JOURNAL OF
EMERGING INVESTIGATORS

Article

Using heptane to extract almond oil

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SUMMARY

Essential oils are mainly extracted out of plants, such as leaves, flowers, bark, and fruit mainly by distilling or pressing. Out of numerous separation methods such as distillation, extraction, sublimation, and chromatography, many companies favor extraction methods over others to extract different oils, which possess great health benefits, including cardiovascular support, skin care, brain function support, and cancer prevention. There are multiple solvents available for almond oil extraction, such as hexane, ethanol, toluene, methanol, acetone, chloroform, diethyl ether, dichloromethane, and combinations thereof. For almond oil extraction, companies typically use either hexane or methanol. However, hexane and methanol are toxic for human consumption and can cause health problems such as nerve damage, blindness, and even irreversible brain damage. For this reason, we hypothesized that a safer chemical, such as heptane, could also be used to extract oils given its chemical structure's similarity to hexane. We were able to extract mixture oil using ethanol, hexane, and heptane and found that heptane and hexane have similar amounts of extracted oil, most likely due to the similar chemical structure between hexane and heptane. Our results show that the extractions overall yielded a reasonable amount of oil extraction from almonds.

INTRODUCTION

Extracting oils from vegetables began thousands of years ago. For example, soy oil was extracted as early as 2000 BCE by the Chinese and the Japanese, while olive oil was even extracted in 3000 BCE by Southern Europeans (1). Furthermore, Mesopotamia is credited as the first civilization to extract essential oil using distillation techniques in 3500 BCE (2). The Egyptians and the Chinese extracted essential oils mainly for aromatherapy. Today, oils serve various purposes, such as wound healing, stress control, cooking, and skin treatment (2).

There are multiple techniques modern companies use to extract nut oils, such as cold pressing, solvent extraction, and distillation. Solvent extraction, also known as liquid-liquid extraction, is the most commonly used method (3). Usually, organic solvents are used to isolate essential oils from desired plants and can be used to extract large amounts of essential oil (4). Solvents such as ethanol, hexane, and methanol are particularly popular for their accessibility, cost, low boiling points, and high extraction rates. However, the method still has its drawbacks: organic solvent residues may remain after production or processing, which could potentially be consumed by humans. Hexane and ethanol are the common solvents used for extraction, but hexane can potentially cause nerve damage and paralysis to the arms and legs (5). Furthermore, serious sensorimotor polyneuropathy, respiratory epithelium damage in the nasal cavity, neurotoxic effects, and blurred vision can occur if consumed for prolonged periods of time (4,5). To avoid these unwanted detriments, we are using heptane for a safer and more effective solution.

Although ethanol is less toxic than hexane, the extraction of unwanted materials can be problematic because ethanol is a polar solvent that can extract hydrophilic compounds from plants and essential oils (6). Since we only want to extract

https://doi.org/10.59720/24-215

essential oils which are mostly hydrophobic compounds, ethanol is not a very effective solvent for our purposes because additional purification might be necessary to separate essential oils from hydrophilic materials. Due to the current availability of ethanol, the choice of most companies is hexane, which can cause many harmful effects if consumed in large quantities or chronically. To avoid detrimental health issues from hexane, we hypothesized that we can substitute hexane with heptane.

Heptane contains one more carbon than hexane, making it less toxic and safer for extracting almond oil (7). Previously, heptane has been used for botanical extraction and not for almond oil extraction. Previous publications reported extracting almond essential oils using hexane, ethanol, and cyclohexane; however, heptane extraction was not reported (8,9). We hypothesized that using heptane as an extraction solvent would yield similar results and be safer than hexane. We concluded that heptane gives a similar quantity or extracted oil compared to hexane and does not produce results that aren't transparently seen when the extraction was performed with ethanol. We can replace hexane with heptane when extracting almond essential oils, thus making the almond essential oil safer to consume and cook with.

RESULTS

To avoid harmful detriments happening towards the body, we swapped out hexane and ethanol for heptane as a safer alternative towards extraction of nut oils. Initially, we determined the optimal amount of heptane per gram of almond nut. We found that 6 mL of heptane produced 2.12 g of crude almond oil, which was more than other volumes used, suggesting that 6 mL of heptane is the optimal volume to use for almond oil extraction (**Figure 1**).

After determining the optimal amount of heptane (1 mL of heptane per 1 g of ground almond), we extracted almond oil using various temperatures to see how temperature influences the extraction. After many trials, we found that stirring at 45°C gave us the best results of a clear solution of the extracted oil (**Figure 2**). Even though raising the temperature to 45°C helped increase the yield by roughly 10%, giving us 2.45 g of crude almond oil at 45°C compared to 2.24 g at room temperature, we decided to carry out the experiment at room temperature because we were still able to recover an acceptable amount of almond oil at room temperature. We decided to find the best stirring time. Stirring for 30 minutes showed the most yield for the stirring time and the oil yield decreased with less time. Thus, we decided to use 30 min stirring time for our experimentations

Finally, we compared our results with ethanol to assess the differences between ethanol and heptane extraction. We found that ethanol gave 3.12 g of crude almond oil and heptane gave 2.16 g of crude almond oil, a difference of 0.96 g (**Figure 3**). After drying out the solvents, we took pictures of each almond oil extracted by different solvents. Ethanol-extracted almond oil looks more yellow in color compared to heptane which produces clearer solutions (**Figure 4**).

DISCUSSION

We tested heptane as an alternative solvent for the extraction of almond oil because heptane is far less toxic than hexane. Heptane is a hydrophobic organic compound and, like hexane, is an oil but with one more carbon than hexane. We found that extraction with heptane gave us similar results to hexane, which is used as a solvent in many different solvent extractions. We used different amounts of heptane to find out the optimal amount of heptane we needed to use to extract almond oil. We found that using 1 mL of heptane per 1 g of ground almonds was optimal. It was also found that the optimal stirring time was 30 minutes.

We tested different temperatures to see how temperature affects extracting almond oil. At higher temperatures, we could get more extracted almond oil; however, we concluded that extracting almond oil at room temperature is sufficient to obtain a high amount of almond oil. Finally, using the optimal extraction conditions, we compared the amount of almond oil extracted using heptane, hexane, or ethanol. As we predicted, hexane and heptane showed very similar results; however, ethanol had more weight than heptane after the oil extraction. We believe that this phenomenon is due to the polarity of ethanol. Ethanol is very polar compared to heptane, and for this reason, ethanol will most likely extract not just oil but water-soluble compounds from almonds. Perhaps this is the reason why almond oil extract using heptane and hexane are clearer due to ethanol extracting more water-soluble compounds than hexane and heptane. This could be confirmed by GC-MS, showing the chemical composition in each mixture.

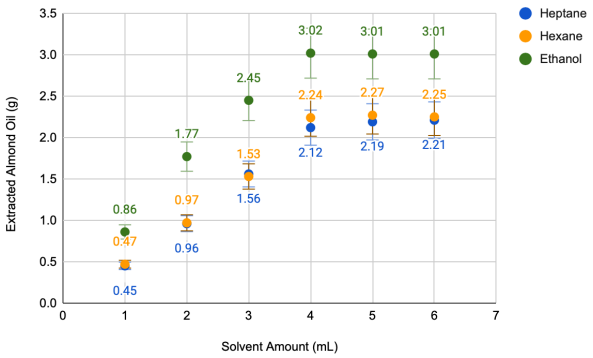

Figure 1: Amount of extracted almond oil increased with solvent amount used. The amount of different solvents (mL) used to extract almond oil (g). Data shown as mean ± SD, three trials were conducted for each solvent and amount.

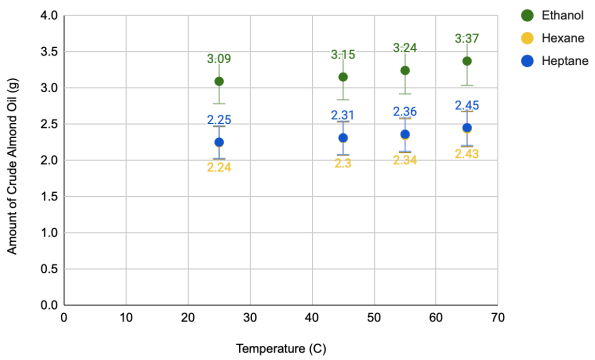

Figure 2: Extraction of almond oil from various temperatures. Impact of temperature on the extraction of almond oil using heptane, hexane, and ethanol. (n=3)

https://doi.org/10.59720/24-215

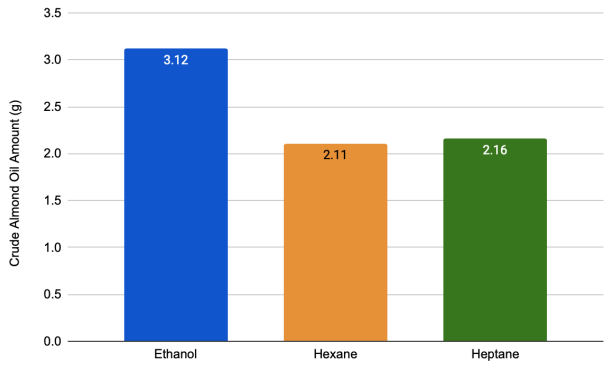

Figure 3: Using optimized conditions to extract crude almond oil. Amount of crude almond oil we were able to extract using optimized conditions for each of the three solvents. (n=3)

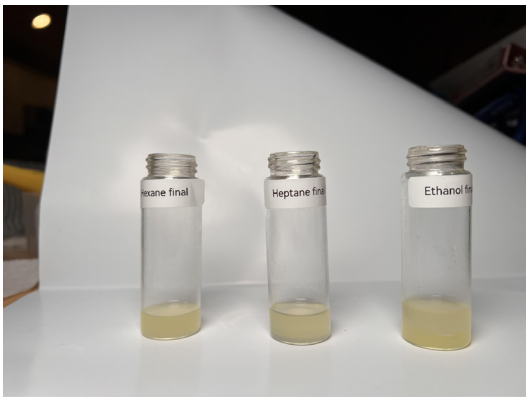

Figure 4: Color of extracted almond oil. Color difference between almond oil extracted from hexane (left), heptane (middle), and ethanol (right).

Also, many oil extraction methods require elevated heat treatment of target compounds including almond oil (10). In a future study, we hope to do elevated heat treatment at various temperatures such as 60°C to see if we can extract more oils. Some drawbacks in our method of extracting oil are that when extracting the oil from the coffee strainer, sometimes, the coffee filter broke due to the chunks of ground up nuts ripping it, causing us to redo the experiment. Therefore, we propose straining the oil with a cheesecloth. In conclusion, heptane extraction is a very effective and safe option for almond oil extraction. Ethanol might be a cheaper option to extract almond oil; however, ethanol extraction requires further purification to remove impurities because ethanol also extracts water-soluble compounds. To further our studies, we would like to try different solvents such as cyclohexane, octane, pentane, and cycloheptane to see any differences in yield. Furthermore, we would also like to extract lavender and ingredients for comparison. Our research and experimentation could be beneficial for the future of extracting oils in terms of safety. Compared to the more toxic hexane and methanol, using heptane for extracting oil is less detrimental to human health than the former. This could potentially be used commercially towards helping and saving lives from detriments.

MATERIALS AND METHODS

Method of extracting almond oil with heptane

Kirkland signature whole almonds were purchased through Costco. 6 g of almonds were placed in mortal and pestle (Laevo) and carefully ground for 10 minutes to yield fine powder. The powdered almonds and 6 mL of high-purity heptane (Chemboys) were placed in a 100 mL beaker and stirred for 10 minutes on a stirring plate before filtration. The crude solution was filtered with a coffee filter, and heptane was evaporated using oilless diaphragm double vacuum pumps (Huanyu, #GM-0.5B) to yield pure almond oil. Each extraction was performed fourteen times under different conditions such as using different temperatures and different ratios of chemicals to nuts.

Method of extracting almond oil with ethanol and hexane

The procedure of extracting almond oil with 95% ethanol (Innovating Science) and high-purity laboratory grade hexane (DIYChemicals) was the same as extracting almond oil with heptane. We used the same methods as the heptane for consistency.

ACKNOWLEDGMENTS

We would like to thank Gina Kim, Grace Choi, Lia Choi, Sophia Lee, Kacey Song, James Lee, Audrey Lee, Andrew Kim, Yechan Park, Hailey Gu, and Taehoon Noh for their one-on-one help with our research.

Received: May 27, 2024
Accepted: December 19, 2024
Published: October 27, 2025

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