Scrubs with Bugs: Cleaning, Disinfecting, and Foaming Properties of Soaps Made with Sustainable Oils

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Abstract

Global population growth presents a variety of new challenges, including demand for products and the associated effects on climate. The palm oil industry has close ties to each of these trends, because it is used in a wide range of materials and demand is increasing. The establishment of oil palm plantations causes the destruction of rainforests, tropical peatlands, and regional biodiversity. At the same time, palm oil is often marketed as our best alternative for vegetable oil because it is inexpensive to grow and yields large quantities of lipids per hectare. For these reasons, palm oil is now found in innumerable products, from chocolate spreads to soap. It is this latter material that forms the focus of this study, which seeks to replace palm oil with lipids extracted from larvae of the black soldier fly, *Hermetia illucens*, also known as BSFL. This insect can be raised on nearly all types of organic waste, redirecting spoiled food and animal droppings from landfills where they might generate methane, a potent greenhouse gas. Plant-based oils that have been marketed as sustainable were also tested in this study, particularly those extracted from coconut (*Cocos nucifera*) and sunflower (*Helianthus annuus*). In all measures of this investigation, which included cleaning, disinfecting, and foaming abilities, soaps made from BSFL oil proved equal or superior to those made from palm oil, though those made with plant-based lipids currently have a more agreeable scent.

Introduction

Of all the chemical reactions that humans have devised, saponification may be one of the most important developments in human civilization. Thanks to this process, which makes soap, we can reduce levels of bacteria and prevent disease, as well as maintain the cleanliness that is considered a virtue to most people. Wherever civilizations thrived, it appears that soap was manufactured, starting in the Fertile Crescent region of Mesopotamia nearly 5,000 years ago and progressing through ancient Egypt, ancient Greece, and the Roman Empire (Vermeil *et al.*, 2019). Instructions to wash even appear in the Bible, as well as other religious texts. Ingredients for these cleaning mixtures include oils and fats that were derived from plants and animals, along with salts of a highly basic character that could be produced from materials such as wood ash (Vermeil *et al.*, 2019). An olive oil soap was first imported into England from Spain during the Medieval Period (Gibbs, 1939), when Europe benefitted from contact with Arab civilization and its emphasis on cleanliness (Ezenkwele & Roodsari, 2013). Such innovations may have helped Europe emerge from its devastating cycles of plague, along with other improvements in sanitation (Vermeil *et al.*, 2019).

The basic reaction that creates soap (Fig. 1) occurs when lye, a solution made from an alkaline salt such as sodium hydroxide, is combined with nonpolar lipids (fats) that are either saturated or unsaturated (Gibbs, 1939). The unique molecules that result from this process can dissolve in water due to the ionic character of the carboxylate (COO^-) region, while they also break the phospholipid bilayer of bacterial cell membranes because of a long, nonpolar tail (Burton et al., 2011). Saturated fats that can be used for soapmaking are generally solids at room temperature, while unsaturated fats are usually liquids. Combinations of these ingredients in different quantities helps to determine whether a soap will be solid (such as bath soap) or liquid (such as many hand soaps). Saturated fats are often derived from animal sources and liquid oils from plant-based sources, but palm oil, cocoa butter, shea butter, and coconut oil are solids at room temperature. Animal-derived products, including fats, generally have a higher carbon footprint than those lipids that are derived from plants (Drewnowski *et al.*, 2015), which is why the development of soaps from vegetable sources can help to meet increasing demand with a reduced environmental impact. Insect-based oil sources may also reduce overall greenhouse gas emissions, particularly when they eat products such as food waste that might otherwise be disposed in landfills or composted (Mertenat et al., 2019).

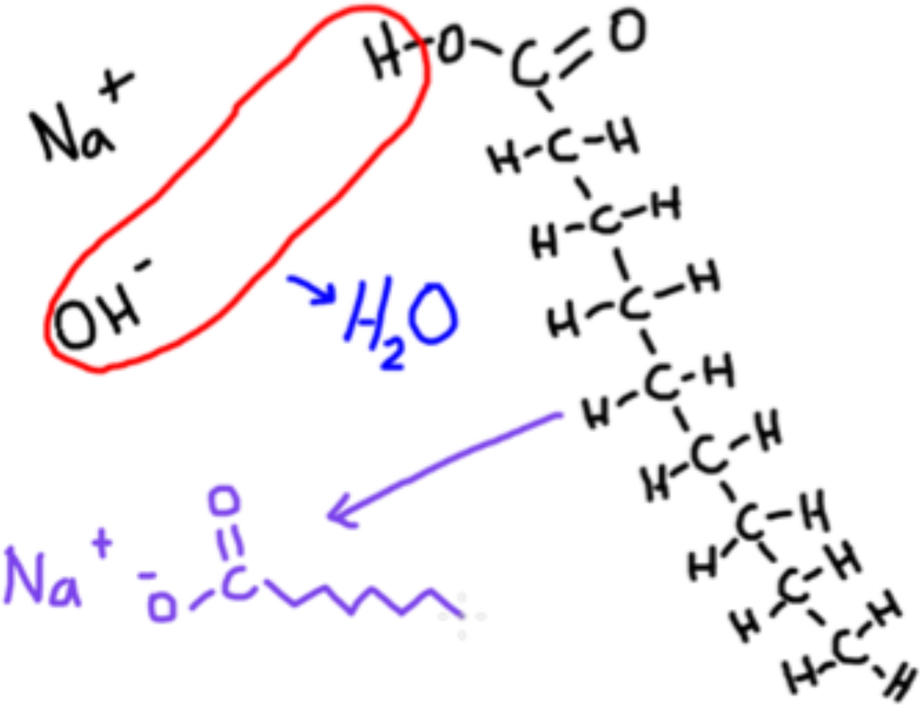

Figure 1: The process of saponification. When sodium hydroxide is in solution, it produces ions of sodium (Na$^+$) and hydroxide (OH$^-$). If hydroxide comes into contact with the carboxyl group at the end of a long chain of carbons on a fatty acid (pictured here as nonanoic acid), the “acidic” hydrogen combines with hydroxide to form water, while the remaining fatty acid becomes an anion (in this case, nonanoate) with a carboxylate (COO$^-$) end. These molecules, with one charged, polar end that mixes with water and one nonpolar end that will bond with oil, grease, and fats through dispersion forces, are what give soap its ability to clean a variety of substances and lyse bacterial cell membranes. Image credit: D. Gonzalez.

In recent years, palm oil has been growing in market share as it is incorporated into more and more products, from foods like hazelnut spread and cream-filled cookies to cosmetics like moisturizing lotion and soap (Gesteiro *et al.*, 2019; Huang *et al.*, 2009). This builds upon a tradition of using these oils within the native range of the oil palm (*Elaeis guineensis*) in West Africa (Ayanlowo *et al.*, 2022). Nowadays, vast quantities of consumable products in stores will list palm oil as an ingredient; it is promoted for its optimal mixture of several lipid compounds (DiGenova *et al.*, 2018) and its ability to yield more oil per hectare than other “oil crops” like canola and soy (Murphy *et al.*, 2021). Palm oil is also an attractive addition to soap products because it is solid at room temperature, unlike many vegetable oils (D. González, personal observation). Other plant oils that are solids at room temperature have significantly lower yields than palm oil's 4,000 kilograms per hectare (Murphy *et al.*, 2021): cocoa butter is up to 750 kg/hectare (Adabe & Ngo-Samnick, 2014) and shea butter is far lower at 33 kg/hectare (Lovett, 2004). Coconut oil comes close at 3,000 kg/hectare (Jagdish, 2019), and it is often produced from small-scale plots in mixed forests with other plants so that biodiversity may be preserved—at least in regions where 92% of coconut oil is produced (Rochmyaningsih, 2020). Palm oil's impacts on the environment are well documented, particularly habitat destruction and increasing climate change (Paterson & Lima, 2017). Among the most threatened of all ecosystems are the tropical peatlands of Borneo, where poor land management due to oil palm agriculture has resulted in the increased release of carbon (Sanwlani *et al.*, 2022). Even promises of "sustainable" palm oil that follows strict protocols for environmental stewardship may not actually reverse such negative effects (Gatti *et al.*, 2019), because tracking and verifying the sources can be so hard (Ramli *et al.*, 2020). It is, therefore, preferable to find an alternative source of oil that will not have such impacts.

For this, we can turn to bugs.

There are many insects that can be farmed to produce oil, including crickets (Tzompa-Sosa *et al.*, 2021), mealworms (Son *et al.*, 2020), and silkworms (Zou *et al.*, 2017). While these species have been considered alternative sources of protein and nutrients, thus becoming ideal candidates for sustainable agriculture (Jantzen da Silva Lucas *et al.*, 2020), only the black soldier fly, *Hermetia illucens*, can be raised on nearly any type of organic substance, including chicken droppings and a wide variety of food waste (D. González, personal observations). When consuming these materials, waste products are diverted from being dumped in landfills, where their decomposition would produce methane, a powerful greenhouse gas (Jain *et al.*, 2021). Prior to pupation, the black soldier fly larva (BSFL) will self-sort from its substrate, making the process of collecting them far easier and less labor intensive than most other insect species (Fig. 2). Combined with the fact that these larvae are approximately 49% protein and 29% fat—much of it saturated to produce a solid oil—these insects present enormous potential as a food source for humans and animals (Wang & Shelomi, 2017). At Princeton High School, where the experiments included within this paper were conducted, there are ongoing projects to raise BSFL in bins and feed them on expired produce that is collected from local markets. These larvae are then fed to chickens and pacu fish (*Piaractus brachypomus*), with plans to expand into saltwater shrimp (*Litopenaeus vannamei*) and tilapia (*Oreochromis niloticus*). This results in a system with many potential benefits, including reduction in greenhouse gases by preventing food waste from decomposing in landfills, greater independence from industrial agriculture, and enhanced educational experiences for the learning community.

During the 2021 – 2022 academic year, I was involved in a variety of activities that investigated further uses of products that could be derived from black soldier fly larvae. Upon learning that a solid fat could be extracted from these insects, which has similar levels of certain fats like lauric acid when compared to coconut oil (Kim *et al.*, 2020), the possibility of making soap from BSFL oil was discussed in combination with other saturated and unsaturated oils. This paper reports on the results of cleansing and disinfecting trials conducted with soaps made from palm oil, coconut oil, or BSFL oil as the solid component, sunflower oil as the liquid component, and beeswax from the European honeybee (New Jersey's state insect) plus fragrance from the violet (New Jersey's state flower) in order to determine how alternative oils would compare to a palm oil-based “gold standard” (Fig. 3). These experiments were all conducted during the 2022 – 2023 academic year.

Figure 2: Black soldier fly larvae (BSFL) that have self-sorted from food waste in preparation to pupate (left). This makes collection of these insects far easier than other species. The oil that is extracted from these larvae has an orange/yellow color (right). Image credit: D. Gonzalez.

Figure 3. Soap made from a mixture of 566 grams of palm oil and 283 grams of sunflower oil. This was considered the “gold standard” soap to which the soaps made from BSFL oil and coconut oil would be compared, because many home soapmaking kits integrate palm oil as the main saturated fat ingredient. Image credit: D. Gonzalez.

Methods

Soapmaking

In the interest of time and safety, there was only one standard procedure by which the soap was produced, known as a “hot process” because heat is added and the final product cures relatively quickly. Cold process soaps take six weeks or longer to cure, while hot process soaps can be ready for use within one week. In all cases, these mixtures were combined under a safety hood that provided adequate ventilation, and procedures were conducted under adult supervision while wearing protective Nitrile gloves, aprons, face shields, and goggles. Once protective equipment was checked to ensure tight seals, the following ingredients were combined: 135 grams sodium hydroxide (NaOH), 255 grams distilled water, 283 grams of sunflower (liquid) oil, 20 grams of beeswax, 30 grams of violet essential oil, and 566 grams of solid (saturated) oil derived from palm, coconut, or BSFL. Aside from BSFL oil, all other ingredients are common in high school laboratories or kitchens at the concentrations that were mixed, therefore none were deemed hazardous. To start, sodium hydroxide was added to the water in small quantities (less than 20 grams at a time) and stirred thoroughly to ensure that all of the crystals dissolved and the heat was allowed to dissipate. Because the molar heat of solution is very high for sodium hydroxide, great care was taken to ensure that the water did not boil. This meant that the NaOH was added in these increments over a period of ten minutes and allowed to cool before further processing.

In a 4-quart (3.79 L) crock pot, the solid and liquid oils plus beeswax were combined and heated until the solid components melted. This mixture was stirred thoroughly with a hand blender until it appeared homogeneous. At this point, seven grams of purple coloring agent (mica powder) was added for aesthetic effect and the sodium hydroxide solution was stirred into the oils over approximately one minute. When the mixture began to thicken, which is described as reaching “trace” for soapmaking, violet essential oil was added for fragrance, mixed again, and the resulting viscous liquid was poured into silicone soap molds. After the soap was allowed to harden over a period of two days, 11 bars weighing 106 grams each were removed from their molds and allowed to cure for an additional 5 days on a shelf (Fig. 4). In all, one batch of soap was made for each solid oil, as well as one additional recipe with coconut oil as the solid base that incorporates 20 grams of baking soda instead of beeswax for purported anti-grease and antibacterial properties. This fourth type of soap was colored blue for differentiation.

Figure 4. Soaps made from oil extracted from black soldier fly larvae (BSFL). After the saponification reaction, the mixture was poured into silicone soap molds, allowed to set for two days, and set on a shelf (pictured here) for an additional five days to cure. Image credit: D. Gonzalez.

Cleaning test

To assess the abilities of soaps to clean grease from skin, a 5.0 x 0.5 centimeter line of black eye grease commonly used for sports was placed on a 19.0 x 14.0 centimeter piece of silicone "practice" skin that is used for tattoo training. After the grease line was made, the skin was washed with consistent and standardized hand movements with lather derived from the soaps previously described and water that was at a constant 24.1ºC (the temperature of cold water from the sink). These repeated hand movements cleaned the silicone skin until the grease was removed to the point that it appeared consistent (Fig. 5), and the time taken to reach that state of cleanliness was recorded. After use, practice skins were washed thoroughly with dish soap and dried for repeated use. In total, 30 replicates for each type of soap were performed and the average times compared using an analysis of variance (ANOVA). Significance was determined with a Tukey honestly significant difference test (HSD).

Figure 5. Cleaning trials for soaps made from different solid oils. At the left is the coconut oil-based soap where baking soda replaced beeswax (labeled APDO on silicone skin surface). Next to it is the coconut oil, sunflower oil, and beeswax soap (labeled BCO), followed on the right by the BSFL oil, sunflower oil, and beeswax soap (DLB) and the soap made from palm oil, sunflower oil, and beeswax on right (CPL). Grease marks were made using nontoxic black eye grease (EyeBlack brand). Marks that appear outside of the lines are from previous trials; the high cost of silicone skin meant that all pieces needed to be reused.

Disinfecting test

Using fresh "practice" skin, 0.2 mL of a culture made with high school-safe *Eschericia coli* bacteria (Carolina Biological variety K-12) with a cell concentration of 9.7 x 10^6 colony forming units (CFUs) per mL was placed on a 1.0 cm x 1.0 cm rectangle in the middle of each test surface. This concentration was determined through serial dilution from 10^{-1} through 10^{-16} of the original culture and plating 0.2 mL on plates that contained tryptic soy agar (TSA). These silicone skin patches with inoculated bacteria were then washed with cold water and lather from one of the selected soaps for a total of 30 seconds, except for one that was left without any washing (positive control), one that was washed only in water (positive control), and one that was washed in a 10% bleach solution that is the laboratory standard for surface sterilization (negative control). After 30 seconds of washing—except for the "no wash" control—each rectangle where the bacteria had been placed was rubbed with a sterile swab, then any recovered bacteria were transferred to a Petri dish containing sterile tryptic soy agar (TSA) and incubated overnight at 37^{o}C to allow surviving *E. coli* to grow and be counted as colonies. After this, all silicone skins were soaked in a 10% bleach solution for one hour, rinsed thoroughly and dried, then used for future experiments. After 24 hours, each Petri dish was examined and colonies counted whenever visible. In total, 30 trials were performed for each type of soap, as well as 30 trials for the two positive controls and the negative control. Given that these trials consisted of 7 different treatments (no washing, water only, palm oil soap, coconut oil soap, BSFL oil soap, baking soda soap, and 10% bleach solution), results were analyzed using an ANOVA and significance was determined with a Tukey honestly significant difference test (HSD).

Figure 6. Disinfecting trials with 0.1 mL of *E.coli* var. K-12 being spread on a 1.0 x 1.0 cm patch of artificial silicone skin. After the bacteria was placed on each sample, it was washed for 30 seconds with water and lather from the soap of choice, except for the controls. These skins were then swabbed and any

surviving bacteria were plated on tryptic soy agar, then incubated at 37°C for 24 hours and the resultant colonies counted.

Foaming properties

In order to assess the quality of foam produced by these different soaps, a 1.0 gram sample of each was placed in 50.0 mL of water and a double whisk milk frother (Pachaco brand) was added for a period of 60 seconds (1 minute). The resultant lather was recovered with a plastic spoon and transferred to a ruled microscope slide with small squares in the focal area that measure 2.0 mm on each side. A cover slip was placed on top of this foam, and pressure applied until one layer of bubbles could be resolved. Measurements were then made for bubble size and quantity per square.

Results

Cleaning test

As can be seen in Figure 7 (next page), soaps derived from oil of black soldier fly larvae (BSFL) and from coconut oil with baking soda added instead of beeswax had significantly shorter average cleaning times than those that used palm oil or coconut oil with added beeswax. After 30 trials, the mean cleaning time for soap made from BSFL oil and beeswax was 87.3 seconds (standard deviation 3.05), for soap containing palm oil and beeswax was 115.0 seconds (standard deviation 3.00), for soap made from coconut oil and beeswax was 109.3 (standard deviation 6.42), and for soap made from coconut oil and baking soda was 87.6 (standard deviation 4.72). Each of these soaps used the same amount of sunflower oil as the liquid fat component, and therefore was not considered as a variable. Independent variables in this portion of the experiment were soap composition (based on solid lipids), and the dependent variable was cleaning time.

When p values were compared via a Tukey honestly significance difference (HSD) test, the cleaning times for soaps made with BSFL oil and baking soda were statistically insignificant from each other ($p = 0.8999$), while p values for BSFL oil and baking soda were all significant ($p = 0.01$) in comparison with the soaps made from palm oil and coconut oil with beeswax. The cleaning times for soaps that contained either palm oil and beeswax or coconut oil and beeswax were not significant from each other, with a p value of 0.464. A visual assessment of the ability of these soaps to clean black grease may be viewed in Figure 8.

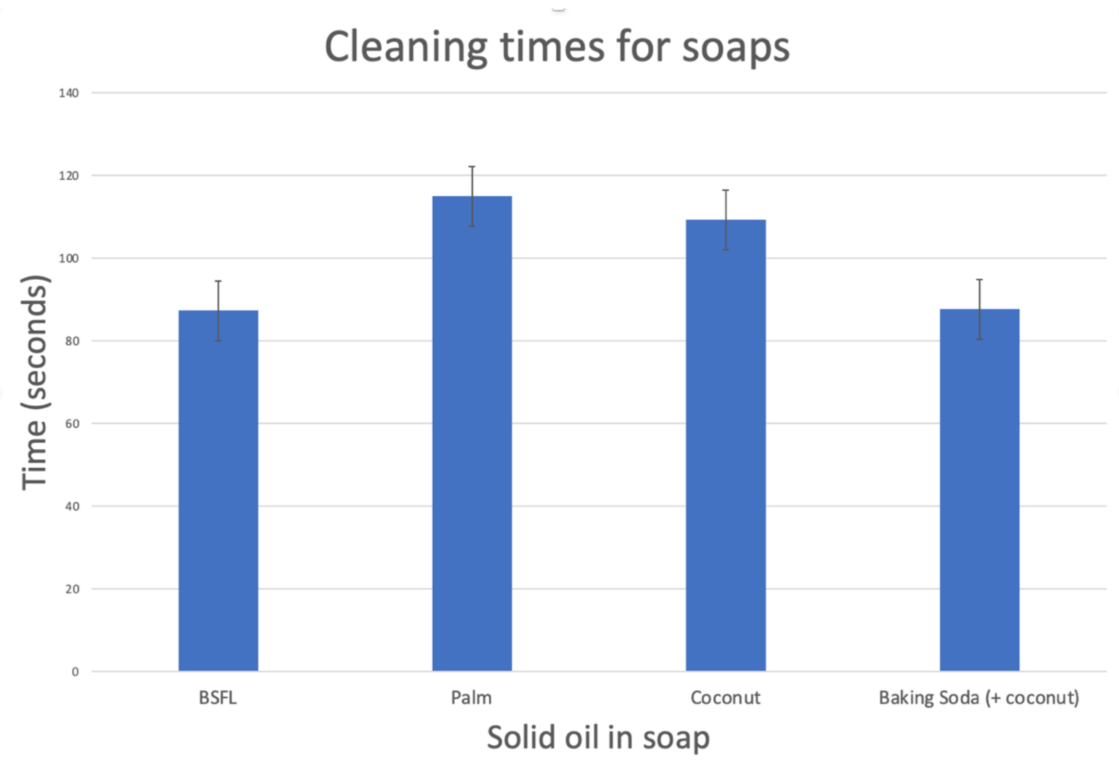

Figure 7. Comparison of the cleaning times for soaps derived from oil of the black soldier fly larva (BSFL) plus beeswax and sunflower oil (left), palm oil plus beeswax and sunflower oil (second from left), coconut oil plus beeswax and sunflower oil (second from right) and coconut oil plus baking soda and sunflower oil (right). The cleaning times for baking soda and BSFL soaps were statistically shorter than palm oil and coconut oil with beeswax.

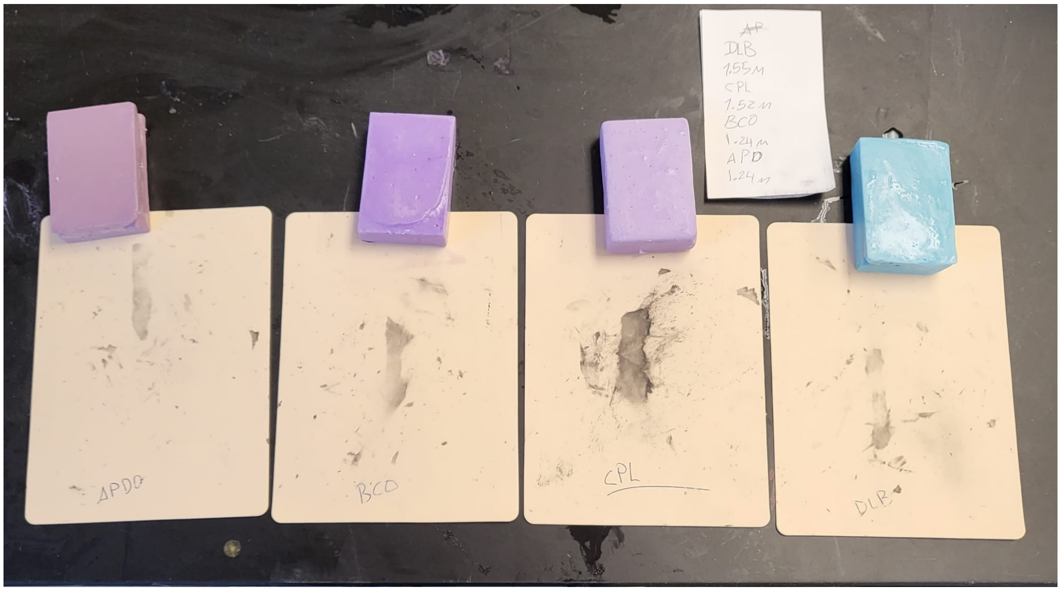

Figure 8. Comparison of cleaning quality after no more black grease could be removed from each patch of silicone "skin." At the left is soap made from BSFL oil, coconut oil is second from the left, palm oil is second from the right, and baking soda soap is on the right. While quantification of the remaining grease proved difficult, it appears that both BSFL oil soap and baking soda soap were able to produce the cleanest skin.

Disinfecting test

For both of the positive controls, which included the unwashed "practice" skin and the skin that was only washed with water, the number of colony-forming units (CFUs)—a standard measure of bacterial concentration—was too high to determine because the *E. coli* colonies grew together into a relatively homogenous "lawn." All of the tested soaps demonstrated considerable ability to reduce *E.coli* populations from the original estimate of 1.94 x 10^6 CFUs in a 0.2 mL sample, and while the average number of colonies formed by the soap made from BSFL was the lowest at 0.33 CFUs in comparison to 7.67 for palm oil soap, 6.8 for coconut oil soap, and 5.2 for soap made from baking soda and coconut oil (Fig. 9), this number was not significant when compared with the disinfecting abilities of the other soaps tested ($p = 0.3722$ for BSFL soap vs. palm oil soap, which was assumed to have the greatest difference). The number of CFUs in each of the trials was highly variable, but never exceeded 30 CFUs for any type of soap and oftentimes was at 0 for each soap variety. Confirmation that the colonies were indeed composed of *E. coli* was accomplished by visual comparison with known samples of this bacterium.

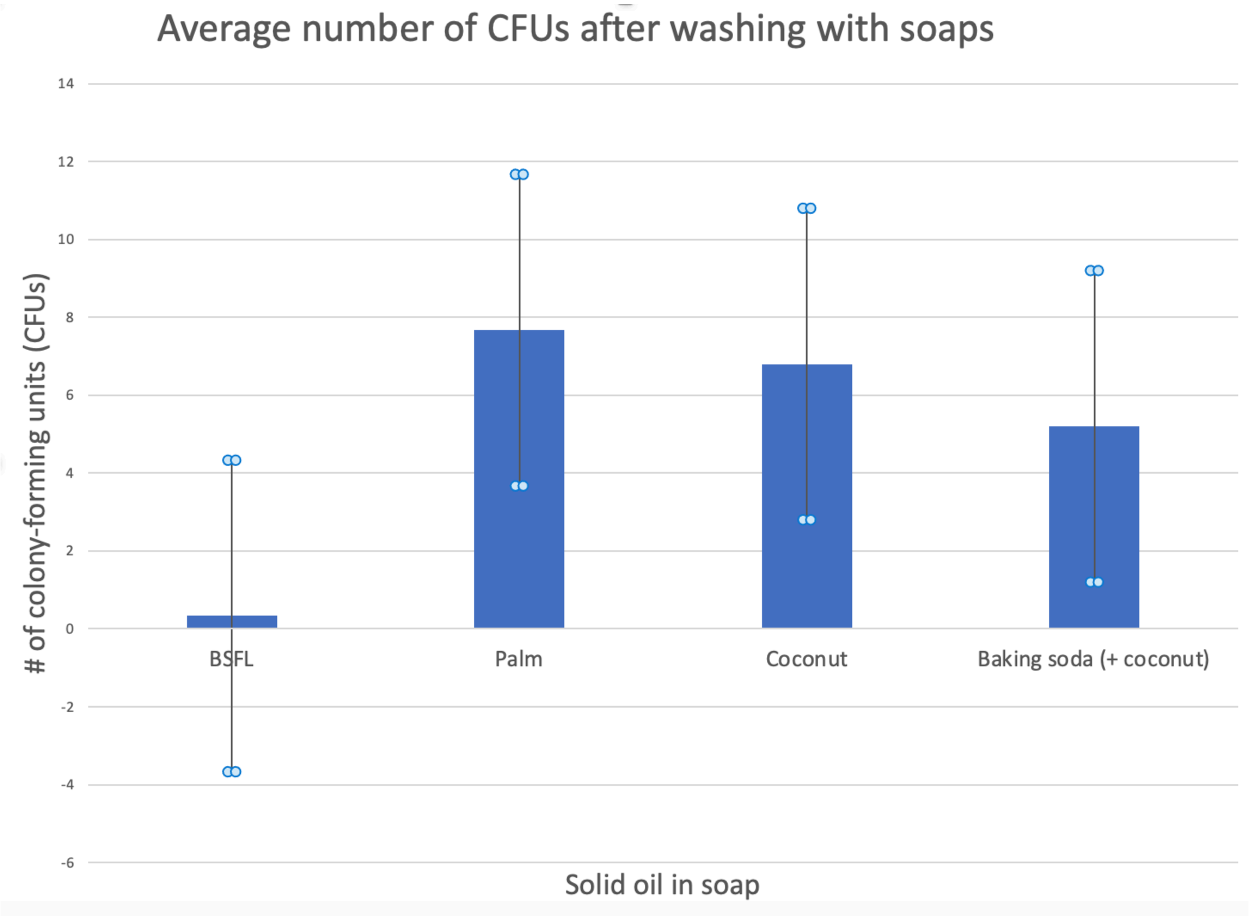

Figure 9. Comparison of bactericidal properties of tested soaps. In all cases, the concentration of *E. coli* bacteria was reduced from a hypothesized maxim abundance of 1.94 x 10^6 CFUs as measured through serial dilutions to less than 30 CFUs that remained. While it may appear that soap made from BSFL oil is more effective at killing *E. coli* bacteria than the other varieties, the results were not significant as can be seen by the large error bars due to a great deal of colony variation.

Foaming properties

Though not necessarily a measure of soap quality, the foam made by each soap tested did have a distinctive profile when viewed microscopically (Fig. 10). Based on estimates derived from each square in the viewing slide being 2.0 mm x 2.0 mm, it appeared that the largest bubbles in the foam were nearly 0.5 mm across, while most bubbles were far smaller and sizes were not necessarily consistent. Palm oil and coconut oil soaps both appeared to generate larger bubbles while those of BSFL and baking soda plus coconut oil were smaller, though there is no indication that these bubble sizes have any impact on a soap's cleansing or disinfecting ability.

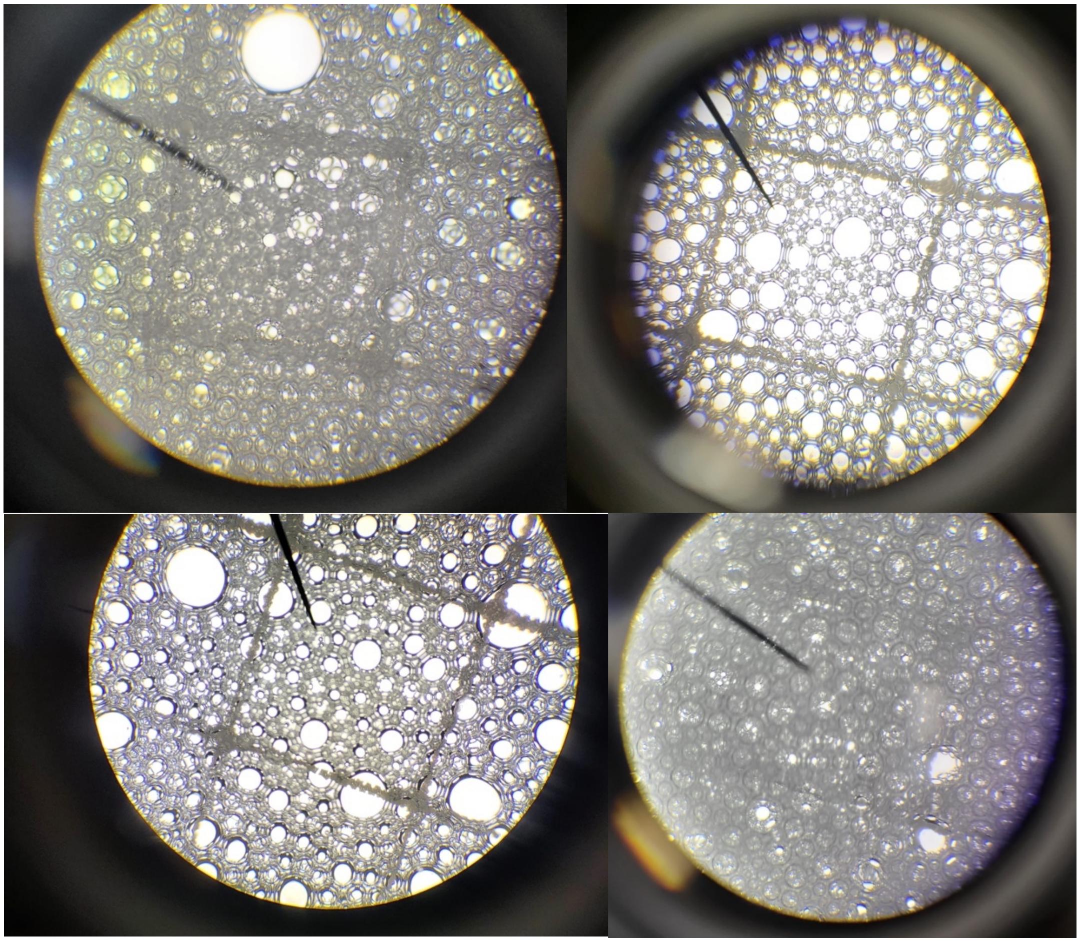

Figure 10: Comparison of the microscopic foaming properties of soap made from BSFL oil (top left), palm oil (top right), coconut oil (bottom left) and baking soda plus coconut oil (bottom right). While palm oil and coconut oil soaps appeared to make larger bubbles, it is not yet known whether this has any bearing on overall soap quality or cleaning ability.

Discussion

These results are preliminary, yet it does appear that black soldier fly oil can be incorporated into soaps that will be at least marginally beneficial to the general population. Soaps made from BSFL oil can clean grease as well as a recommended "grease-busting" soap formula that contains baking soda, which presumably has this ability to clean nonpolar substances because it can initiate a new process of saponification and make grease water-soluble. This would not be the case for soap made from BSFL oil and beeswax; the mechanism for this improved cleansing ability cannot yet be determined. The disinfecting properties of this soap were shown to be effective against *E. coli* inoculation on artificial skin, although it is not yet known how it might work against other varieties of bacteria such as *Staphylococcus aureus* and other pathogens like fungi (particularly the genus *Candida*) or viruses. It is recommended that this experiment be repeated with microorganisms on actual human skin, but such a protocol—especially if it includes potentially harmful species—lies outside of the purview of a high school science lab.

The ability of BSFL oil-based soap to clean grease is presumed to be similar to the process by which other soaps are able to clean; the ionized carboxylate end of the molecule binds tightly to water while the nonpolar end is able to interact with oily and waxy substances. This forms the "micelle," in which the polar ends of soap molecules form a spherical shape around a nonpolar interior where molecules of lipids can be trapped (Fig. 11). It is understood that this is the process by which most soaps work, though further testing of the specific chemical reactions between BSFL soap and grease would be needed to determined if this is indeed what is happening. In addition, other forms of "dirt" that might be found in one's everyday interactions should be tested, as well as whether BSFL oil soap might have any negative effect on the skin. The drying qualities of many soaps vs. the moisturizing qualities of others were not explored in this study because of safety protocols that recommended against using human skin, as well as the additional permissions and clearances—not to mention time—that would be needed for a survey. While it is known that some people exhibit allergic reactions to particular compounds that may be found in insects and shellfish, it is not known whether such substances can be found in BSFL oil and therefore greater analysis of the full chemistry of BSFL oil is needed.

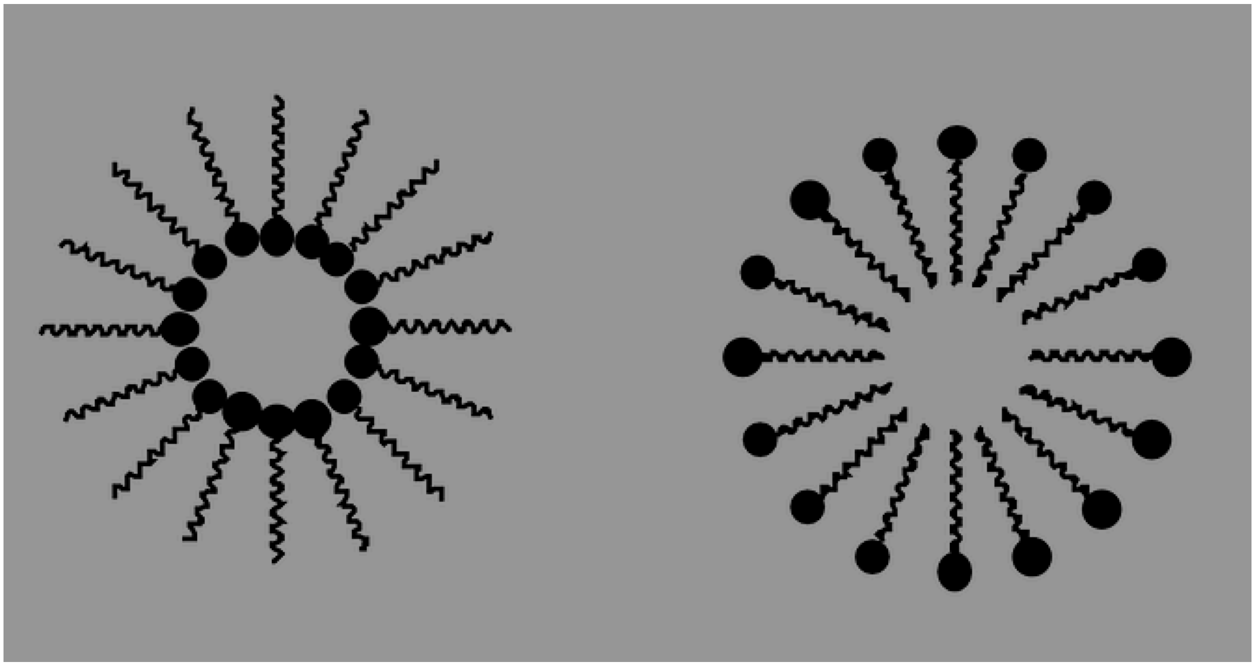

Figure 11: Behavior of soap molecules in nonpolar solvents (left) and polar liquids (right). The carboxylate (COO^-) ion in each of these molecules is represented by the rounded "head," while the nonpolar chain of hydrocarbons is represented by the squiggly line. In liquids like water, the spherical micelle forms around nonpolar substances, allowing them to be washed away.

This chemical analysis also applies to the bactericidal components that might be found in BSFL extracts, because these insects are known to reduce bacterial populations in the substrates where they grow (Gold et al., 2020), possibly because of antimicrobial proteins that they are known to produce (Zhang et al., 2022). It is not expected that antimicrobial proteins might be found within the lipid fraction of BSFL extracts, yet it does remain a possibility if these proteins are effective even at very low concentrations and the process of refinement is not 100% effective. Beeswax is also suspected to have antimicrobial properties (Fratini et al., 2016), and the fact that the tested soaps containing beeswax were effective at killing bacteria may also be a factor that needs to be considered.

At present, further refining of BSFL oil to make soap appears to be a distinct need. While no formal surveys were conducted, those students who have smelled this oil have reported that it "smells like cat food" or "nuts," the variation of which may be a consequence of differences in odor receptors or sensory perception. As the leader of this study, I did not fall within the category of those who think that BSFL oil smells very bad, yet it is understandable that BSFL oil may not yet be easily marketable. All participants were in agreement that there was no disagreeable odor that emanated from palm oil nor coconut oil, suggesting that the latter may be used at a suitable and sustainable soap ingredient in the short term before BSFL oil can be further refined.

While the current investigation primarily examined whether soap made from black soldier fly larvae could be produced, and if its qualities resembled the soaps that are typically made from palm oil, there are many factors that will need to be considered for future data collection. To begin, the factors that were used to determine the soap's quality may not be the only qualities that one might use when selecting a cleaning product, and they may not all be weighted equally. Hardness and texture are other factors that might need to be considered, because some of the mixtures will produce soaps that are more "crumbly" than others. In a future extension of this project, which will include a survey, I intend to come up with a "hardness" metric for subsequent research, as well as texture—a characteristic that can be described as a smoothness and/or grittiness to the touch.

In addition to these future measures, I plan to examine people's buying habits, particularly the qualities that they might seek in soap purchases. Such knowledge will be essential if people can be convinced that soap made from "bug oil"—no matter how sustainable—is an acceptable alternative. Scent is probably one of the most defining characteristics, and it is likely that this would outweigh all other considerations. For those customers who think that the soap smells bad, there is little chance that they could be convinced to buy it. Texture and hardness might be other weighted factors, though these might vary more than scent. It would be interesting to determine whether people might consider purchasing these soaps to reduce their environmental impact or carbon footprint—even if perceived to be of inferior quality. With that said, the carbon footprint of BSFL oil in comparison to palm oil has yet to be determined, but the fact that the BSFL used in this study were raised exclusively on food waste and chicken droppings that would have generated methane gas if buried in a landfill suggests that there would be a significantly lower footprint. The overall amount of oil that can be produced from BSFL living on food waste also needs to be determined, and the plan will be to measure this production if our culturing facilities can be expanded beyond their current bounds.

Should there be some means to eliminate the odor from BSFL oil that some find disagreeable, this product could likely generate higher interest. This has been the case with previous experiments that sought to replace vegetable oils with insect-derived oils in which the researchers report that a deodorization process performed by high-temperature steam distillation under a vacuum leads to the production of a "bland" oil with most of the color and odor- causing compounds removed (Tzompa-Sosa *et al.*, 2021b). While this additional energy input will increase the carbon footprint of insect oil by a factor that remains to be determined, the greater likelihood that such a product might be acceptable to a wider market might be used to justify the added expenditure.

One additional discovery that was made but not reported in the results was the effect of incorporating honey into the soapmaking process. This was only attempted one time, with the goal of making the first "New Jersey" soap that included violet (the New Jersey state flower) plus honey from New Jersey's state insect that was produced from nectar collected from the blueberry (New Jersey's state fruit). Unfortunately, when 50 mL of honey was added to the aforementioned recipe that contained 100% BSFL oil as the solid component, the soap became very gritty to the touch. While this soap still lathered, and honey has been known to have microbicidal properties, the overall texture was considered undesirable. This is why beeswax was selected as an alternative.

Conclusion

Prior to the experiments that were reported in this paper, it was not known whether soaps could be produced with oil made from the black soldier fly larva (BSFL). If they could, it was also not known how they might compare to those made from other oils. The research conducted demonstrates that such a product is possible, with adequate capacities to lather, clean, and kill bacteria, though the scent has been described by some as disagreeable. More investigations need to be conducted, particularly on this soap's ability to clean other substances and kill a wider range of potential pathogens. There remains a distinct possibility that BSFL will find a new role in assisting more people obtain life-enhancing products on a planet where non-renewable resources are dwindling. Such a development will help improve both environmental sustainability and mitigate climate effects.

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