according to the log values obtained before and after heat treatment with ECOSTOVE Thermal Chamber, considering the position of the inoculum on the mattresses. I: inside area of the mattresses. S: surface area of the mattresses. The bars corresponding to the mean of the log values obtained in the five inoculation positions. The lines corresponding to the standard deviation.

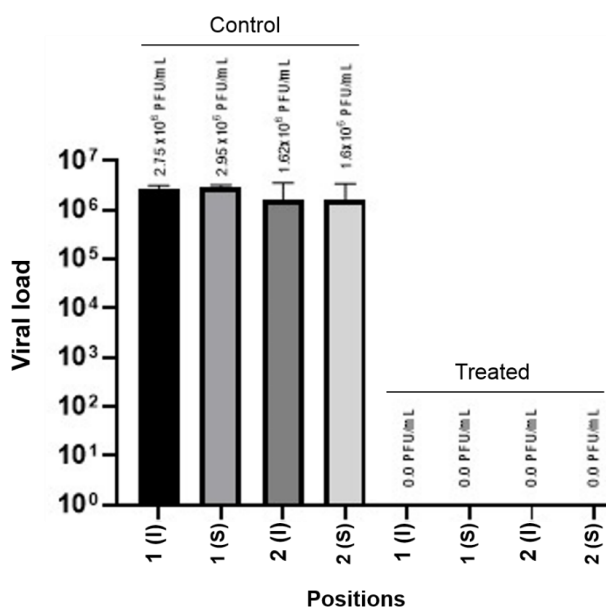


Figure 4: Results of the microbiological tests for Chikungunya virus. Viral load expressed in PFC ml⁻¹, considering the position of the inoculum on the mattresses and the time of sampling (before and after heat treatment with ECOSTOVE Thermal Chamber). I: inside area of the mattresses. S: surface area of the mattresses. The bars corresponding to the viral load. The lines corresponding to the standard deviation.

Yu et. al [9] analyzed the surface and inner parts of mattresses in nurseries and observed failures in mattress permeability and bacterial growth in 60% of them. In another study, bacterial growth was observed in 61.4% of hospital mattresses analyzed as well as

the identification of methicillin-resistant *S. aureus*; Vancomycin-resistant *Enterococcus faecalis*; *Acinetobacter baumannii* resistant to ciprofloxacin, ceftriaxone, and imipenem; *Pseudomonas aeruginosa* resistant to imipenem, ciprofloxacin, and ceftazidime; *K. pneumoniae* resistant to ampicillin, imipenem and ceftriaxone; *Escherichia coli* resistant to ampicillin, ceftriaxone and imipenem. In the same study, 54% of the microorganisms isolated on the mattresses were not associated with current occupant of the bed but rather previous occupants [15].

In the hospital environment, disinfection can be medium level with products based on chlorine, phenols, iodophors and alcohols, and low-level disinfection, in which basically 0.02% sodium hypochlorite and quaternary ammonium are used. However, for the disinfection processes to be successful, it is necessary for the chemical agent to maintain effective contact with the microorganisms present in the material to be disinfected so that microbial death occurs [16].

Studies indicate that the effectiveness of mechanical cleaning provides a decrease of 80% in the number of microorganisms and with the use of disinfectant it increases to 90% to 95%. Alcohols, for example, are more than 50% effective, but require an indicated exposure time of ten minutes at a 70% concentration, in which they must be applied and rubbed until drying, and this process is repeated three to five times [17-19].

Sodium hypochlorite, its effectiveness depends exclusively on its concentration and the time of exposure of the product, with concentrations varying between 0.01% and 5.25%. However, studies report greater effectiveness of sodium hypochlorite when compared to alcohol, with a cleaning rate greater than 95%, with action against biofilm [20, 21]. Regarding the properties and disadvantages of using disinfectants, 70% alcohol is the most available on the market, mainly due to its low cost, being considered the most accessible due to its germicidal action and lower toxicity, although it can damage plastic and rubber. Sodium hypochlorite is used for the disinfection of non-metallic surfaces in general due to its corrosive action, having a broad spectrum of antimicrobial activity, low cost and fast action, however, it is substantially inactivated in the presence of blood, thus requiring that the surface be clean before application [20, 22].

Given that thermal processes such as the use of thermal chamber for the disinfection of hospital beds have not been reported in the literature, we cannot compare our results. Although new technologies such as ultraviolet light, hydrogen peroxide vapor, ozone, and cold plasma jet, are being implemented as alternative disinfection processes for hospital environments, they only act on the surface, differing in performance with the thermal chamber studied which acts on both the interior and exterior areas [4, 23, 24]. The equipment ECOSTOVE and method used brings efficiency, optimization, automation, and safety in the process that today is flawed and with high costs throughout the chain of steps in the sanitization of these components.

In this context, the disinfection of mattresses and other hospital items in frequent contact with patients is essential for the prevention and control of healthcare-associated infections. Based on the results obtained in this study, we believe that ECOSTOVE thermal chamber acts as an effective tool in the elimination or reduction of microorganisms from hospital mattresses, all clinical importance. The chamber's antimicrobial action both on the inside and outside of the mattress was extremely satisfactory, with expressive reduction or elimination of different groups of microorganisms.

We believe that the ECOSTOVE Thermal Chamber can be installed in hospitals, as a new alternative to control of healthcare-associated infections. Based on the antimicrobial action observed in the results, the ECOSTOVE Thermal Chamber is an additional tool to standard procedures for cleaning and disinfecting hospital articles.

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Conflicts of Interest: None.

Supplementary Materials: None.

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