RESEARCH ARTICLE

Personal care formulations demonstrate virucidal efficacy against multiple SARS-CoV-2 variants of concern: Implications for hand hygiene and public health

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Abstract

Despite considerable progress being made on vaccine roll out, practicing proper hand hygiene has been advocated as a consistent precautionary intervention against the circulating and emerging variants of SARS-CoV-2. Two variants of concern, namely beta and delta, have been shown to exhibit enhanced transmissibility, high viral load, and ability to escape antibody-mediated neutralization. In this report we have empirically determined the efficacy of selected personal care formulations from Unilever in inactivating the beta and delta variants of SARS-CoV-2 under simulated real-life conditions. All the formulations demonstrated greater than 99.9% reduction in viral infective titres which is comparable to inactivation of the original strain of SARS-CoV-2 virus tested under the same conditions. Therefore, it can be concluded that well-designed personal care formulations when tested under consumer-centric conditions, and with proven efficacy against the parent strain of SARS-CoV-2 will continue to be effective against extant and emerging variants of SARS-CoV-2.

Introduction

Generation of successive variants is an expected consequence of viral evolution and results primarily from extended viral persistence and propagation in the human population. While majority of genetic variants are of insignificant consequence to the human host, certain traits of a selected number of variants could prolong the pandemic and reintroduce risk of COVID-19 even among vaccinated individuals [1, 2]. In an analysis of the global spread of SARS-CoV-2 variants and estimated changes in the effective reproduction numbers (R_0) at country-specific level, it was clearly demonstrated that WHO-designated VOC have rapidly replaced previously circulating lineages with estimated transmissibility increases of 29%, 25%, 38% and 97% respectively for Alpha, Beta, Gamma, and Delta [3]. In addition to enhanced transmissibility, many of these VOC have shown increased potential for immune evasion / escape [4, 5].

Reinfection by Beta variant is also possible after COVID-19 as neutralization by convalescent serum was found to be significantly reduced [6]. Similarly, in-depth studies with the Delta variant have shown that reduction in neutralization titres using convalescent or vaccine sera may lead to some breakthrough infections. Additionally, the study results suggest that a proportion of unvaccinated individuals infected previously with Beta and Gamma variants may be at higher risk of reinfection with Delta [7].

Although vaccination remains the main-stay of protection from COVID-19, and extensive research is currently underway to understand the correlates of protection against SARS-CoV-2 and the circulating variants, health authorities have continued to emphasize the role of proper hand and respiratory hygiene in reducing the risks of infection and transmission among the susceptible population [8, 9]. Proper hand-hygiene is considered one of the most accessible and economic public health measures to reduce transmission of germs across community settings. Hand hygiene (practiced through use of soaps and sanitizers) when performed at all touchpoints where potential contact with the virus may occur greatly reduces the chance of the virus being transmitted via the hands to mouth, eyes, or nose and from hand to hand or hand to surface. This significantly diminishes the chance of getting infected as the viral particles are inactivated rapidly upon contact with the surfactants present in soaps and handwashes and with the alcohol present in the sanitizers. Multiple systematic reviews and meta-analysis have firmly established the role of good hand hygiene in low-, middle-, and high-income countries in reducing incidence of acute respiratory tract infections including seasonal influenza and viral pneumonia [10–12]. A recently published systematic review and meta-analysis suggested that several personal protective and social measures such as handwashing, mask wearing and physical distancing are associated with reductions in the incidence of COVID-19, with an estimated 53% non-statistically significant reduction from handwashing alone [13]. In similar lines we have previously established that marketed personal care formulations such as bar soap, liquid handwash, and alcohol-based sanitizer are capable of greater than 99.9% reduction of infective viral titre of the primary SARS-CoV-2 strain when tested under in-vitro conditions mimicking real life usage conditions [14]. In this brief report, we seek to establish and re-affirm the efficacy of selected and previously tested personal care formulations in inactivating two major VOC, namely Beta and Delta, under standardized test methods with conditions relevant to end-user.

Materials and method

Viruses and cell culture

Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) strains hCoV-19/South Africa/KRISP-EC-K005321/2020 (PANGO lineage B.1.351 / Beta VOC) and hCoV-19/USA/PHC658/2021 (PANGO lineage B.1.617.2 / Delta VOC) were commercially sourced from BEI Resources. Vero-E6 cells were obtained from ATCC (#CRL-1586).

Test products

The following commercially available personal care formulations from Unilever were tested—proprietary soap bar with minimum 30% (w/w) total soluble surfactant (soluble soap with added soluble surfactant); proprietary liquid cleansers (handwashes) with surfactant concentrations of 7.8% (w/w) and 12% (w/w) comprising of a combination of anionic (SLES, sodium lauryl ether sulfate / sodium laureth sulfate), amphoteric (CAPB, cocamidopropyl betaine) and non-ionic (CMEA, cocamide monoethanolamine) surfactants; proprietary alcohol-based sanitizer containing 65% ethanol (w/w).

Assay for virus inactivation

Fully formulated products were evaluated in suspension for virucidal efficacy based on the ASTM International Standard E1052-20. All tests were conducted at Microbac Laboratories, Inc., Sterling, Virginia, USA under Biosafety Level 3 conditions. Bar cleansers were prepared as 8% w/v solutions and assessed at $40^{\circ} \pm 2^{\circ}\text{C}$ for 20 seconds contact time. Liquid cleansers were prepared as 50% w/v solutions while hand sanitizers were evaluated neat; both were tested at $20^{\circ} \pm 2^{\circ}\text{C}$ for 20- and 10-seconds contact time respectively. Each test product was tested in triplicate. All controls (virus recovery, neutralization, and cytotoxicity) were performed according to ASTM standard. Host cells were examined microscopically for virus-specific cytopathic effects and product-specific cytotoxic effects. No cytotoxicity was observed for the dilutions for which cytopathic were considered.

Measurement of titre

The 50% tissue culture infective dose per mL ($\text{TCID}_{50}/\text{mL}$) was determined using the Spearman-Kärber method, and in cases where no virus was detectable, a statistical analysis using the Poisson distribution was performed to determine the theoretical maximum possible titre for the product. The average $\log_{10}$ reduction was calculated as the difference in TCID_{50} between the test product and virus recovery control.

Results

Inactivation of SARS-CoV-2 variants by personal care products

The virucidal efficacy of three classes of fully formulated commercial products namely bar soap, liquid handwash, and alcohol-based sanitizer was tested against two SARS-CoV-2 VOC namely Beta and Delta. As shown in Table 1, soap bar gave greater than equal to $\log_{10}$ 3.4 ($\geq 99.9\%$) reduction of SARS-CoV-2 Beta variant titre and greater than equal to $\log_{10}$ 3.2 ($\geq 99.9\%$) reduction of SARS-CoV-2 Delta variant titre. Next, we investigated the efficacy of liquid handwash with two different total surfactant contents of 7.8% and 12% and found that they reduced the input titre of Beta variant by greater than equal to $\log_{10}$ 3.7 ($\geq 99.9\%$) and by greater than equal to $\log_{10}$ 3.1 ($\geq 99.9\%$) of Delta variant. The contact duration of both the above sets of experiments were in accordance with the WHO's recommendation of 20 seconds of handwashing.

Table 1. Virucidal efficacy of a range of commercially available proprietary personal care formulations tested against selected SARS-CoV-2 variants of concern (VOC) at user relevant dilutions and contact duration. TCID_{50} , 50% tissue culture infective dose.

SARS-CoV-2 VOC	Product format	Product Description	Test temperature	Test concentration	Contact time	Initial viral load ($\log_{10}$ TCID_{50} / mL)	Output viral load ($\log_{10}$ TCID_{50} / mL)	$\log_{10}$ reduction
Beta (PANGO lineage B.1.351)	Bar soap	Minimum 30% (w/w) total soluble surfactant	$40^{\circ} \pm 2^{\circ}\text{C}$	8%	20 sec	7.56	≤ 4.13	≥ 3.43
	Liquid cleanser	7.8% surfactants (w/w)	$20^{\circ} \pm 2^{\circ}\text{C}$	50%	20 sec	7.37	≤ 3.61	≥ 3.76
	Alcohol based Sanitizer	65% alcohol (w/w)	$20^{\circ} \pm 2^{\circ}\text{C}$	100%	10 sec	7.04	≤ 2.61	≥ 4.43
Delta (PANGO lineage B.1.617.2)	Bar soap	Minimum 30% (w/w) total soluble surfactant	$40^{\circ} \pm 2^{\circ}\text{C}$	8%	20 sec	7.39	≤ 4.13	≥ 3.26
	Liquid cleanser	12% surfactants (w/w)	$20^{\circ} \pm 2^{\circ}\text{C}$	50%	20 sec	7.71	≤ 4.61	≥ 3.10
	Alcohol based Sanitizer	65% alcohol (w/w)	$20^{\circ} \pm 2^{\circ}\text{C}$	100%	10 sec	5.87	≤ 2.61	≥ 3.26

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In the absence of soap and water, the CDC recommends the use of alcohol-based hand rub containing at least 60% alcohol (w/w) for hand disinfection. Therefore, we evaluated alcohol-based hand sanitizer containing 65% alcohol (w/w) for virucidal efficacy against the SARS-CoV-2 VOC. As noted previously with hand washing, we believe that even for alcohol-based hand sanitizers it is critical to look at lower contact time-points which are more consumer relevant. In an observation of 50 episodes of hand hygiene with an alcohol-based hand rub of health care personnel working in an intensive care unit, it was recorded that the mean time of application (i.e., rubbing product onto hands) was 11.6 seconds with a median time of 10 seconds [15]. As shown in Table 1, the 65% alcohol-based sanitizer gave greater than equal to $\log_{10}$ 4.4 ($\geq 99.99\%$) reduction of SARS-CoV-2 Beta titre in 10 seconds while the same sanitizer achieved greater than equal to $\log_{10}$ 3.2 ($\geq 99.9\%$) reduction for Delta over the same contact duration. It is worthwhile to mention here that this discrepancy can be accounted for by the lower input titre that was employed for the Delta variant. All the test products reduced the infective titre of SARS-CoV-2 VOC below detectable limits by greater than 99.9% within 10 to 20 seconds of exposure and at dilutions relevant to end-user usage.

Discussion

As of September 6, 2021, reported cases of infection by Delta variant have crossed the million-mark having spread across 150 countries and accounting for almost 100% of new infections detected in the UK, USA and Denmark (data from GISAID). Here we established the virucidal efficacy of a range of marketed personal care products against both the Beta and Delta variants of SARS-CoV-2 and found them to be comparable to previously demonstrated efficacy of similar range of personal care products against the original SARS-CoV-2 strain. To the best of our knowledge, this is the first study to report inactivation of Beta and Delta VOC by commercially formulated personal care products for cleansing. Our results re-affirm the importance of hand-hygiene products in context of public health in both developed and developing economies. We believe that these results will lend confidence to members of the public and encourage them to continue to practice good hand hygiene. However, we should not lose sight of the fact that the world at this point is closely monitoring the spread and behaviour of multiple variants of interest (VOI) namely Eta, Iota, Kappa, Lambda and Mu, and numerous variants of high consequence, all of which have the potential to become future VOC [16]. Therefore, it is important to consider whether daily hygiene measures involving handwashing and hand-sanitization with soaps and alcohol-based hand-rubs should be expected to be effective as a public health intervention against emerging VOC. To answer this, we must look at the mechanism of action as related to viral mutations and their effects on fundamental virus particle structure and function.

Coronaviruses including SARS-CoV-2 are multimolecular assemblies of virally derived nucleic acids (RNA), proteins (spike, membrane, envelope and nucleocapsid), and host derived lipids (viral envelope). The nucleocapsid which encloses the viral genomic RNA is surrounded by the lipid bilayer in which the spike proteins, membrane glycoproteins, and envelope proteins are anchored. The different constituents of a mature virion are held together by non-covalent interactions. These non-covalent interactions are weak in nature and the virus relies on the host-derived envelope for its shape, integrity, and infectivity.

Surfactants present in soaps, liquid handwashes and detergents, are amphipathic molecules with a hydrophobic fatty acid tail and a hydrophilic head group. When the surfactants encounter the virus, they insert themselves into the lipid bilayer aided by the hydrophobic tails while the hydrophilic head groups remain outside in contact with water. The key tendency of a micelle-forming amphiphile inserting into a lipid bilayer is its preference for a locally curved

interface (its spontaneous curvature) that conflicts with the planar topology of a bilayer. This misfit causes a curvature stress. As more and more surfactant molecules wedge themselves into the ordered lipid bilayer, the viral envelope is ruptured thereby destroying the multimolecular assembly and rendering the virus inactive. When the surfactant concentration reaches the critical micellar concentration (CMC), micelles form around the disintegrated viral particles and remove them during rinsing [17, 18].

Most alcohol-based sanitizers contain either ethanol, 1-propanol, 2-propanol (IPA), or a combination of these molecules dissolved in water. Alcohol-based products inactivate SARS-CoV-2 virus particles by disrupting the structure of the proteins (a process called denaturing) on the surface of the virus. On exposure, alcohols displace the hydrogen bonds between amino acids that hold the viral proteins in shape, causing the proteins to lose their structure and function, thereby inactivating the virus. The water present in majority of hand sanitizers including the one studied here, plays a key role as proteins are difficult to disrupt by this method in the absence of water. This means that alcohol solutions are most effective when they contain 60–80% alcohol rather than 100%. Alcohols also disrupt the virus lipid membrane, but this occurs by a different mechanism. The higher the lipid content and the larger the virus particle, the more susceptible the virus is to alcohols. The alcohols used in sanitizers are small polar molecules that can interact with the surface of the lipid membrane. When alcohols are present in sufficient concentrations, they disrupt the ordered structure of the membrane, breaking open the viral particle [19–21].

Many other broad-spectrum virucidal agents such as organic acids, quaternary ammonium compounds, phenolics, and oxidizers are also known to disrupt the viral envelope, the viral genome, and the viral envelope proteins through physico-chemical modes of action [22–24]. The representative everyday hand hygiene products studied here do not contain such agents, but it would be expected that potent formulations containing the above-mentioned agents would also be minimally impacted by viral mutations given similar mechanisms of action to those ingredients discussed here. While the mutations giving rise to the VOC affect binding of the RBD to the receptor or antibodies at the molecular level, they do not alter the macromolecular property of spike protein which therefore remains susceptible to denaturation by soaps, surfactants, alcohols, organic acids, phenolic compounds and oxidizers. Similarly, the lipid components of the host-derived viral envelope remain completely permissive to disruption by surfactants and alcohol as they are unaffected by the mutations and remain unchanged across the variants. While the outcome of this in-vitro study against two VOCs re-assures the scientific community, public health experts, regulatory authorities, and the general public regarding the efficacy of commercially available hand hygiene formulations at user-relevant dilutions and duration of usage, this is not a clinical study measuring the impact of such non-pharmaceutical interventions against the emerged and evolving VOCs.

In conclusion, we have provided empirical proof that marketed personal care formulations have high virucidal efficacy against the SARS-CoV-2 variants Beta and Delta. This direct experimental evidence fully supports the broader argument that well-designed personal care hand hygiene products capable of delivering efficacy in user centric conditions which act through physico-chemical mechanism against the basic structure of the virus particle should be efficacious regardless of mutations [25]. Furthermore, we argue that due to broad-spectrum mode of action of these tested formulations, the continued practice of good hand hygiene practices with everyday used products such as those described herein holds significant promise as an easily accessible, economic and effective non-therapeutic public health intervention towards reducing the transmission of present and future variants of SARS-CoV-2 across communities and populations.

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References

1. Harvey WT, Carabelli AM, Jackson B, Gupta RK, Thomson EC, Harrison EM, et al. SARS-CoV-2 variants, spike mutations and immune escape. *Nat Rev Microbiol*. 2021 Jul; 19(7):409–24. <https://doi.org/10.1038/s41579-021-00573-0> PMID: 34075212
2. Yi H, Wang J, Wang J, Lu Y, Zhang Y, Peng R, et al. The Emergence and Spread of Novel SARS-CoV-2 Variants. *Front Public Health*. 2021; 9:696664. <https://doi.org/10.3389/fpubh.2021.696664> PMID: 34409009
3. Campbell F, Archer B, Laurenson-Schafer H, Jinnai Y, Konings F, Batra N, et al. Increased transmissibility and global spread of SARS-CoV-2 variants of concern as at June 2021. *Euro Surveill*. 2021 Jun; 26(24). <https://doi.org/10.2807/1560-7917.ES.2021.26.24.2100509> PMID: 34142653
4. Skelly DT, Harding AC, Gilbert-Jaramillo J, Knight ML, Longest S, Brown A, et al. Two doses of SARS-CoV-2 vaccination induce robust immune responses to emerging SARS-CoV-2 variants of concern. *Nat Commun*. 2021 Aug 17; 12(1):5061. <https://doi.org/10.1038/s41467-021-25167-5> PMID: 34404775
5. Garcia-Beltran WF, Lam EC, Astudillo MG, Yang D, Miller TE, Feldman J, et al. COVID-19-neutralizing antibodies predict disease severity and survival. *Cell*. 2021 Jan 21; 184(2):476–88 e11. <https://doi.org/10.1016/j.cell.2020.12.015> PMID: 33412089
6. Staub T, Arendt V, Lasso de la Vega EC, Braquet P, Michaux C, Kohnen M, et al. Case series of four re-infections with a SARS-CoV-2 B.1.351 variant, Luxembourg, February 2021. *Euro Surveill*. 2021 May; 26(18).
7. Liu C, Ginn HM, Dejnirattisai W, Supasa P, Wang B, Tuekprakhon A, et al. Reduced neutralization of SARS-CoV-2 B.1.617 by vaccine and convalescent serum. *Cell*. 2021 Aug 5; 184(16):4220–36 e13. <https://doi.org/10.1016/j.cell.2021.06.020> PMID: 34242578
8. Haque M. Handwashing in averting infectious diseases: Relevance to COVID-19. *J Popul Ther Clin Pharmacol*. 2020 Jul 12; 27(S Pt 1):e37–e52. <https://doi.org/10.15586/jptcp.v27SP1.711> PMID: 32757544
9. Krammer F. Correlates of protection from SARS-CoV-2 infection. *Lancet*. 2021 Apr 17; 397(10283):1421–3. [https://doi.org/10.1016/S0140-6736\(21\)00782-0](https://doi.org/10.1016/S0140-6736(21)00782-0) PMID: 33844964
10. Aiello AE, Coulborn RM, Perez V, Larson EL. Effect of hand hygiene on infectious disease risk in the community setting: a meta-analysis. *Am J Public Health*. 2008 Aug; 98(8):1372–81. <https://doi.org/10.2105/AJPH.2007.124610> PMID: 18556606
11. McGuinness SL, Barker SF, O'Toole J, Cheng AC, Forbes AB, Sinclair M, et al. Effect of hygiene interventions on acute respiratory infections in childcare, school and domestic settings in low- and middle-

- income countries: a systematic review. *Trop Med Int Health*. 2018 Aug; 23(8):816–33. <https://doi.org/10.1111/tmi.13080> PMID: 29799658
12. Warren-Gash C, Fragaszy E, Hayward AC. Hand hygiene to reduce community transmission of influenza and acute respiratory tract infection: a systematic review. *Influenza Other Respir Viruses*. 2013 Sep; 7(5):738–49. <https://doi.org/10.1111/irv.12015> PMID: 23043518
 13. Talic S, Shah S, Wild H, Gasevic D, Maharaj A, Ademi Z, et al. Effectiveness of public health measures in reducing the incidence of covid-19, SARS-CoV-2 transmission, and covid-19 mortality: systematic review and meta-analysis. *BMJ*. 2021 Nov 17; 375:e068302. <https://doi.org/10.1136/bmj-2021-068302> PMID: 34789505
 14. Mukherjee S, Vincent CK, Jayasekera HW, Yekhe AS. Antiviral efficacy of personal care formulations against Severe Acute Respiratory Syndrome Coronavirus 2. *Infect Dis Health*. 2021 Feb; 26(1):63–6. <https://doi.org/10.1016/j.idh.2020.09.003> PMID: 33012695
 15. Sickbert-Bennett EE, Weber DJ, Gergen-Teague MF, Sobsey MD, Samsa GP, Rutala WA. Comparative efficacy of hand hygiene agents in the reduction of bacteria and viruses. *Am J Infect Control*. 2005 Mar; 33(2):67–77. <https://doi.org/10.1016/j.ajic.2004.08.005> PMID: 15761405
 16. Yi K, Kim SY, Bleazard T, Kim T, Youk J, Ju YS. Mutational spectrum of SARS-CoV-2 during the global pandemic. *Exp Mol Med*. 2021 Aug; 53(8):1229–37. <https://doi.org/10.1038/s12276-021-00658-z> PMID: 34453107
 17. Falk NA. Surfactants as Antimicrobials: A Brief Overview of Microbial Interfacial Chemistry and Surfactant Antimicrobial Activity. *J Surfactants Deterg*. 2019 Sep; 22(5):1119–27. <https://doi.org/10.1002/jsde.12293> PMID: 32336911
 18. Nazari M, Kurdi M, Heerklotz H. Classifying surfactants with respect to their effect on lipid membrane order. *Biophys J*. 2012 Feb 8; 102(3):498–506. <https://doi.org/10.1016/j.bpj.2011.12.029> PMID: 22325272
 19. Eslami H, Das S, Zhou T, Muller-Plathe F. How Alcoholic Disinfectants Affect Coronavirus Model Membranes: Membrane Fluidity, Permeability, and Disintegration. *J Phys Chem B*. 2020 Nov 19; 124(46):10374–85. <https://doi.org/10.1021/acs.jpcc.0c08296> PMID: 33172260
 20. Golin AP, Choi D, Ghahary A. Hand sanitizers: A review of ingredients, mechanisms of action, modes of delivery, and efficacy against coronaviruses. *Am J Infect Control*. 2020 Sep; 48(9):1062–7. <https://doi.org/10.1016/j.ajic.2020.06.182> PMID: 32565272
 21. Ingolfsson HI, Andersen OS. Alcohol's effects on lipid bilayer properties. *Biophys J*. 2011 Aug 17; 101(4):847–55. <https://doi.org/10.1016/j.bpj.2011.07.013> PMID: 21843475
 22. Ijaz MK, Nims RW, de Szalay S, Rubino JR. Soap, water, and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2): an ancient handwashing strategy for preventing dissemination of a novel virus. *PeerJ*. 2021; 9:e12041. <https://doi.org/10.7717/peerj.12041> PMID: 34616601
 23. Ijaz MK, Nims RW, Zhou SS, Whitehead K, Srinivasan V, Kapes T, et al. Microbicidal actives with virucidal efficacy against SARS-CoV-2 and other beta- and alpha-coronaviruses and implications for future emerging coronaviruses and other enveloped viruses. *Sci Rep*. 2021 Mar 11; 11(1):5626. <https://doi.org/10.1038/s41598-021-84842-1> PMID: 33707476
 24. Xiling G, Yin C, Ling W, Xiaosong W, Jingjing F, Fang L, et al. In vitro inactivation of SARS-CoV-2 by commonly used disinfection products and methods. *Sci Rep*. 2021 Jan 28; 11(1):2418. <https://doi.org/10.1038/s41598-021-82148-w> PMID: 33510320
 25. Meister TL, Fortmann J, Todt D, Heinen N, Ludwig A, Bruggemann Y, et al. Comparable Environmental Stability and Disinfection Profiles of the Currently Circulating SARS-CoV-2 Variants of Concern B.1.1.7 and B.1.351. *J Infect Dis*. 2021 Aug 2; 224(3):420–4. <https://doi.org/10.1093/infdis/jiab260> PMID: 33993274