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Green Soap: An Extraction and Saponification of Avocado Oil

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Supporting Information

ABSTRACT: An introductory level green chemistry experiment is described that places a new twist on soap-making in lab. In this experiment, oil is extracted from an avocado, after which the oil is saponified to produce bars of green craft soap. Commonly used extraction solvents, such as petroleum ether, methylene chloride, and hexane, are replaced with safer ethyl acetate to extract the oil. Students find the experiment helpful in discovering the reality of fats and oils in foods, and in becoming aware of the direct relationship between oils in plants and soap. This experiment has been successfully carried out by students of introductory organic chemistry lab classes, but could be used by a general chemistry or an advanced placement high school class.

KEYWORDS: *First-Year Undergraduate/General, Second-Year Undergraduate, Organic Chemistry, Hands-On Learning/Manipulatives, Inquiry-Based/Discovery Learning, Green Chemistry, Natural Products, Solutions/Solvents*

In a new twist to an old experiment, the procedure reported herein provides an inquiry-based, real-world examination of the process of preparing a soft, green, craft soap beginning with the extraction of green-colored oil from an avocado using a greener (safer) extraction solvent. As early as 1925, an article appeared in this *Journal* describing the soap industry.[1] By 1947, the high school textbook "Applied Chemistry" listed a student laboratory experiment on soap making.[2] Several authors in this *Journal* have described the soap-making process in detail for the undergraduate and high school laboratory,[3−6] with one illustrating the versatility of the starting fats (solids) or oils (liquid fats).[3] All of these articles include images of chemical structures of fats and soaps and explain the process of soap making. Likewise, extractions using solvents are common in introductory organic chemistry laboratories, as well as in research and industrial laboratories. In this updated experiment, both the oil extraction and soap-making techniques are combined in a unique and fun way that illustrates the connectivity between seemingly disparate industrial processes. The experiment also encourages students to recognize the presence of fats and oils in foods, and in becoming aware of the direct relationship between oils in plants and soap.

The current experiment utilizes a greener solvent to extract the oil from avocado by using the relatively less toxic solvent ethyl acetate rather than the more commonly used chlorinated solvents, petroleum ether, or hexane.[7−9] Ethyl acetate is not only regarded as a highly efficient solvent, but is also easily degraded in the water and air compared to other solvents.[10,11] Using a greener solvent emphasizes attention to the Principles of Green Chemistry and to the toxicity to which many students are unnecessarily subjected in some undergraduate laboratory procedures.[12]

PRE-LAB ASSIGNMENT

The introductory material for the lab experiment includes information about elaioplastids, the cell structures of plants that contain the oil, and explains why isopropyl alcohol is used in conjunction with ethyl acetate to break down cell structures. It also explains that using ethyl acetate is a safer solvent than those used historically for extractions. However, it challenges students to find on their own the structures of fats, soap, and ethyl acetate, as well as the chemical reaction for making soap, and then to draw them by hand or by using molecular drawing software. This inquiry-based, pre-lab exercise is meant to reinforce the molecular theory behind the soap-making process. Additionally, the combination of a fat extraction plus saponification reaction during a single lab helps to exemplify the real-world nature of soap production.

METHOD FOR SOAP MAKING

Students work in pairs; the experiment requires 4 h to complete. An avocado is peeled, the pit is removed, and the flesh is extracted with a solution of ethyl acetate and isopropyl alcohol. The decanted solvent containing the oil is evaporated under the hood using a warm water bath. The oil, along with additional solid fat (Crisco) and vegetable oil, is saponified by mixing with aqueous NaOH. During a 20−30 min mixing time, students build molecular models of fat and soap. Bars of soap are cured for 4−6 weeks, during which time the saponification reaction continues and the pH of the soap decreases from >12 to near neutral. Complete pre-lab and step-by-step instructions are included in the Supporting Information.

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■ HAZARDS

Eye protection and gloves should be worn throughout this procedure. Ethyl acetate and isopropyl alcohol are both flammable, minimally toxic if inhaled, but are toxic if consumed. A laboratory hood should be used for evaporation of the solvents. Sodium hydroxide is caustic and should be handled carefully. The newly prepared bars of soap have a high pH (>12) due to residual NaOH, so they should not be handled for some time after they are poured. The pH decreases to near neutral (~8) after curing for 4−6 weeks.

■ DISCUSSION

Avocado was chosen for its high fat content (~14%). The greener solvent, ethyl acetate, was a reasonable substitute for other, more toxic solvents to extract avocado oil with 10 students reporting yields of 7.4−14.4% fat by weight (Figure 1).

Figure 1. Three completed bars of soap and avocado oil.

The average amount of fat obtained was about 14 ± 3 g of avocado oil per avocado. Isopropyl alcohol was used in conjunction with the ethyl acetate to break down cell structures so that the oils were more easily extracted. This oil is both a coloring agent and a portion of the total fats used in the soap-making process. Since the volume of avocado oil is relatively small, additional fats are added to create approximately normal-sized bars of soap. This procedure did not use a "salting out" procedure that was commonly employed in lab exercises, but is generally not used in craft soap-making.[13] Rather, the soap was allowed to cure slowly for 4−6 weeks, consistently crafting three bars of a mild soap. Finally, because students complained that the 20−30 min for "trace" to form could be better used, instructions were recently added for students to build molecular models of fat and soap while waiting.

This experiment has been used very successfully in four classes, with approximately 60 students (30 pairs) in 4 h organic chemistry labs that are almost exclusively populated by biology majors. However, the two parts of this lab, extraction and soap making, could be easily separated into two, 2 h sections to accommodate other lab schedules. A lab assessment procedure indicated that students were able to conceptualize the theory behind extraction and reapply the extraction procedure during another, more open-ended experiment later in the semester. Students reported significant satisfaction with this lab and found the experiment helpful in recognizing the presence of fats and oils in foods, and in becoming aware of the direct relationship between oils in plants and soap. Their comments included

- *Overall I really liked this lab. I was able to see how you make natural soaps....It was fun and easy and it teaches you the basics of organic chemistry. I never would have guessed it could be so simple.*
- *This lab was definitely very interesting. I never knew that avocados contained that much fat.*
- *This particular lab was interesting as it both helped me understand the real synthesis aspects of soap and then view it in real time.*
- *I enjoyed this lab thoroughly and thought that it was worthwhile both from an educational perspective and a hands-on learning opportunity to produce a useful substance.*
- *I really liked the lab! It was straight forward and easy to follow and I can't wait to see how it comes out.*

■ ASSOCIATED CONTENT

Supporting Information

A complete lab handout including inquiry based pre-lab assignment, instructions, an example of student results and a table listing the mass of avocado flesh compared to avocado oil obtained by 10 students is included. This material is available via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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