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Original article

Baby bottle and other disinfection devices used during travel to low electrical voltage (110V) regions: A practical experiment with implications for baby, lactating mothers and patient safety

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ABSTRACT

Background: Baby bottle steam disinfectors are important for the disinfection of devices used with baby nutrition, lactating mothers and respiratory patients (e.g. nebulisers). There have been no reports to date describing the effect of incorrect voltage on thermal performance. It was the aim of this study to evaluate thermal output, at low (110 V) voltage compared to 220 V. Such data will determine if variation in voltage, results in temperature differences, constituting a microbiological safety risk.

Methods: Thermal performance was evaluated by positioning calibrated thermocouple probes in multiple locations operating the device at 110 V and 220–240 V.

Results: Within the upper tray at 220–240 V, a maximum temperature ($Temp_{MAX}$) of 100 °C was achieved, with the unit remaining at 90 °C for 420 s ($A_0 = 3000$), whereas at 110 V, $Temp_{MAX} = 71.1$ °C, remaining at >70 °C for 630 s. Most importantly, when the lower tray of the device was examined at 110 V, $Temp_{MAX} = 48.6$ °C at one location, remaining >40 °C for 1140 s, whereas at 220–240 V, the lowest temperature achieved was 86.1 °C, with an A_0 equivalence of $A_0 = 60$.

Conclusions: This study showed that input voltage of 110 V to the baby bottle steam disinfector had an adverse effect on thermal performance, by not achieving intended time/temperature combinations, compared to 220–240 V. Parents of babies and infants need to be made aware of the microbiological safety risks of operating such devices outside the manufacturers' specification. For the safety of babies, infants, mothers and patients, users must ensure that such devices are always operated safely within manufacturer's specifications and instructions for use.

1. Introduction

The United States of America and the Caribbean are popular family holiday destinations for Europeans, especially family theme parks located on the East and West coasts. Around 3.8 million British nationals visit the US each year for a variety of reasons, including work, business and leisure [1]. In 2018, EU citizens made 10,288,682 trips to North America, which accounted for 9% of outbound trips made by EU residents outside the EU [2]. A significant proportion of these visits are made by families with babies, infants and lactating mothers, who require the facility of washing and disinfecting milk-based nutritional devices, including baby bottles, baby pacifiers (dummies), teething rings, as well as maternal milk-expression devices. Additionally, people with chronic respiratory conditions, such as cystic fibrosis (CF) also require facilities to hygienically maintain their respiratory devices, including nebulisers. Employment of domestic baby bottle steam disinfectors has become a popular choice with parents, as well as with CF patients on account of such disinfectors' versatility, availability, cost

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and most importantly, their ability to successfully disinfect travellers' equipment and devices from non-sporeforming microorganisms [3,4]. In Europe, these disinfectors are normally manufactured to take a mains electricity supply at a fixed voltage of 220–240AC 50 Hz and time/-temperature combinations are derived and validated based on these manufacturers' specifications, to provide optimal microbiological safety. However, these devices are not designed to be operated at alternative voltages, such as 110 V, which is the national mains electricity standard in North America and the Caribbean. Therefore, European travellers who bring along their electric baby bottle disinfector to maintain hygienic recycling of baby bottles, pacifiers breast milk collection/lactation devices and also those patients who travel with their disinfector device to maintain hygiene of their nebuliser, will be using the device outside of the manufacturer's specification. In real world terms, such travellers may try to use things out of the manufacturers' specification, without realising that such actions create microbiological safety issues, so it is vital that evidence is available to allow healthcare professionals to give robust and meaningful advice, in order help guide recommended practices/specifications, thus keeping baby, mum and patients safe.

There have been no reports to date describing the effect of incorrect voltage on the thermal performance of electric baby bottle disinfectors and therefore it was the aim of this study to evaluate disinfector performance, as measured by thermal output, at low (110 V) voltage, thereby emulating travelling conditions with respect to voltage supply (110 V versus 220 V). Such data will determine if variation in voltage, results in temperature differences, constituting a microbiological safety risk.

1.1. Materials and methods

The "*Nuby Natural Touch Steriliser and Dryer*" (Model number: BB1022-GS; 220–240 V; 50–60 Hz; 650 W) (Nuby UK Ltd. Tyne & Wear, UK) domestic steam disinfector was examined at low voltage (110 V). Full thermal performance data on the operation of this device at 220–240 V under manufacturer's instructions has been recently reported [3]. The device consists of five components, namely; the Base, Main Body, Lower Tray, Upper Tray and Lid. The lower tray is designed to hold five bottles upside down via locators, with the top tray used for accessories (teat and screw rings). The device can be operated solely in disinfection mode, as well as in disinfection + drying mode (short drying time [15 min s] or long drying time [30 min s]). In the drying mode, the fan dryer commences 2 min, after the disinfection mode has ended, without any further heating. All steam disinfection studies were performed at GPS Co-ordinates; 54588699, −5.942102 (54°35′19.3"N 5°56′31.6"W) at altitude 12 m above sea level. In brief, the device was disassembled and water (90 mls recommended fill volume) was placed in the heating element reservoir. The device was re-assembled and the cycle started, which lasted approximately 5 min, until all water had boiled off the element. The temperatures reached by the disinfector device were recorded using a combination of integrated probes (Tinytag Ultra 2, TGU-4020 with thermistor probe and Tinytag Ultra 2, TGU-4550 with a type K thermocouple), all which were formally calibrated. All probes had an expanded uncertainty of 0.08 °C and had been recently calibrated externally to ISO 17025:2005. Probes were placed at various geometrical locations on the upper and lower trays. Probes were programmed to record the temperature every 20–30 s, using the TinyTag Explorer software (TinyTag UK). Temperatures at several geometric locations within the steam disinfector were assessed over several cycles, when operated normally at 220–240 V AC mains voltage, taken from the hospital mains supply from the National Grid. Additionally, the above procedure was repeated by operating the baby bottle disinfector at 110 V AC. 110 V AC was achieved by employing a Bronson++ TI 1000 Watt 110v Transformer (Bronson++, Berlin, Germany), whereby mains AC electricity (220–240 V AC) was supplied to the stepdown transformer and reduced to 110 V AC, which was fed to the disinfector unit. A_0 thermal performance values were calculated, as described previously [5], where the A_0 value represents the most common method for disinfection of medical devices in the hospital setting and denotes the inactivation of microorganisms [5]. The A_0 value allows equivalent disinfection efficiencies to a reference time/temperature to occur at other disinfection temperatures [5].

2. Results

The thermal performance of the baby bottle disinfector at 220–240 V and 110 V are shown in Figs. 1–3. Fig. 1 shows the temperature profile of the upper tray at 220 V and 110 V, where there was a marked difference in maximum temperature reached by the device at 110 V. At 110 V, a maximum temperature of 71.1 °C was obtained, which was 28.9% lower compared to operating the device at 220–240 V. Fig. 2 shows the thermal performance of the baby bottle steam disinfector's lower tray at 220–240 V, where some variation can be seen, depending on the geographical location of the thermocouple probes. Likewise, in Fig. 3, wider variation can be seen in the lower tray of the device, whilst operating at 110 V.

3. Discussion

Domestic baby bottle steam disinfectors, when operated properly under manufacturers' specifications and guidance, offer a relatively inexpensive, simple, versatile and widely available technology for the elimination of common pathogens with baby and infant devices, as well as fomites within the hospital-at-home scenario, thereby enhancing patient safety [3]. In addition, these devices have been shown previously to eradicate respiratory pathogens, including the non-tuberculous mycobacteria (NTMs), from nebulisers in patients with cystic fibrosis [6] and are currently the preferred method of disinfection of such respiratory equipment, as advocated by recently published infection control and prevention guidelines [7]. Recently, our group reported on the thermal performance of these disinfectors in the hospital-at-home environment and showed that they reached extremely high temperatures capable of eradicating non-sporeforming bacteria [3]. However, this previous study did not examine reduced voltage parameters with steam disinfectors, particularly simulating when young families travelling and operating their disinfector whilst on holiday abroad, or when patients are travelling with their respiratory equipment abroad and are planning to use steam disinfection to maintain optimal nebuliser hygiene.

Voltage plays an important role in the performance of such baby bottle disinfector devices. Differences in performance relating to voltage can be explained using Ohms Law; Power (W) = Voltage^2 (V)/Resistance (R, ohms). As resistance will remain unchanged it can be ignored, changing the equation to: time factor = (Initial Voltage/New Voltage)^2 or $(240/120)^2 = 4$ times longer.

For the disinfector at 240 V at 650 W, Resistance = Voltage^2 (V)/Power, $240^2/650 = 88.6\ \Omega$. Assuming resistance stays constant, the power (W) of the disinfector at 110 V at 88.6 Ω equates to 136.6 W ($110^2/88.6$). It would take approximately 2min 35sec to start boiling 90 mL water (t = 30.14 KJ/0.14 KW) and 9 min 10 s for 225 mL (t = 77.02 KJ/0.14 KW), just over 4.5 times longer. [x 4.68 and x 4.58, respectively].

Successful cleaning and disinfection of baby and infant nutritional devices, as well as breast-pumps to express milk with lactating mothers, is important to avoid contamination of equipment with food and waterborne pathogens, as well as from pathogenic environmental organisms. This is particularly important as residual microbial contamination due to improper disinfection would allow for the survival of organisms which may proliferate in breastmilk or in infant formula and be exacerbated by these devices being carried remotely, often with a lack of properly maintained cold chain and temperature abuse. Steam disinfection, when performed optimally, is an excellent mode of disinfection, as it allows the terminal disinfection of plasticware, following

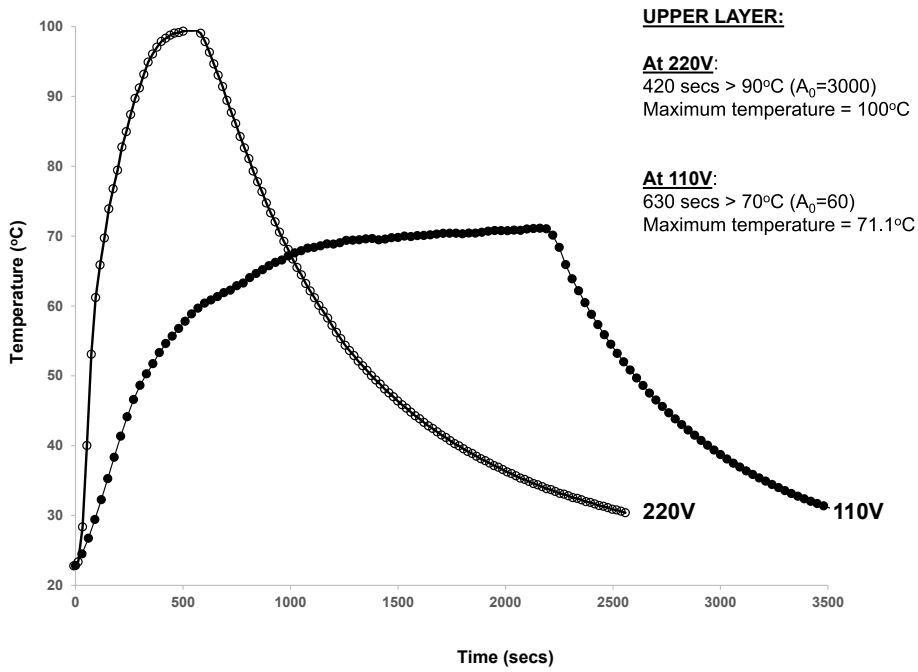

Fig. 1. Thermal performance of disinfector UPPER TRAY at 220 V and 110 V.

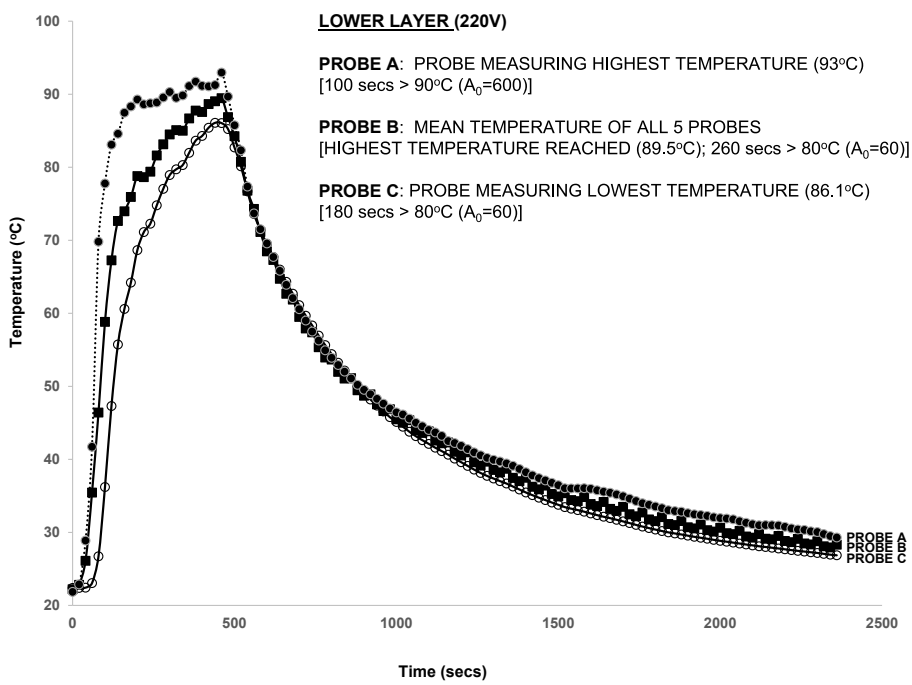

Fig. 2. Thermal performance of disinfector LOWER TRAY at 220 V.

washing and rinsing, thus allowing for the elimination of microbial contaminants, which may enter from sinks, tap water and the environment. The steam disinfector device also allows for the safe storage of disinfected plasticware until such equipment is next used.

Thermal performance of the steam disinfector operating outside of the manufacturer's specification and instructions at 110 V showed markedly lower temperatures (Figs. 1–3). This was most noted with the lower tray of the device, where the maximum temperature achieved was 48.6 °C, whereas at 220–240 V, the maximum temperature reached was 86.1 °C, with an A_0 equivalence of at least $A_0 = 60$. At this temperature, it is unlikely that any bacterial pathogens would be killed and thus, such organisms would be able to persist on equipment processed at the location within the disinfector at this voltage.

This study showed that alteration of input voltage to 110 V had an adverse effect on disinfector thermal performance. Therefore, education of the parents of babies and infants and patients of respiratory equipment is important, as highlighted in Fig. 4.

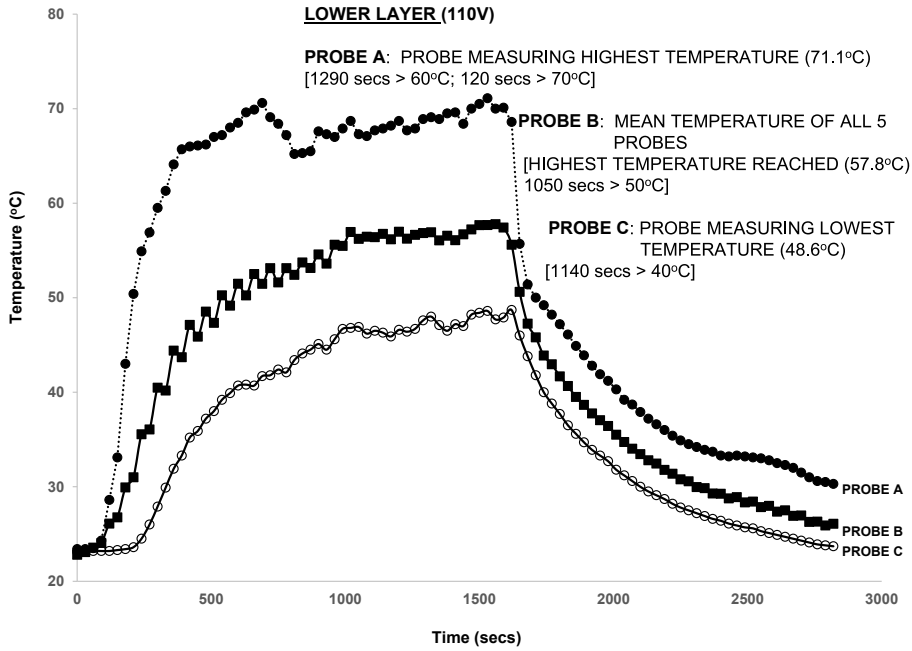

Fig. 3. Thermal performance of disinfector LOWER TRAY at 110 V.

- The importance of continuing with disinfection of baby/infant nutritional equipment and patients' respiratory equipment, when travelling or on holiday, at home or abroad,
- Baby bottle steam disinfector thermal performance is severely and adversely affected through using a fixed voltage disinfector (220-240V) with the incorrect voltage (110V), which will result in the device not producing equivalent heat output at the lower voltage compared to 220-240V,
- Simply using the correct plug adapter will not correct mains voltage supply problems for the disinfector whilst abroad,
- It is important to ensure that the disinfector is supplied with the recommended voltage in accordance with the device manufacturers' operating specifications, in order to perform optimally,
- When travelling to countries with voltage differences to the parents or patient's home country, it is impractical due to size, weight, cost and inconvenience, to carry a voltage transformer to step up the voltage from 110V to 220-240V, therefore parents of young children and patients should stop using their home device outside the manufacturers' specification (220-240V) and instead purchase a steam disinfector device locally which is compatible with local (110V) voltage or switch to an alternative form of heat disinfection, such as steam disinfection via a domestic microwave oven device [8].

Fig. 4. Real world affects and clinical consequences of altered (110 V) voltage supply to heat-based disinfection devices.
When travelling, parents of babies and infants, lactating mothers and patients should always ensure optimal operation of their steam disinfector device. When this is not possible, the disinfector device should not be used and an effective alternative sought, including the generation of heat/steam via an alternative means [8] to maintain disinfection vigilance.

4. Conclusion

This study showed that input voltage of 110 V to the baby bottle steam disinfector had an adverse effect on thermal performance, by not achieving intended time/temperature combinations, as at 220–240 V. Parents of babies and infants need to be made aware of the microbiological safety risks of operating such devices outside the manufacturers' specification. For the safety of babies, infants, mothers and patients, users must ensure that such devices are always operated safely within manufacturer's specifications and instructions for use.

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Jonathan Stirling: Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – review & editing. **John E. Moore:** Conceptualization, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Jane Bell:** Writing – review & editing. **Beverley C. Millar:** Conceptualization, Formal analysis, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors do not have any conflicts of interest with this manuscript.

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