INSIDE:
Study proves alcohol hand sanitiser is more efficacious as foam rather than gel

Prevalence of nasal carriage MRSA in ICU workers at Dos de Mayo Hospital, Lima, Peru

Sharp injury and healthcare workers: an experience from a tertiary care hospital in India

Cameroon book drive
ABSTRACT

The purpose of this study was to test the hypothesis that alcohol-based hand sanitizers delivered in a non-aerosol foam format have greater bactericidal efficacy than alcohol-based hand sanitizers delivered in thickened gel format.

The determination of antimicrobial efficacy was measured using an adapted version of the internationally recognised EN1500 test, an in vivo test for evaluating bactericidal reduction rates obtained with alcohol-based hand rubs.

Test formulations of alcohol-based hand sanitiser included Deb Instant-FOAM® Foaming Alcohol Hand Sanitizer [Product A], a thickened gel version of the same formulation [Product B] and a market alcohol gel [Product C] were compared. Final test data was evaluated utilising the Wilcoxon signed-rank test for comparing two related samples.

The results of the tests have led us to conclude that, according to our test conditions, the bactericidal efficacy on Escherichia coli of alcohol-based hand sanitizers [Product A] are significantly superior when the same formulation is delivered in foam format compared to thickened gel [Product B] and market alcohol gel [Product C].

INTRODUCTION

Alcohol-based hand sanitizers have been in use for decades in various formats. Originally provided as a viscous liquid used primarily in healthcare settings, more recent developments produced alcohol-based gels in the 1980s and non-aerosol alcohol-based foam in 2006. With the advent of more user-friendly formats, the use of alcohol-based skin sanitizers has expanded from healthcare to included widespread personal use, whether at home, in the workplace or in the community.

Both thickened gel and thickener-free foam format products are easy-to-use, safe (5), do not require water or wiping and are not susceptible to induce bacterial resistance (1). Alcohol-based hand sanitizers are also known for being effective on most pathogenic micro-organisms including Gram positive and Gram negative bacteria, yeasts, moulds and viruses (2,3,7).

Alcohols have a non-specific mode of antimicrobial action; they denature proteins, inhibit enzymes and induce lysis of the cytoplasmic membrane. They have no sporicidal activity but they inhibit the spore germination (6,8). In addition, because alcohols are characterised by a high exponent value ($\eta > 4$) efficacy can be dramatically affected by the concentration of alcohol in the formulation (1).
For a given format of alcohol-based hand sanitisers (liquid, gel, foam), some variations of efficacy level have been observed from format to format. In 2002, Prof A. Kramer et al. (6) identified the “limited efficacy of alcohol-based hand gels” when compared to alcohol-based hand sanitisers in the traditional liquid format.

Our hypothesis relates to the fact that thickening agents used in gel products (cellulose ethers, acrylic acid-based polymers) affect the microbial killing kinetics, by slowing down the diffusion of the alcohols through the cell membranes. Further, because the non-aerosol foam format of alcohol-based skin sanitisers does not include thickening agents, these products should wet and spread better and the efficacy for the foaming product is expected to be better than comparable gels.

To test our hypothesis, simply stated as “foam is better than gel”, this study compared the in vivo bactericidal activity of Deb InstantFoam® Foaming Alcohol Hand Sanitiser [Product A] versus a thickened gel version of the same formulation [Product B] and another market alcohol gel [Product C]. The compositions of the test-products are given in Table 1.

Prior to doing this, we also experimentally compared the spreadability of the alcohol foam [Product A] to its thickened gel version [Product B]. This experiment was conducted in order to reinforce our hypothesis that foam spreads better than gel; because of this, foam should also be more effective at covering a larger surface of skin and, therefore, at sanitising the skin better within a given length of time.

**EXPERIMENTAL COMPARATIVE EVALUATION OF THE SPREADABILITY**

The spreadability approach by measurement of the contact angle method

In order to obtain the highest possible level of antimicrobial efficacy, important parameters seem to be the wettability of the treated surface (the skin), and the wetting power as well as the spreadability, of the fluid (the skin sanitisers). We assumed that, for all these parameters, the higher the better.

The wetting and the spreading of a liquid on a solid surface are governed by a thermodynamic-related process (4,10). One criterion, which allows differentiating complete from partial wetting, is the contact angle (Fig. 1).

Perfect wetting is obtained if the contact angle qe = 0°, but this is pure theory as, in reality, only partial wetting (defined by qe > 0°) may be obtained. That said, three interfaces are involved in this process; the liquid, the surface and the air. Therefore, their respective interfacial tensions must be taken into account in the Young’s equation, which describes the wetting behaviour (Equation 1).

Although surface tensions of the test products were quite similar, the spreadability of the foam was much higher (S > 0) than that of the gel (S < 0), spontaneous spreading occurs and the equilibrium is obtained when the liquid spreads onto the solid. Then, 50 μl of test-product was put on the dorsal surface of the middle phalanx of the left index finger, and close-up pictures were immediately taken using a digital camera.

Contact angles were measured on the 20 pictures taken for each product (Fig. 2, Fig. 3). Then, spreadability could be calculated (Table 2) using equation Eq2.

EQUATION 1

\[
\cos \theta_{ev} = \frac{Y_{sv} - Y_{sl}}{Y_{lv}}
\]

Where \( \theta_{ev} \) = contact angle (0° ≤ \( \theta_{ev} < 180° \))

\( Y_{sv} \) = interfacial tension Solid-Vapour (mN/m⁻¹)

\( Y_{sl} \) = interfacial tension Solid-Liquid (mN/m⁻¹)

\( Y_{lv} \) = interfacial tension Liquid-Vapour (mN/m⁻¹)

EQUATION 2

\[
S = \frac{Y_{lv} (\cos \theta_{ev} - 1)}
\]

Where \( S \) = spreadability coefficient

\( \theta_{ev} \) = contact angle (0° ≤ \( \theta_{ev} < 180° \))

\( Y_{sv} \) = interfacial tension Solid-Vapour (mN/m⁻¹)

\( Y_{sl} \) = interfacial tension Solid-Liquid (mN/m⁻¹)

\( Y_{lv} \) = interfacial tension Liquid-Vapour (mN/m⁻¹)
the need of extra mechanical energy, whereas gel cannot. When observing foam on the hand prior to rubbing, it is noticeable that it simply spreads due to its own weight and as a consequence of the shape of the bubbles and the wettability of the liquid.

**The microscopic structure approach**

Soap foam is a polyhedral 3D network system (Fig. 4) of liquid and gas characterised by developed internal surface. The general physical characteristics of the foam (drainage, spreadability, durability, are related to the fact that bubbles are inter-connected.

To illustrate the increased spreadability of foam, a simple observation through the microscope (Olympus with apochromatic objectives) revealed that the structure of alcohol foam (Product A) was very different from the structure of soap foam (Fig. 4). The observed marble-like structures of alcohol foam might also explain the greater spreadability, with the possibility of the microscopic bubbles rolling on each other with low mechanical constraint.

**EXPERIMENTAL COMPARATIVE EVALUATION OF THE BACTERICIDAL EFFICACY**

**Principle:** The study was based on the comparison, using an adapted EN1500 test-method (11), of the bactericidal efficacy of three different doses of products A, B and C on 15 subjects (male and female, aged 20 to 50), with hands artificially contaminated with a calibrated suspension of *Escherichia coli* CIP 54.117 (*E. coli* K12 NCTC 10538).

Product A was tested as a foam and each dose (corresponding to respectively 0.7ml, 1.4ml and 2.1ml of liquid formulation) was dispensed from a 1L sealed cartridge.

Products B and C were tested as gel and each dose (respectively 0.7ml, 1.4ml and 2.1ml of gel) was pipeted onto hands using disposable sterile 1ml pipets (Sarstedt).

The results were calculated by comparing the level of initial hand contamination (initial value) with the level of residual contamination after all three sanitisations (final value). All results were expressed in terms of Log10 reductions and compared using the Wilcoxon statistical test.

No biocide-neutraliser was required for this test because the actives (alcohols only) evaporate without leaving any inhibitory residue on the skin after application.

**TABLE 2 Summary Calculations**

<table>
<thead>
<tr>
<th>Test-products</th>
<th>Foam A</th>
<th>Gel B</th>
<th>Gel C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active ingredients</td>
<td>Ethanol 65% w/w N-Propanol 10% w/w</td>
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<td>Ethanol 85% w/w</td>
</tr>
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<td>Non-active ingredients</td>
<td>Purified water Non-ionic surfactants Skin conditioning agent Glycerin</td>
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<td>Purified water Glycerin Thickener: Acrylates/C10-30 Alkyl Acrylate Crosspolymer</td>
</tr>
<tr>
<td>Characteristics:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscosity at 20°C (Brookfield LVII)</td>
<td>&lt; 100 cP</td>
<td>3540 cP</td>
<td>4400 cP</td>
</tr>
<tr>
<td>Surface tension at 20°C (Tensiometer Du Nouy)</td>
<td>22 mN/m⁻¹</td>
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**TABLE 1**

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Determination of Initial and Final Values of Each Dosage

For each individual test-dose, and prior to the test, all subjects were asked to wash their hands with an alkaline soap, without any further instructions, hands were dried with disposable paper. Hands were then sanitised by rubbing both sides of the hands with 3ml of propanol 60% v/v for one minute.

Immediately afterwards, hands were contaminated by rubbing both sides with 1ml of a calibrated suspension of *Escherichia coli* adjusted at 1.10^8 to 3.10^8 cfu/ml and then applied onto large Petri dishes containing TSA medium. Both sides of each hand were applied for five seconds on separate sets of Petri dishes (initial values).

Then, for each test involving one, two or three doses, hands were sanitised by rubbing both sides and then both sides were again applied for five seconds onto separate sets large Petri dishes containing TSA (Tryptoph-Soy-Agar).

Hands were washed and sanitised with isopropyl alcohol before each test.

Petri dishes were incubated at 37°C for 24 hours, and colonies were counted directly on the Petri dishes. The Petri dishes were each photographed (see typical examples of initial value on page 22).

Test Results

Comparative log reductions for one, two and three doses are shown in Graph 2. Summary of the Wilcoxon results are given in Table 3.

As shown in Graph 2 and Table 3, with one, two and three doses, the bactericidal efficacy (log reductions) of product A (alcohol foam) superior to the efficacy of product B (alcohol gel) and product C (alcohol gel).

Furthermore, the Wilcoxon statistics prove also that the differences between A and B and C are significant (for n = 15 and a level of significance p = 0.1).

It can also be noted that the tested products were generally more effective when applied onto the palm of the hands. The authors believe this is likely to be due to the fact that it is easier to rub the products on the palms (more strength and better homogeneity of the application) and/or to the presence of hairs (complex structures) on the back of the hands.

Conclusion

This study suggests that foam [Product A], spreads much better than that of thickened gel [Product B] and that of the market gel [Product C]. We also observed that the marble-like microscopic structure of the foamed product was different from that of soap as the bubbles were not interconnected.

This first part of the study, the spreadability test, reinforced our hypothesis that a foam-
ing alcohol-based hand sanitiser should have higher bactericidal power than that of thickened equivalent gel products but does not prove it. This is due to the involved gel thickener that is supposed to slow down the diffusion of the alcohols into the bacterial cells. Therefore, an in vivo antimicrobial study was necessary. A modified EN1500 test-method allowed us to demonstrate that Product A (applied as foam) onto the hands, has significantly higher (for n=15 testers and level of significance p=0.1) log reduction when applied in consecutive doses on hands than that of the same formulation (Product B) with thickener (average additional log reductions for the palm and for the back of the hands were respectively 1.437 and 0.591), and than that of the market alcohol gel C (average additional log reductions for the palm and for the back of the hands were respectively 1.584 and 0.715).}

REFERENCES


