Chemistry Around us

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15 October, 2015

Essential Oils of Plants as an avenue to Critical Thinking and self- motivated learning

Abstract: It is well known that experiential events are very effective in capturing the interest of inquisitive minds. Moving from that initial "capture" to critical thinking is non-trivial as the avenue of stimulus for the sake of stimulus and its attending emission of adrenalin can render a barely controllable situation into chaos. Talented professional teaching individuals in K-12 are well aware of this thin line. It is this author's opinion that the greatest gift a student can give a teacher is to become inspired to learn and the greatest gift a teacher can give a student is the catalyst to that behavior.

The experiential learning plan expressed in this presentation is an attempt at threading that needle in a manner that can be accomplished even with significant focus on minimizing the impact to financial resources and instructional preparation time to allow the teacher and student more opportunity. It is proposed that merely by following the theme of Essential Oils, a significant amount of the overall human knowledge base can be actually "tapped" and/or exposed for the learner.

Plan: Essential Oils.

This proposed study plan is to first expose the learners to the essential oils which they find in one or at most two botanical sources, then move into ancillary information about the materials as well as identify a number of opportunistic experiments for further studies, with intent to employ the Socratic method of teaching beyond the initial "capture" phase. Even the term "essential oils" itself is a term which empowers the opportunity for learning about fields well beyond science and technology. A set of class sessions will now be outlined, yet the educator is most welcome to improve on this sketch and choreograph a far superior scheme for their specific application.

Background: Essential Oils.

Every living entity synthesizes chemicals. In fact, this process is a fundamental component of that which we call "LIFE". Graciously, many plant species synthesize specific essential oils which have been found to be easy to extract and of significant benefit to human civilization over millennia. Of these materials, while many are available throughout the globe in plants around us, this treatise will discuss

three sources and then select one specific material in the interest of economy and simplicity for instructional uses. Those three sources are fragrant flowers, The Mint Family[1] (Lamiaceae) and citrus fruit[2]. Of those, an outline of opportunistic experiential learning utilizing citrus fruit will be presented. Extension opportunities into the other two sources will first be discussed as well as the reasoning behind selection of the Citrus fruit as the initial study. The three sources have been selected in part due to popular interest which is believed to be an opportunity of leverage toward inspirational learning.

Fragrant flowers: Most individuals enjoy the fragrance of flowers. In Oregon as in the majority of the civilized world, Roses are in abundance and readily available. It is quite easy to generate "Rose Water" and that in itself is utilized both for its fragrance and in some cultures (in fact roughly 75% of the earth's population!) as a cooking fluid[3]. A very good opportunity for further studies by individual or teams of learners, it was not selected for the initial exposure due to the fact that fragrances indeed also can induce allergenic reactions in a small, but well established fraction of the population, and hence requires more self-selection than the next two essential oil sources.

Mint family: Some members of Lamiaceae, the mint family are found practically everywhere on the planet. They are in general a very hardy family and easily identified in the wild. Of the family, three specific groups: Spearmint, Peppermint, and this author's favorite, Bee Balm, all contain easily extracted quantities of essential oils. A major component of these oils, Menthol[4] is well known to have significant pharmacological properties as well as the ability to provide astounding flavors such that practically everyone has heard of or eaten a refreshing "mint". Very few people are in any manner allergic to peppermint or spearmint. Prior to engaging exploratory work on native plants of the mint family obtained and brought to the classroom, it is beneficial to identify the specific family member obtained as some of this family indeed have quite dermatological reactive compounds. As an example, consider the plant "hedge nettle". While the member of the mint family is not stinging, there is another plant "stinging nettle" which does have that characteristic and is found in some locations in Oregon. It doesn't look very similar, yet novice botanists might erroneously select it without prior warning. It is not likely that stinging nettle will provide life-threatening debilities, yet the experience is a bit unpleasant. Luckily, another local plant, the "Jewel Weed" offers respite from the "sting", but that would be an advanced study in essential oils from plants and beyond the scope of this paper.

Citrus Fruit: All members of the citrus family have fruit of which many varieties are quite familiar in our region. Examples include Oranges, Lemons, Limes, Grapefruit and the occasional Kumquat. Generally speaking, Oranges are found in practically every grocery in the USA and are an exceptionally good choice for initial study of an essential oil from a plant. The d-limonene found in abundance in the exterior (colored) portion of the rind is easily extracted and has some fascinating chemical capabilities[5].

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[1] http://www.wildflowers-and-weeds.com/Plant_Families/Lamiaceae.htm

[2] http://www.wellnessresources.com/health/articles/d-limonene_help_for_digestion_metabolism_detoxification_anxiety_breast_canc/

[3] http://www.bbc.co.uk/food/rosewater

[4] http://www.ncbi.nlm.nih.gov/pubmed/23061635

[5] http://hellonatural.co/21-smart-household-uses-orange-oil/

Prime examples which enable rapid utilization of Citrus oil in a learning process are as follows:

1. It is in high concentration in practically any orange rind.
2. It is extremely easy to extract using any of three simple extraction methods.
3. The amount found in an orange rind is dramatically affected by variety, ripeness, and processing conditions hence there is a wealth of opportunity for extended investigations.
4. It easily separates from water as it has a low density and is only very sparingly soluble, so it will form a layer quickly during extraction.
5. It is a very effective glue remover, and that property is easily demonstrated.
6. It is safe to handle in modest quantities as will be experienced in the classroom study.

Outline:

With that introduction, the next material in this paper is an outline of some suggested classroom segments which can utilize the Orange and its rind to explore Chemistry in a manner which offers relevance to the majority of the human population and it is believed, can lead to interest as well as the opportunity to learn components of Science, Technology, Engineering and Mathematics (STEM) topics for participants.

Of course, such learning will be accomplished best with the talents and guidance of a capable educator!

Class segments are as follows:

Module 1: Demonstrate an essential oil extraction. (Orange Oil)

Segment 1: Extract Orange Oil from Orange Peel outer surface[6]

- Discover that orange oil exists
  - Reason Orange Oil Exists?
- Enjoy oranges
  - Flavor? Purpose of an Orange?
- Learn one method of essential oil extraction: Solvent Free Microwave Extraction.
  - SFME is a type of "Steam Distillation" requiring simple household equipment readily and easily maintained.
  - This example will utilize a device invented at Oregon State University[7] which is placed in a standard household microwave oven and does not require any laboratory facilities.
  - If time permits, some learners may perform the method
    - How does this process work?

[6] A detail of the process this author would perform is in Appendix "A".
[7] The device is available via a local Corvallis, Oregon Company: www.oilextech.com

Segment 2: Let everyone extract orange oil. (Reinforcement session)

- For each group of 4, 15 minutes with apparatus of which 7 are with microwave. *Note: Likely on first few sessions, 30 minutes will be a normal duration, and duration may in fact be a function of observed learning processes.*
    - Sample data acquisition (see detail information[8])
- Compile results from each team (and previous learners[9])
    - Discover variance in results exist
- Create plan for additional segments:
        - Reason for variance?
        - Other Plants?
        - Other aromas, flavors, oils?
        - The term Essential Oil?
        - Other ways to extract oil?
        - Reason for essential oils?
        - How did humans learn about these?
        - Uses for essential oils developed by humans?
        - Other questions from learners

Segment 3: Expansion and division:

- Self-selection (or forced) into teams with specific objectives based on Segment 2.
- Schedule additional extractions for each team, based on proposed experiments.
- Structure of time utilization for class depending on teacher's desires

Segments 4 to "N-1": Continuation on learning track.

- This is open-ended, and depends on available time as well as possible expansion into "beyond formal classroom time".

Segment N:

- Remarkable reinforcement
    - Summarize key discoveries: (Interactive between learners and teacher).
    - Optional: Track progress toward structured learning objectives

Module 2: The Natural Sciences of Essential Oils:

Segment 1: Extraction from Mint family member[10].

- Study purpose of essential oil to plant.
    - Location of essential oil: Mint leaf, flower, stem, or root?
- Identify plant invaders that might be of interest.

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[8] Sample Data acquisition detailed in Appendix "B" including suggested form for data.

[9] Retain results using data acquisition format to combine for future teams.

[10] Plants in the mint family all have varying degrees of extractable essential oils and are very easy to identify due to their characteristic "square-sided" stems. This reduces the potential for a beginning (*and novice botanist*) student to collect a botanical with some undesirable odor or toxin prior to a better knowledge of botany.

    - Insects? Fungi? Birds? Etc….
- Develop experiment with mint oil on some plant invader(s).
    - Example: Fruit flies.

Segment 2: Extraction from Flower (Rose or other with significant odor)

- Soluble vs insoluble essential oils.
- Study purpose of flower scents.
- Intensity of odor compared to volume of compound.

Segment 3 - 6: Extraction from various parts and types of Orange Peel:

- White portion vs orange portion
- "Certified Organic" vs "Generic"
- Valencia vs Navel vs Mandarin

Module 3: The Engineering of a process of extracting essential Oils:

(Optimization, Statistics, Process Control, Experimental result analysis, "Scientific Method")

Segment 1: Process of extraction – Orange Oil

- Understand the actual process of extraction[11]
- Experiment with effect of grated vs not grated
    - Decide whether remainder of experiments will be grated or not grated.
- Process variables and their significance
    - Examples: Grated/Not, Orange part/White Part, size of pieces, adding water, total mass of botanical, pre-heated reactor, duration in microwave excitation, type of microwave oven, size of microwave oven, ambient temperature, humidity, ice vs dry ice, type of orange, ripeness, color….

Segment 2 - 5: Optimization of Extraction Efficiency

- How to minimize variations in starting material (botanical) to enable optimization.
- Simplex optimization process.
- Half-factorial experiment design.
- Averages, Standard Deviation[12]:
- Students "t" test and other means to remove deviant data
- 5th session: Compile results and run best case 2-3 times.

[11] Technical details on the particular form of Steam Distillation used - called "Solvent Free Microwave Extraction" is in the scientific literature and at the OilExTech, LLC website. Further detail will be provided on request.

[12] With practice, a group can accomplish 4 runs in 45 minutes, enabling statistical experimental design control during one standard class session.

Segment 6: Assess efficiency of extraction

- Identify exact computation for efficiency[13].
    - Learn how the computation dramatically affects the interpretation[14].
- Graphical comparison of data[15].
    - Learn measurement techniques, precision and accuracy as well as conclusion generation mechanisms.

Module 4: Other extraction methods:

Segment 1: Pressing method[16]:

- Mortar/Pestle vs Vice experiments
- Yield and contamination

Segment 2: Supercritical CO2 method[17]:

- Special (yet simple) apparatus.
- Yield estimation (if practical)
- Process understanding.

Segment 3: Comparison of three extraction approaches:

- Qualitative and quantitative analysis
- Value statements and performance to a value statement.

Module 4: Opportunistic Explorations: Multi-track sessions:

Segment A1 – A5: The language and social ramifications of terms:

- Study the words, meanings, context and implications.
    - Essential, Oil, Essential Oil, Organic, Certified, Certified Organic, Natural, Microwave Oven, Radiation, Electromagnetic Radiation, Microwaves, Denature, Denatured Protein.
- Literature (news included) commentary about Radiation.
    - Human confusion regarding words with multiple definitions
        - Radiation
            - Obtain all definitions and compare to public discourse, current or past.

[13] A "normal" efficiency calculation algorithm is in Appendix "B".
[14] Efficiency of a process can be computed in many ways, as it is by its nature, a dimensionless parameter generally measured in "per-cent". Depending on the choice of the computational algorithm, amazingly different conclusions can be accomplished. This in itself is an incredibly rich experiential learning tool. The instructor is invited to utilize the tool to their specific advantage in the educational process!
[15] The impact of graphical presentation of data is profound.
[16] Method described in Appendix "C".
[17] Method described in Appendix "D".

Segment B1 – B5: Natural Sciences Exploration:

- Other plants with essential oils
- Other plant defense mechanisms
- Synergy of defense mechanisms in plants
- Influence of natural environment on defense mechanism
- Other oils in plants (example is energy storage oils).
- Other features of plants

Segment C1 – C5: Engineering Exploration:

- Improvements in existing Device
    - Better separator, collector, condenser, capacity, botanical preparing devices, storage containers, etc.
- Energy use of extraction techniques
    - Comparison between three techniques.
- Sustainability of extraction techniques
    - Total energy balance for construction of tool and use period.
- Scale-up of process
- Measurement of performance methods and tools.

Segment D1 – D5: Anthropology of Essential Oils:

- Human discovery of Essential Oils
- Human utilization of Essential Oils
    - as gifts of admiration
    - as masking agents
    - as hallucinogens
    - in aboriginal cultures
    - in Medicine, Cuisine, Ambience
- Effect on Society and Cultures of Essential Oils
- Effect and uses in Medicine of Essential Oils.
- References to Essential Oils in literature
- Naturopathic, Eastern, Western utilization of Essential Oils

Segment E1 – E5: The Economics of Essential Oils:

- International Commerce of Essential Oils
- Values of Essential Oils (Prices and costs associated)
- Trade of Essential Oils
    - History of Essential Oil Trade
- Synthetic vs Natural product Essential Oils Trade and Value
- Essential oils in the Black Market

Appendix "A" Detailed description of First Module, First Segment.

Note: Due to the recognition by this author that many of the readers of this material are likely far more capable and talented in instructional preparations than the author, detail at this level will not be offered for the other topic ideas offered in this treatise so as to avoid the need of the readers to return an abundance of clearly appropriate errata and edit suggestions. Compilations of the observed "best practices" will be made available at the OilExTech, LLC Website at no expense as will literature references. Due to copyright laws, some existing material from other authors which is of value need be acquired through normal processes respecting intellectual property and cannot be included at the website. Upon request and as OilExTech resources allow, additional materials will be generated and made available.

Module 1

Segment 1: The first class session will involve the extraction of the essential oil d-limonene[18] from the grated surface layer of orange rind. As this session is instrumental in setting the stage for all future utilizations of this learning track, an example procedure will be offered.

Session plan objectives:

- Allow the learners to physically be involved (DO SOMETHING) before they need to move into more deep intellectual focus.
- Enable the learners the opportunity to relax in a manner that is conducive to continued involvement.
- Begin a Socratic discovery process and stimulate self-reliance on answer and factuality of acquired information during the exploration.
- Introduce the theme and the future session plans.

Suggested Steps:

- Divide class into groups of 2-4
  - If nitrile® or latex® gloves are to be used, have students apply gloves[19]
  - While not absolutely necessary, Safety Glasses are recommended to be in use!

[18] The major component of Orange Oil is d-limonene!

[19] Nitrile gloves will eliminate contamination from students' skin on the oranges should plans be to consume them and/or the orange oil during or after the classroom process demonstration. Proper lab practices involving gloves and safety glasses will need to be trained and a means to monitor the population will be important. This author has taught bacteriology classes in Pre-Med student populations and even in those cases, has observed students rubbing their nose, eyes, and other portions of their anatomy with laboratory gloves! In any laboratory class, this type of behavior can lead to severe biological vector transport, hence if observed, proper remediation techniques should be enforced. This type of training is indeed another life learning opportunity that practically all individuals could do well to experience.

- Instruct in the process to how to safely grate the orange colored component of an outer orange skin onto a paper/wax paper sheet, towel or into a bowl. Include safety instructions regarding the use of a standard home kitchen manual food grater.
- Hand each group one Orange, a piece of wax paper or small plastic bowl and a kitchen grater (or equivalent) and some paper towels! A minimum of 4 Oranges need be used.
- Commence the grating process.
- Retrieve the first 50 grams of orange gratings (this should be possible within the first 5 minutes of grating processing in a class of at least 4 groups.
- While grating continues, run the EssenEx-100® using the normal Orange oil extraction process[20]. Estimated time for this process is 15 minutes.
    - During the process, teacher (or selected trained learners if exceptional learners are a component of the group). Will be utilizing the following time blocks:
        - 2 minutes: Placement of EssenEx®-100 components in proper filling layout
        - 2 minutes: Placement of orange grating into proper region of EssenEx®-100.
        - 6 minutes: Microwave excitation period with Reactor and cup inside
        - 4 minutes: Cool-down of reactor after removal (with insulated oven mittens) from microwave and placement on a soft surface (towel or insulated heat pad, for example.)
        - 1 minute: Removal of collection vessel and pour into separation flask.
- Allow the students to observe the hydrosol and oil in the collection vessel and collect additional orange gratings at the same time.
- Pour the top 50 ml (+/-) into the separation flask
- Allow the students to observe the oil layer in the separation flask.
- If time permits, select one group to run the unit with a second 50 grams of orange gratings.
- Allow the students to "feel, touch, taste" the orange oil and to write down their impressions.
- During this process, consumption of the oranges by the students is quite possible if acceptable to the teacher assuming proper hygienic behavior during the peel grating process was employed. The Oranges have in no manner been contaminated during the process, aside from handling by the students.
    - Have each group grate the "orange part of the skin" into their bowl or piece of wax paper. Note that care need be exercised to avoid grating fingers![21]

Materials needed:

- All sessions of Module 1 need at least one "EssenEx®-100" essential oil extractor. Usually, to be able to make multiple runs during one 45 minute class period, two units or more is superior. One complete run requires roughly 15 minutes.

<u>Segments 1 through 3: Initial exposure and actions:</u>

- Orange Peel: For each extraction process, approximately 50g of orange peel grind.

[20] See Appendix "E"

[21] Alternatively, one can use a kitchen blender / grinder instead of a kitchen grater if the potential danger of use of the kitchen grater is unacceptable.

    - This amount can be acquired from 4 to 6 regular size oranges, but any citrus (Lemon, Lime, Orange, Grapefruit) are acceptable. It is recommended to have at least enough Oranges or Orange peels to enable teams of 2 to 4 students to work together in grating the peel. For you mathematicians: bring in the greater of 5 or N/2 to N/4 fresh oranges (N is the number of students in the classroom).
- Kitchen Graters: To grate the surface "orange portion" of the orange rind, the optimal tool is a Microplane® Grater[22], yet a standard inexpensive kitchen grater will suffice.
    - Generally speaking, practically every kitchen in the world has such a device, yet if necessary, stock the classroom with enough graters that teams of 2 to 4 students can have utilization of their individual grater for 15 minutes. Graters adequate for this task start at US$ 1.00 each (2015 price).
- Microwave Oven: A standard "kitchen" or "Break room" grade 1000 Watt microwave oven with vertical clearance inside the cooking region in the unit of at least 6.75 Inches (17.2 cm) and a width of 10 Inches (25.4 cm).
- Freezer: For use prior to the actual class event, space in a freezer to create the "ice cores" is needed. Ice core molds are supplied with the EssenEx®-100.
    - Ice Chest: The freezer need not be easily accessible in the work area, but if it is not, then use of a portable ice chest to transport the frozen ice cores into and store them in the classroom area during the process is very effective. This author tends to use very inexpensive "Styrofoam®" ice chests for this purpose and sometimes will place a small block of dry ice in the bottom to ensure a temperature below 0C.
- Cleaning materials: It is advised to have a roll of paper towels or cloth towels
    - Wash basin access and some water as orange peels tend to emit waxes and oils that are better washed off the skin. Depending on the degree of zeal in the experience, materials may require clean-up after the operation. The EssenEx®-100 reactor can be easily cleaned in a normal sink with cold water or thoroughly in a dishwasher.

Sessions 4-10 (advanced process sessions): additional equipment:

- Balance. Ideal is a device capable of 3KG masses with a resolution of 0.01 Gram. There are only a few such balances on the market, one is the "MyWeigh 3100"[23]. It is capable of this range, has 0.01 g resolution and has a computer data output port as well. Alternatively, a relatively low cost kitchen or postal scale is useable[24]. The balance may be easily shared between many student teams.
- Timer. Usually the microwave oven as well as various "smartphones" will have an abundance of such devices.
- Camera: Usually many "smartphones" will have an abundance of such devices.

[22] For example the Microplane® classic Zester/Grater is a very good quality tool: http://us.microplane.com
[23] http://myweigh.com/product/ibalance-i3100/
[24] While the scientific community uses the MKS-SI system of units, other units are fine as conversions between systems of measure is also a very useful educational experience! Kitchen and postal scales are readily available. Prices for new units start at US$ 2.50 and proceed to any amount one wishes to pay. (simple web search.)

- Ruler with mm markings.
- Clean food/beverage cans, jars, and/or bottles with affixed labels. These will be used to demonstrate the effectiveness of d-limonene in removing affixed labels.

Appendix "B": Data Acquisition: (Excel® Spread sheet available)

Date:	Operators:			Time:	Units
5/14/2014	*Sara Smith, John Doe, etc.*			15:45	HH:MM
Botanical Material:	*Orange Peel (example)*				
Run #	Power Level	Duration (MM:SS)	Cool Down (MM:SS)		
1	High	05:00	02:00		MM:SS
lid mass: g	139.94		initial ice mass	160.06	g
lid+ice mass: g	300		final ice mass	30.06	g
lid +remaining ice mass: g	170		Net Water from ice	130.00	g
Beaker:	Before (g)	110.8			g
	After (g)	240			g
Water + oil Collected				129.2	g
apparatus +inner shield mass:		1048.44			g
apparatus +inner shield w/botanical mass	before:	1106.4	botanical mass (g)	57.96	g
Water added : g		0			g
apparatus +inner shield w/botanical mass & water					
	after:	1098.5	botanical mass transfer	7.9	g
flask #	number here				
vial mass:	g	1.3	oil (mm): note 1	8	mm
vial mass+oil mass:	g	6.4			
mm/ml conversion factor	Note 2	1.00	oil (ml): note 3	8	ml
Oil Density	Note 4	0.83	oil (conv gm): note 4	6.64	g
	oil pipetted g	5.10	oil yield (conv g)/g:	0.11	g/g
			oil yield (g/g) pipetted:	0.09	g/g
			Direct Mass	**Conversion**	
Extraction Efficiency	**Mass Oil/Mass Botanical**		0.15%	0.20%	% g/g
BLUE TEXT: TO BE ENTERED					

ORANGE TEXT: TO BE ENTERED ONCE AFTER CONVERSION CALCULATED					
BLACK TEXT: COMPUTED					
Vial mass method has error of pipetting included					
botanical mass transfer may not match other items					
Note 1:	mm of column of oil in neck of separation vessel				
Note 2:					
		Compute the mm per ml of water as water has Density 1.0 g/ml			
Note 3:	Computed by dividing mm of column by conversion factor				
Note 4:	Computed by multiplying ml of oil by density of oil.				

Include a description of the microwave oven used, model number, manufacture date, serial number, power source (110VAC or other), any other significant features of the unit. Similarly, identify the botanical source and details therein. Utilize appropriate scientific description techniques.

Appendix “C”: Mechanical (Press) method of essential oil extraction:

Many essential oils, primarily the triglyceride types, but also including some of the components of orange oil such as d-limonene can be “expelled” from the botanical matrix in which they are produced by a simple press method. Large presses are used for such work for canola, soy, camilina, sunflower and other oilseed pressing. Most of the seed presses on the market are far too large to utilize in an educational setting and are intended to press tons of seed, resulting in hundreds or thousands of gallons of oil. For small volume applications, the following mechanisms function to essentially inefficiently extract minor amounts of pressed oil:

a. Use of a laboratory Mortar and Pestle:

Procedure: Chop botanical into appropriately sized pieces and grind with pestle. Oil will exude from material and be present in the mortar. Difficult to perform a quantitative method as oil will tend to adhere to inner surface of mortar and some also will remain in the crushed botanical materials. Nonetheless, oil can be won from the botanical in this manner. Orange rind can have a portion of the oil extracted in this manner.

b. Use of a standard shop Vise and freezer bags:
    a. Place botanical in polyethylene freezer bag
    b. Remove majority of air from bag
    c. Wrap bag with one layer of paper towel and a second layer of aluminum foil.
    d. Place bag in vise and squeeze botanical
        i. Leave adequate amount of freezer bag out of the vice grip to enable air pocket. Usually, placing the air pocket on the top and leaving the bag zip-lok® with an escape path aids in avoiding bag rupture.
    e. Oil (and water) will exude from botanical and remain in the freezer bag.
        i. While this method is simple and effective, bag failures are possible. Be prepared!

c. Simple Limonene (orange oil) demonstration:
    a. For orange oil, it is possible to hold a piece of orange peel near an open flame (such as a lit wax birthday candle) and by squeezing the peel between thumb and forefinger (flexing the orange peel outward from hand), witness small flashes of combustion as the limonene is expelled from the outer surface of the skin.

d. Purchase of a small scale seed oil expeller:
    a. Some modest cost seed oil expellers are available on-line. The quality of construction varies from exceptionally good to the opposite end of the spectrum.

e. Use of a screw press (cider or wine)
    a. Possible for Orange rind pressing. Other seeds likely to damage the press.

Appendix "D": Supercritical CO_2 Extraction:

One of the most effective mechanisms to extract liquid organic materials from an organic matrix is Supercritical CO_2 extraction. An excellent article describing a method to use 15ml plastic centrifuge tubes to perform a very small scale, yet informative extraction from Orange peel is offered in the following article:

Green chemical processing in the teaching laboratory: a convenient liquid CO_2 extraction of natural products†

Lallie C. McKenzie,*a* John E. Thompson,*b* Randy Sullivan*c* and James E. Hutchisona***
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Green Chem., 2004, **6**, 355–358

http://www.rsc.org/journals-books-databases/about-journals/green-chemistry/?e=1

It has been our experience that the process is safe for operation, and that sometimes the centrifuge tubes do not seal properly. This means that sometimes the result is not an extraction, but after some expertise in the assembly process is developed, it is relatively effective. The amount of orange oil extracted is rather small since the amount of orange botanical that can be placed in the chamber is no more than roughly 15 ml.

The method requires a source of solid CO_2, and since dry ice is readily available at many grocery stores within the USA, the only challenges are:

a. Safely getting the solid CO_2 into the size necessary for insertion into the chamber.
b. Keeping additional solid CO_2 in the laboratory for additional operations. (Styrofoam cooler).

We (this author) are working on a means to scale this process up to a somewhat larger capacity while retaining the same degree of laboratory safety.

Appendix "E": Discovering essential oils, additional opportunities:

Practically every individual on this planet has used essential oils from plants in a variety of activities. Most are truly unaware of their origins, and of those that are aware, few realize that it is relatively simple to extract them from everyday botanical materials. This discovery portion will focus on two relatively easily obtained sources of essential oils. One is an easily separated oil, that found in the colored portion of the skin of citrus and the other is the aroma from Rose petals. Both of these materials are generally readily available throughout the entire state of Oregon (and the USA for that matter). Other materials usually available throughout Oregon, yet possibly slightly difficult in some regions include the following: Peppermint, Lavender, Juniper Berries and Sage.

Steps to the experiential learning opportunity:

1. Assemble the tools for the opportunity
    a. Essential Oil Materials:
        i. Oranges → Local Grocery Store
        ii. Rose Petals → Local rose gardens, flower shops.
        iii. Peppermint → Either peppermint tea bags or local MIRC members.
            1. Also available from Frontier coop: www.frontiercoop.com
                a. (Peppermint Leaf – 1 lb $17.50)
        iv. Lavender → Local Lavender farms or home plants.
            1. Also available from Frontier Coop, but much less expensive if obtained locally. – 1 lb $48.00
        v. Juniper Berries → harvest in Central Oregon.
            1. Also available from Frontier Coop
                a. (Juniper Berry – 1 lb $17.50)
        vi. Explore!

Web references in this paper:

http://www.wellnessresources.com/health/articles/d-limonene_help_for_digestion_metabolism_detoxification_anxiety_breast_canc/

This reference is an example of information about the major essential oil in citrus rind. It is not to be considered a scholarly article and it is recommended that it be used as an avenue for further investigations to provide a complete understanding of the characteristics of d-limonene. As an aside, the compound d-limonene has many chemical properties and has been utilized as a substitute for chlorinate solvents in many "green chemistry" replacements of industrial, commercial, and home chemical products. Consider study of the report by the world health organization (WHO) to aid in understanding the full ramifications of d-limonene. http://www.who.int/ipcs/publications/cicad/cicads_alphabetical/en/ look up "limonene" in this catalog. (Or anything else that you find interesting!)

http://www.ncbi.nlm.nih.gov/pubmed/23061635 This is a paper in the National Institutes of Health database regarding menthol pharmacological properties.

http://www.wildflowers-and-weeds.com/Plant_Families/Lamiaceae.htm An interesting resource regarding identification of botanical species.

http://www.bbc.co.uk/food/rosewater an opportunity to engage students of Middle Eastern and other Asian families exists in this intriguing use of rosewater, sadly practically invisible for centuries in mainstream USA cooking.

http://hellonatural.co/21-smart-household-uses-orange-oil/ This reference is offered as it lists a wide variety of uses for d-limonene as found in Orange oil. Some of these uses are based on scientific proof of effectiveness and others may not have that support.

Other Information on Limonene:

http://www.innovateus.net/science/what-limonene