Emulsions

Unit: Culinary Science

Problem Area: Food Science

Lesson: Emulsions

Student Learning Objectives.

Instruction in this lesson should result in students achieving the following objectives:

1. **Define and explain the emulsion process.**
2. **Describe common emulsifiers and emulsions.**

Resources.

The following resources may be useful in teaching this lesson:

Culinary Institute of America. *The Professional Chef*, 8th ed. Wiley, August 2006.

Duncan, A.W. *The Chemistry of Food and Nutrition*. Qontro Classic Books, July 2010.

"Emulsifiers," *Food Additives*. Accessed July 24, 2011. <http://www.foodadditivesworld.com/emulsifiers.html>.

"Emulsifiers," *Food Additives*. Accessed July 24, 2011. <http://www.understandingfoodadditives.org/pages/Ch2p2-1.htm>.

Gisslen, Wayne. *Professional Baking*, 5th ed. Wiley, 2010.

McWilliams, Margaret. *Foods: Experimental Perspectives*, 6th ed. Prentice Hall, 2007.

Equipment, Tools, Supplies, and Facilities

- ✓ Overhead or PowerPoint projector
- ✓ Visual(s) from accompanying master(s)
- ✓ Copies of sample test, lab sheet(s), and/or other items designed for duplication
- ✓ Materials listed on duplicated items
- ✓ Computers with printers and Internet access
- ✓ Classroom resource and reference materials
- ✓ Optional supplies Interest Approach: Oil, red wine vinegar, cruet with lid, and a bottle of commercially prepared emulsified vinaigrette (such as a zesty Italian type)

Key Terms. The following terms are presented in this lesson (shown in bold italics):

- break
- density
- diglycerides
- emulsification
- emulsifiers
- emulsion
- energy
- gums
- hollandaise sauce
- homogenous
- immiscible
- lecithin
- mayonnaise
- monoglycerides
- sodium stearoyl lactylate (SSL)
- stabilizers
- surfactants
- temporary emulsion

Interest Approach. Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

> *A great way to introduce the topic of emulsions is to show one in action. Have a lidded cruet filled half with oil and half with vinegar. (Red wine vinegar would be visually more appealing.) Then ask different students to shake the bottle until the mixture comes together as a uniform mixture. Of course, the mixture will separate when the shaking stops. Point this out.*

Next, ask students why they cannot get the two liquids to stay mixed. Listen to the answers. It is doubtful the real reason (lack of an emulsifier) will be offered. Finally, produce a bottle of commercially prepared emulsified vinaigrette dressing, and show it to your students. Why doesn't the commercial dressing separate? Ask a student to read the ingredients on the label to see if anyone makes the connection. You may need to point out that emulsifiers include sorbitan monostearate, magnesium stearate, and lecithin from egg yolk. Use this class discussion to introduce the topic of emulsions and emulsification.

CONTENT SUMMARY AND TEACHING STRATEGIES

Objective 1: Define and explain the emulsion process.

Anticipated Problem: What is an emulsion? How is one produced?

I. Emulsion process

A. An ***emulsion*** is a semi-liquid and stable mixture in which one liquid is suspended in another. Emulsions are uniform (***homogenous***) mixtures; they consist of two or more unmixable (***immiscible***) ingredients. One ingredient suspends the other in tiny globules throughout the mixture. Typically, an emulsion involves a fat or oil and another liquid (e.g., stock or wine). Due to the difference in ***density*** (compactness or crowding together of the molecules within a product; thickness) between fats and other liquids, the tighter the molecules are packed together, the denser (thicker) the product. Liquids of different density levels effectively repel each other, preventing an even suspension of the two liquids.

B. ***Emulsification*** is the process through which two or more unmixable ingredients become an emulsion. Emulsification brings the ingredients together into a stable mixture in which the "droplets" of liquids are uniformly combined and remain combined. Without emulsification, the mixture separates just as water and oil do when shaken and allowed to sit. Typically, emulsified mixtures are thicker than any of the ingredients were alone. Making an emulsion requires several elements, including:

1. ***Energy*** is the physical mixing, beating, or whipping of the ingredients, which is one way to bring the ingredients together. A ***temporary emulsion*** is a mixture that stays together only while the mixing is taking place. When the mixing stops, the temporary emulsion begins to separate. When a mixture remains in a homogenous state, it is emulsified. Energy may be transmitted to the ingredients by hand—with a whisk—or by use of a blender or food processor. Mechanical tools are faster and produce a more stable emulsion due to the higher input of energy.

2. ***Emulsifiers*** are food additives that allow normally immiscible liquids—such as oil and water—to form a stable mixture. Vigorously beating egg yolks with a fat (e.g., oil or butter) or stock causes the liquid to become evenly suspended in the egg, and the elements are bound together.
    a. According to the Food Additives World website, emulsifiers have an "oil-friendly molecule on one end and a water-friendly molecule on the other." The additive may be natural (e.g., eggs, egg yolks, honey, and mustard) or chemical (e.g., monoglyceride and sorbitan ester). One or more may be used in any mixture.
    b. Regardless of the type of emulsifier used, most require the addition of energy to bring the ingredients together.
3. ***Surfactants*** are additives that reduce the surface tension between ingredients of different density, allowing a more efficient emulsification to occur. Some emulsifiers are natural surfactants (e.g., lecithin in egg yolks), and others are chemical surfactants with specific purposes. For example:
    a. Anti-scaling in baked goods
    b. Foaming in whipped toppings and icings
    c. Modifying crystals in shortenings and margarines
    d. Wetting in drink mixes
4. ***Stabilizers*** are additives (binders) used in small amounts to ensure an emulsification "holds" and retains body. Stabilizers improve a product's texture, palatability, and shelf life. Sorbitan monostearate is an example of a stabilizer that is also an emulsifier.

Teaching Strategy: *Use VM–A. Assign LS–A.*

Objective 2: Describe common emulsifiers and emulsions.

Anticipated Problem: What are common emulsifiers and emulsions?

II. Emulsifiers and emulsions

A. ***Lecithin*** is the most common, most easily used, and only organic emulsifier; it is a naturally occurring compound (hygroscopic phospholipid) in egg yolks. The major importance of eggs in sauce making is their ability to form emulsions with different liquids. Yolks are used extensively in baking, dressings, ice creams, and sauces to enrich (due to the fat content of yolks) and emulsify the product. Lecithin is available as an additive for products in which egg yolks are not desired or feasible for use. The use of energy, by beating or whipping, is essential for full incorporation of the ingredients and to allow the surfactant nature of lecithin to work in the product.

1. Eggs yolks and whole eggs are a common emulsifier in salad dressings and other cooking operations (e.g., custards, cakes, and high-fat icing) in which oil and water (or vinegar, wine, milk, or cream) are bound together in a creamy

mixture. An example is ***mayonnaise***, which is a cold sauce made primarily from egg yolks, oil, and seasonings blended or beaten into a thick emulsion. Typically, chefs allow that one egg yolk will absorb one cup of oil. Proportions vary based on use.

2. Eggs yolks and whole eggs are binding emulsifiers used in classic sauces. An example is ***hollandaise sauce***, which is a rich, hot, and creamy sauce usually prepared by beating cold butter cubes into warmed egg yolks and adding lemon juice.
3. Eggs yolks and whole eggs are the only emulsifier that adds flavor to an emulsion.

B. Emulsions made with eggs are delicate.

1. Successful egg-based emulsions require careful control of time, temperature, and the application of heat. To create a standard emulsion:
   a. All ingredients should be at room temperature. Chilled ingredients are too viscous (resistant to flow; too stiff) to blend well in a sauce.
   b. Oil must be added to eggs and/or egg yolks very slowly. While beating the egg yolks vigorously, oil should be added a drop at a time at first. As the mixture thickens, oil can be added in a controlled trickle.
   c. Gently cooking warm sauces heats the eggs enough to enhance thickening and body. If the applied heat is too high, the mixture curdles (eggs or yolks separate from the liquid) or breaks. One solution to the curdling and breaking of a warm sauce is to use a water bath (double boiler) to heat the mixture slowly instead of having direct contact with the heat source.
2. Emulsions ***break*** (liquefy) when the oil is added too quickly to the eggs or yolks, as for mayonnaise, or when the applied heat is too high, as with hollandaise sauce. In both cases, the suspension of the oil droplets within the egg yolks is broken. The visual effect of a "break" is a mixture that at once looks curdled, oily, and runny. To "fix" a broken sauce, a person may do the following:
   a. Cold sauces—It is necessary to beat one fresh, room-temperature egg yolk in a clean dry bowl and then very slowly whisk in the broken mayonnaise or other sauce.
   b. Hot sauces— It is necessary to cool the mixture and then add extra yolks. Sometimes broken mixtures cannot be salvaged, especially when excessive heat has caused the yolks to cook and coagulate (harden) in the mixture.
3. Mayonnaise emulsions prepared in a blender or food processor are nearly foolproof. However, to ensure that the mixture is thin enough, whole eggs (not egg yolks only) must be used. The use of egg yolks only causes the mixture to become too thick. Blender-type emulsions are not as rich as yolk-based, hand-whisked varieties.

C. Chemical emulsifiers are extremely common in food products and in non-consumable items. Products that contain yolks/lecithin may contain chemical emulsifying additives because they are also used to add stability to a product.

1. ***Monoglycerides*** and ***diglycerides*** are tiny fat molecules (derived from soybean, sunflower, palm, and other oils) that act as an emulsifier for other fats and ingredients. These fat molecules are artificially manipulated by heating glycerin and oil to create a special type of fat with exceptional emulsifying and stabilizing properties. Their particular strength is in attracting and holding moisture.
    a. Monoglycerides are commonly added to chewing gum, toothpaste, some salad dressings, margarine, ice cream, pudding, some instant potatoes, and breads. Aside from their emulsifying properties, they improve texture, palatability, and shelf life.
    b. Glycerin's special ability to attract and hold moisture has made it an essential element in soaps. Glycerin's "gentle nature" and skin moisturizing properties also make it a popular addition to shampoos and body lotions. Pure glycerin soap in bar shape is transparent.
2. ***Sodium stearoyl lactylate (SSL)*** is a chemically made chain of salt and acids that have uncommon properties that emulsify food and non-consumable products. SSL is a chemical emulsifier.
    a. It is useful in commercial bread making, particularly in mass-produced loaves that have an uncommonly soft texture and that remain "fresh" for extended periods. When used as an emulsifier, it provides improved texture and shelf life.
    b. SSL improves the texture and shelf life of puddings, icing, spreads, chips, cheese products, artificial coffee creamers, dessert toppings, and cake mixes.
    c. It is useful in soap, shampoo, toothpaste, skin cream, hair conditioner, furniture polish, shaving cream, and more.
3. ***Gums*** are processed natural plant products (fiber) used as emulsifiers. Emulsification of a product with a gum results in an exceptionally homogenous and unified product. Gums swell easily and absorb moisture to create an emulsified, thickened product. Gums are designed to readily absorb moisture and cling to fat molecules, making the need for energy to form the emulsion minimal. Xanthan gum, guar gum, and acacia gum are typical examples of gum-type emulsifiers used as thickening agents. Gum emulsifiers are typically found in:
    a. Salad dressing
    b. Ice cream
    c. Jelly and jam
    d. Candy
    e. Toppings and glazes

Teaching Strategy: *Use VM–B, VM–C, and VM–D. Assign LS–B.*

- **Review/Summary.** Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different angle. Questions at the ends of textbook chapters may also be used in the Review/ Summary.

- **Application.** Use the included visual master(s) and lab sheet(s) to apply the information presented in the lesson.

- **Evaluation.** Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the application activities. A sample written test is provided.

- **Answers to Sample Test:**

Part One: Matching

1. d
2. e
3. a
4. c
5. b
6. f
7. g

Part Two: Completion

1. emulsion
2. energy
3. fat
4. bread
5. plants (or fiber)
6. heat

Part Three: True/False

1. T
2. F
3. F
4. F
5. T
6. T

Sample Test

Name _____

Emulsions

Part One: Matching

Instructions: **Match the term with the correct definition.**

a. lecithin
b. surfactants
c. density
d. emulsion
e. gums
f. break
g. mayonnaise

_____1. A semi-liquid and stable mixture in which one liquid is suspended in another

_____2. Processed natural plant products (fiber) used as emulsifiers

_____3. The most common, most easily used, and only natural emulsifier

_____4. The compactness or crowding together of the molecules within a product; thickness

_____5. Additives that reduce the surface tension between ingredients of different density, allowing a more efficient emulsification to occur

_____6. Liquefy

_____7. A cold sauce made primarily from egg yolks, oil, and seasonings blended or beaten into a thick emulsion

Part Two: Completion

Instructions: **Provide the word or words to complete the following statements.**

1. A uniform mixture of two or more unmixable ingredients is a/an _____.

2. Making mayonnaise usually requires the use of _____, along with any additives, to bind the ingredients together.

3. Monoglycerides and diglycerides are small _____ molecules.
4. Sodium stearoyl lactylate is the preferred emulsifier for _____ because the product stays fresh longer.
5. The source of gum emulsifiers is _____.
6. Hollandaise sauce is known to break due to the use of too high _____.

Part Three: True/False

Instructions: **Write *T* for true or *F* for false.**

_____1. The use of a blender or food processor makes for more foolproof emulsions because of the increased amount of energy added to the mixture.

_____2. Gums improve the flavor of the products they emulsify.

_____3. Emulsions that break become too thick to use.

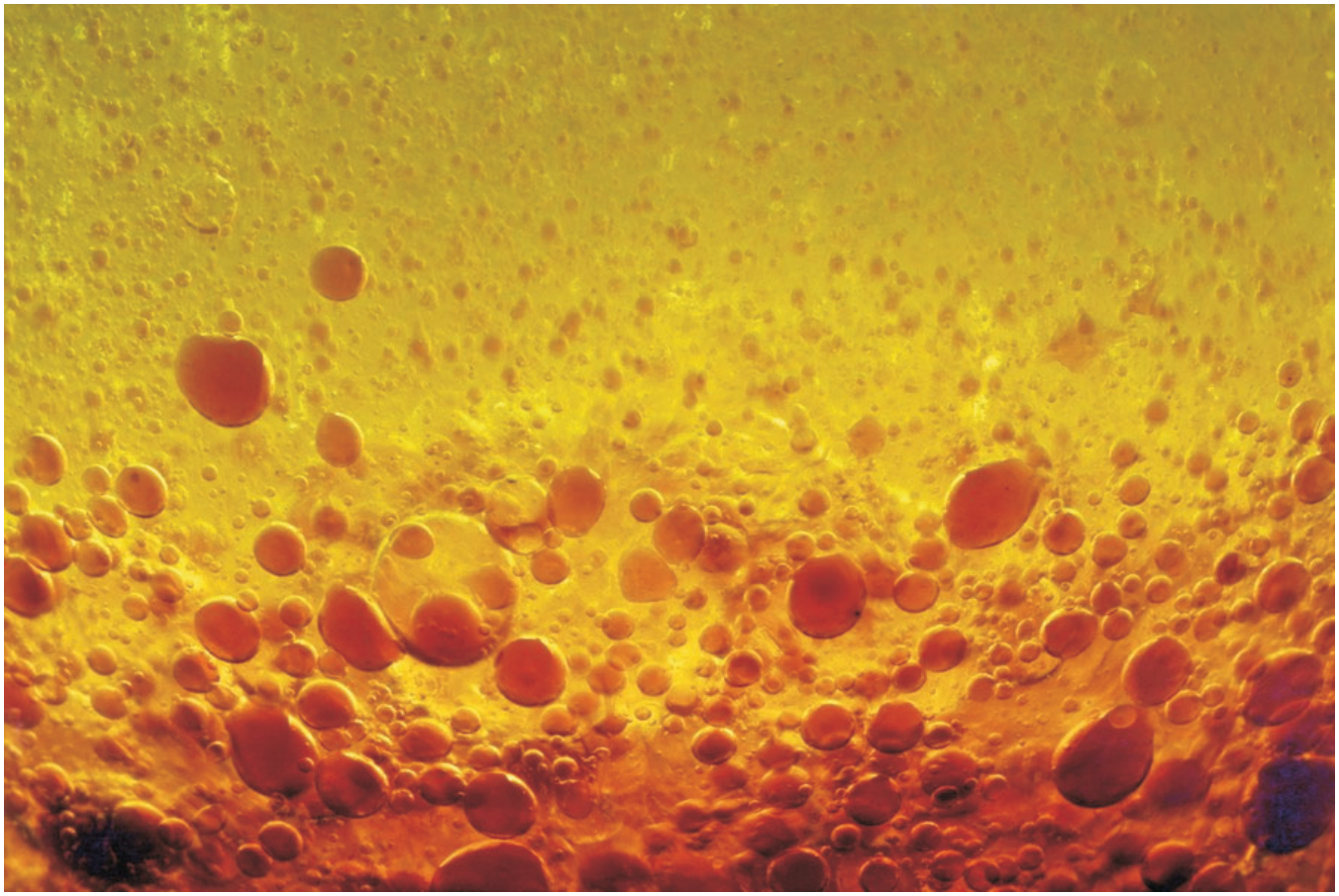
_____4. Jelly and margarine are typically emulsified with sodium stearoyl lactylate.

_____5. Cake, icing, and custard are often emulsified with lecithin.

_____6. Stabilizers are additives (often called binders) used in small amounts to ensure an emulsification "holds" and retains body.

LIQUID DENSITY AND EMULSION

Notice how the globules of vinegar remain as separate droplets within the oil.

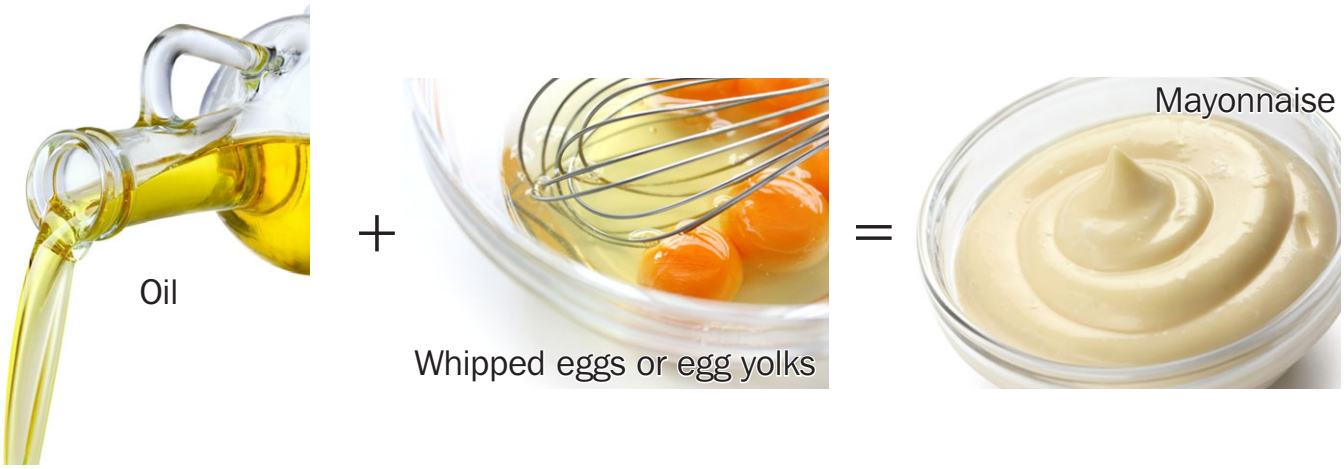


This homemade vinaigrette shows how the oil continues to separate (rise to the top) even though the dressing has clearly been mixed.

The addition of energy—with whisks, mixers, and blenders—is a common way to enhance the emulsification of a product.

EGG AND EGG YOLK EMULSIONS

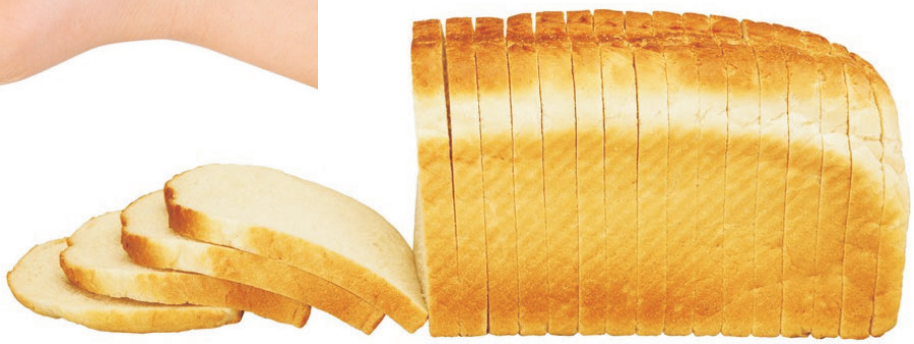
Oil + whipped eggs or egg yolks = mayonnaise



Lecithin is the compound in egg yolks that emulsifies oil and other liquids.

CHEMICAL EMULSIFIERS

Sodium stearoyl lactylate emulsifies everything from shampoo to bread to cheese spread.



Monoglycerides and diglycerides are common in commercial dressings, puddings, and margarine.

GUM EMULSIFIERS

Agar agar is a powdered gel thickener similar to xantham, guar, and acacia gums. All result in thickened, emulsified products—such as salad dressings, puddings, and ice cream.

Name _____

Emulsion Lab

Purpose

The purpose of this activity is to create a stable emulsion.

Objectives

1. Prepare by hand a standard and emulsified vinaigrette dressing.
2. Compare the two processes to mix vinaigrette dressing.
3. Compare the texture, consistency, and taste of the two products.
4. Recognize the properties of a stable emulsified dressing.

Materials

- lab sheet with two recipes
- writing utensil
- two mixing bowls
- hand whip or whisk
- 1 T. salt
- ½ t. white pepper
- 1 T. paprika
- 1 T. dry mustard
- 1 T. granulated sugar
- 1 T. dry oregano
- 4 oz. wine vinegar or cider vinegar
- 24 oz. salad oil
- 3 oz. fresh lemon juice
- 2 eggs
- salad greens, plates, and forks for tasting

Procedure

1. Work with two or three other students.
2. Read each dressing recipe carefully. Know the process.
3. Mise en place: Gather all equipment and supplies prior to production of the dressings. Measure all ingredients prior to assembly.
4. Each team will make two vinaigrette salad dressings—nearly identical. One is emulsified, and one is not. At the end of the activity, you will recognize the emulsified vinaigrette as something you have seen many times.
5. Prepare the dressings one at a time, following the directions exactly and noting the consistency, texture, and taste of each.

Standard Vinaigrette Dressing

1½ t. salt
¼ t. white pepper
1½ t. paprika
1½ t. dry mustard
1½ t. granulated sugar
1½ t. dry oregano
2 oz. wine vinegar or cider vinegar
12 oz. salad oil
1½ oz. fresh lemon juice

a. Combine the dry ingredients with approximately 1 oz. of vinegar. Mix well.
b. Use a hand whisk while adding about half of the oil very slowly to the vinegar mixture while beating the mixture vigorously and constantly. Again, add the oil slowly (about 2 teaspoons at a time) while whisking vigorously and constantly.
c. After adding half of the oil very slowly, add the remaining oil in a very slow and steady stream. Occasionally, add a bit more of the remaining vinegar and the lemon juice alternately with the oil. Continue until all the oil, vinegar, and lemon juice are incorporated. At this point, the dressing is complete.
d. Note the texture, consistency, and taste of the final product.
e. Adjust the flavor if necessary.

Emulsified Vinaigrette Dressing

1 egg + 1 yolk
1½ t. salt
¼ t. white pepper
1½ t. paprika
1½ t. dry mustard
1½ t. granulated sugar
1½ t. dry oregano
2 oz. wine vinegar or cider vinegar
12 oz. salad oil
1½ oz. fresh lemon juice

a. Place the egg and yolk in a clean, dry bowl. Beat the egg mixture vigorously with a hand whip until frothy.
b. Add all the dry ingredients and approximately 1 oz. of vinegar to the egg mixture. Whip the mixture rapidly to combine.
c. Use a hand whisk, to constantly and vigorously beat the egg mixture, while adding about half of the oil one drop at a time until the mixture begins to thicken. As the mixture thickens, you may add the oil in a controlled trickle. If your arm gets tired, switch off with another group member.
d. Occasionally, thin the dressing by adding a little vinegar and lemon juice. Continue until all the oil, vinegar, and lemon juice are incorporated. The entire process takes between 5 and 10 minutes, depending on how fast you can whip. The dressing should have NO visible oil on the surface and should be fairly thick. If the mixture becomes too thick, you may thin it by whisking in a bit more lemon juice, vinegar, or water.
e. Note the texture, consistency, and taste of the final product.
f. Taste a small amount. Adjust the flavor if necessary.

6. Conduct a side-by-side taste test of the two dressings. Assemble a salad plate with greens and a fork for each team member. Try the Standard Vinaigrette Dressing first. Evaluate it for texture, consistency, and taste. Then conduct the same process with the Emulsified Vinaigrette Dressing.

7. While conducting the taste tests, answer the following Post Lab Questions:

   a. What is the main difference between the two dressings?

   b. What was the main preparation difference between the two versions?

c. What provided the “energy” that assisted in making the emulsion?

d. Describe the difference in texture between the two dressings.

e. Describe the difference in consistency between the two dressings.

f. Describe the difference in taste between the two dressings.

g. What is the connection between how fast the emulsified dressing was “mixed” and the thickness of the dressing?

8. Participate in a discussion based on the answers to the Post Lab Questions.
9. Turn in your completed Post Lab Questions to your instructor.

LS–B

Name _____

Emulsion Review and Research

Purpose

The purpose of this activity is to review the theory related to emulsions, emulsifiers, and how they work.

Objectives

1. Use your class notes and research to explain how emulsifiers work.
2. Use your class notes and research to explain how an emulsion is produced.
3. List various emulsifiers and emulsifications.

Materials

- lab sheet
- writing utensil
- cookbooks and culinary reference books
- computer with Internet access, optional

Procedure

1. Work independently to answer the following questions. Use at least two complete sentences for each answer.

   a. Aside from emulsifying ingredients, what value do products such as guar gum and xanthan gum provide to a mixture?

b. Which food item is an emulsifier? What is the name of the ingredient in that food that helps it produce an emulsion? Give two examples of products emulsified with this ingredient.

c. When oil and vinegar are shaken vigorously, what type of emulsion is produced?

d. How does the *density* of ingredients affect an emulsion?

e. Describe monoglycerides and diglycerides. How are they used in food production?

f. What role do *surfactants* play in emulsions?

g. Which emulsifier is particularly useful in keeping breads fresh? What other properties make this emulsifier important?

2. Discuss your responses with the class and your teacher. Turn in your completed lab sheet to your instructor.

Emulsion Review and Research

a. Aside from emulsifying ingredients, what value do products such as guar gum and xanthan gum provide to a mixture?

The gums retain high levels of moisture and provide good palatability to foods. They require far less energy to be applied to the mixture than products emulsified with eggs or egg yolks. Though they are commercially processed, they are plant-based emulsifiers rather than chemicals. Gums are superior thickening agents.

b. Which food item is an emulsifier? What is the name of the ingredient in that food that helps it produce an emulsion? Give two examples of products emulsified with this ingredient.

Eggs and/or egg yolks are emulsifiers. Egg yolks contain the compound lecithin that assists in emulsification. Products that eggs emulsify include salad dressing, mayonnaise, ice cream, and custard. They improve emulsification in other baked goods in which they are used.

c. When oil and vinegar are shaken vigorously, what type of emulsion is produced?

This is a temporary emulsion.

d. How does the *density* of ingredients affect an emulsion?

Liquids of different molecular density effectively repel each other and prevent a uniform mixture. Emulsifiers act as a conduit to bring the molecules into a full and uniform suspension.

e. Describe monoglycerides and diglycerides. How are they used in food production?

Monoglycerides and diglycerides are actually tiny fat molecules that have been manipulated with heat and glycerin to act as emulsifiers with other ingredients. They are often used in margarine, ice cream, pudding, some salad dressings, instant potatoes, and breads.

f. What role do *surfactants* play in emulsions?

Whether a natural part of the emulsifier or a separate agent, surfactants lower the surface tension of molecules. This lowering of the surface tension allows the surfactants to merge together and stay together, particularly with the addition of energy that helps to "force" the emulsion.

g. Which emulsifier is particularly useful in keeping breads fresh? What other properties make this emulsifier important?

Sodium stearoyl lactylate (SSL) is the most effective emulsifier in keeping breads fresh. SSL is the same chemical used in cheese spread, coffee creamer, cake mix, and most notably non-consumable products (e.g., shampoo, hair conditioner, skin cream, and soap). Monoglycerides and diglycerides also help keep bread fresh, but not to the extent of SSL.