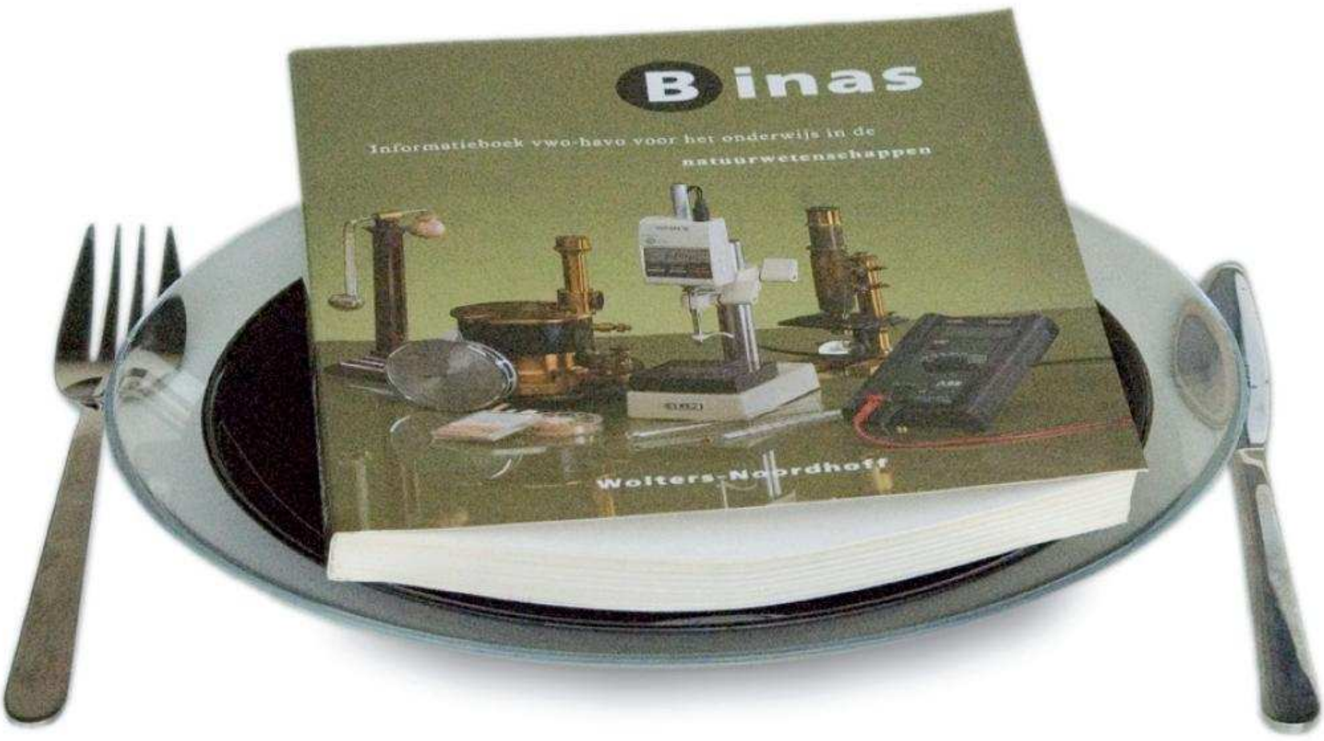
MOLECULAIRE GASTRONOMIE

Practical Course On Emulsions



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Practical Course on Emulsions

Molecular gastronomy is a field of science aimed at improving existing recipes by, for example, looking into the causes of the most recurrent problems when following recipes. Molecular gastronomy also opens the door to new recipes. You will become acquainted with both aspects in this practical course.
In the first part you will analyse mayonnaise in the lab, taking a close look at two properties that regularly cause problems, namely the type of emulsion and the viscosity. In the second part, you will dive into the kitchen for an assignment where you will use your knowledge to make a new product.
You will be working in groups of two.

Learning goals

- You will learn to translate a theoretical concept (HLB value) into practice
- You will know the two factors that affect the type of emulsion (W/O) or (O/W)
- You will learn that emulsions can turn from O/W to W/O and vice versa
- You will understand the relationship between the quantity of emulsion droplets and the thickness of the emulsion
- You will learn how to measure the product's characteristic viscosity
- You will learn how to calculate the viscosity of an emulsion using Stokes' law
- You will be able to use your knowledge on molecular interactions to make a new type of mayonnaise

Skills

- Working with a microscope
- Working with a magnetic stirrer
- Making an emulsion
- Calculating the viscosity of an emulsion

Part I: The Lab

The type of emulsion and viscosity

Experiment 1: HLB values

When you make an emulsion of equal parts of water and oil, the HLB value of your emulsifier will determine whether an oil in water (O/W) or a water in oil (W/O) emulsion is formed. We will test this fact in the next experiment. We use coloured oil to make two emulsions with the same quantities of water and oil. The emulsifiers that we will be using are Tween 60 and PGPR. The HLB values of these emulsifiers are 14.9 and 4.7, respectively. Then we will look under the microscope to see whether an O/W or a W/O emulsion has formed. You can find more information on HLB values and emulsifiers in section *3.4 Emulsifiers (surfactants).*

Equipment

- PGPR
- Tween 60
- water
- oil dyed with Sudan III
- 2 test-tubes
- glass cylinder
- microscope
- slides
- cover glasses
- spatula
- Pasteur pipette

Method

1. Pour 6 ml water and 6 ml coloured oil into both test-tubes.
2. Using a Pasteur pipette add a few drops of Tween 60 to one of the test-tubes and a few drops of PGPR to the other. Label the test-tubes.
3. Shake the test-tubes just long enough until a stable emulsion forms.
4. Using a pipette place a drop of emulsion on a slide and cover it with a cover glass.
5. Look at both emulsions under the microscope and draw what you see in figure 1.

Figure 1: drawings of microscopic image of emulsion 1 and 2

Questions

1. *Which fluid is in the continuous phase and which is in the dispersed phase in emulsion 1 and in emulsion 2?*
2. *Which is the oil in water and which the water in oil emulsion?*
3. *Which fluid does the emulsifier PGPR prefer? and Tween 60?*

The recipe for mayonnaise is one that often goes wrong. This is because two properties of the mayonnaise work against each other: the type of the emulsion (O/W) and the viscosity. The viscosity is determined by the quantity of oil droplets (dispersed phase) in the water phase (continuous phase) of the mayonnaise. The more oil droplets, the greater the viscosity.
In the experiment above, you saw that the HLB value of the emulsifier determines the type of emulsion. However, this is only the case with virtually similar quantities of oil and water. If there is significantly more of one of the fluids, this will become the continuous phase.
In mayonnaise there is a lot more oil than water (70% vs. 30%), but it is nevertheless an oil in water emulsion. As a result, the emulsion is relatively unstable and caution is required when making mayonnaise. If you add too much oil at once in the water phase, the mayonnaise turns from an O/W emulsion to a W/O emulsion (see figure 2). Since there are more droplets of oil in water, it is more likely that they will come into contact with each other, and therefore the risk of them coalescing is greater. The W/O emulsion which is then created has a lower viscosity, since there are fewer droplets present. There is nonetheless less water than oil present. We will analyse the two above-mentioned properties in the following experiments.

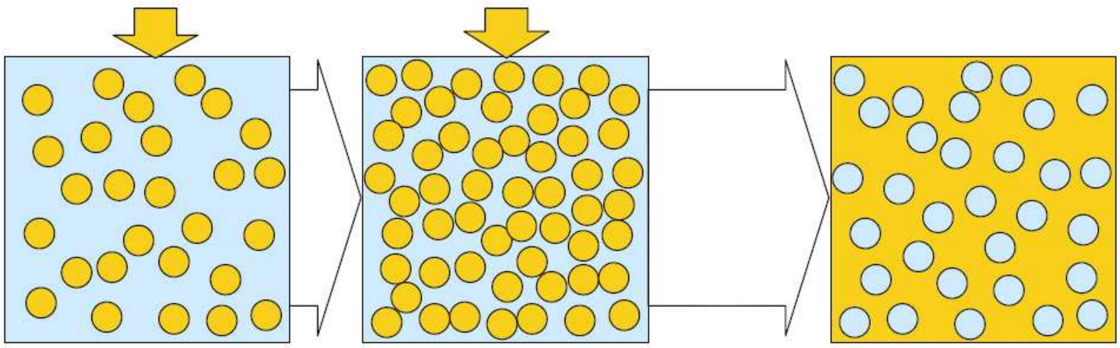

Figure 2: When making mayonnaise, oil is added to water. If too much oil is added at once, the mayonnaise turns from an oil in water emulsion to a water in oil emulsion.

Experiment 2: Two methods for making mayonnaise

In this experiment you will be making mayonnaise using two different methods:

1. By adding all ingredients at once and then mixing all together
2. By adding the oil gradually to the other ingredients while mixing

You will notice that there are distinct differences in the viscosity of each emulsion. In both recipes you start with about 70% oil and 30% water. If water is the continuous phase, there are an extremely large number of oil droplets in a small space. If you move a spoon through these droplets, a frictional force arises in the opposite direction to the movement of the spoon. This makes it more difficult to move the spoon through the emulsion. (Compare this to a room full of people in which you want to walk from one side to the other. You are the spoon and all those people are the oil droplets). If there are a lot of droplets it is more difficult to move the spoon through the emulsion than if there are fewer droplets present.

When a mayonnaise 'turns', there is 30% water in 70% oil, thus far fewer droplets. (It's easier to get to the other side of the room if there are fewer people in it.)
So, it's a matter of how many droplets and not what the droplets consist of. An oil in water emulsion and a water in oil emulsion will be almost equally thick, if they both consist of 50% water and 50% oil.

Equipment (per sample)

- magnetic stirrer
- stirrer
- 300 ml glass beaker
- 30 ml vinegar
- 1 egg yolk
- ½ teaspoon mustard
- ½ teaspoon salt
- ½ teaspoon pepper
- 105 ml sunflower oil
- hand-held blender

Method

1. Separate the egg yolk from the egg white.
2. Put all the ingredients for 1 sample in a glass beaker and mix everything on maximum power with the stirrer to a smooth mass.
3. Mix everything once more with the hand-held blender and label it as *Mayo 1*.
4. Now take another glass beaker and again put all the ingredients for 1 sample in the beaker except the sunflower oil.
5. Mix everything together on maximum power with the stirrer to a smooth mass.
6. Now put the magnetic stirrer on a setting which will mix well and gradually add 80 ml of the sunflower oil (10-15 portions).
7. The magnetic stirrer will now have difficulty mixing because the mayonnaise is getting thicker. We will therefore mix in the last 25 ml using the hand-held blender.
8. Take the stirrer out of the glass beaker.
9. Add the remaining oil in two lots and mix well both times using the hand-held blender.
10. Label this beaker *Mayo 2.*

Questions

4. *Which mayonnaise is thicker, Mayo 1 or Mayo 2?*
5. *What type of emulsion is Mayo 1 and what type is Mayo 2 (W/O or O/W)?*
6. *When making Mayo 2, the mixture kept getting thicker. Explain why.*
7. *Which property do you measure if you are measuring the thickness of mayonnaise?*
8. *Explain how the factors 'type of emulsion' and 'viscosity' can work against each other in this case when making mayonnaise.*
9. *What is the relationship between the number of droplets in the dispersed phase and the frictional force/drag force?*
10. *What is the relationship between the frictional force and the thickness of an emulsion?*

Experiment 3: Viscosity of mayonnaises

In this experiment you will determine the viscosity of various mayonnaises using a derivation of Stokes' law. You will fill a glass cylinder with mayonnaise. Then you will drop a glass bead into it. You will measure the time it takes for the glass bead to reach the bottom of the cylinder. This test will give you enough data to calculate the viscosity of the mayonnaise.

The derivation of Stokes' law: $v=(4(\rho_g-\rho_m)*g*r^2)/18*\eta_m$

Where v is the speed at which the glass bead reaches the bottom, ρ_g is the density of the glass bead, ρ_m is the density of the mayonnaise, g is the gravitational acceleration, r is the radius of the glass bead and η_m is the viscosity of the mayonnaise. You can find more information on Stokes' law and the viscosity of emulsions in section *3.6. Stability of emulsions*.

Equipment

- 3 different mayonnaises: A, B and C
- glass cylinder (10 ml)
- glass bead
- stopwatch
- weighing scales

Method

1. Determine the mass and radius of the glass bead and note this in table 1.
2. Determine the mass and volume of the mayonnaises using a glass cylinder and note these in table 1. Use these data to calculate the density of the mayonnaises and note these in table 2. Use the correct units!
3. Measure height *a* from the bottom of the glass cylinder to the 10 ml gradation and note this height behind *a* in table 1.
4. Fill the glass cylinder with 10 ml mayonnaise A.
5. Carefully release the glass bead from the top of the glass cylinder into the mayonnaise. Start the stopwatch as soon as you let go of the glass bead and stop the time when the bead reaches the bottom. You will see the bead better if you hold a light behind the cylinder.
6. Carry out step 5 twice and note the average of the two recorded times in table 1.
7. Repeat the test for mayonnaises B and C.

Table 1: Measurements			
	mayo A	**mayo B**	**mayo C**
m_g (mg)			
R_g (m)			
m_m (mg)			
V_m (ml)			
a (m)			
t (s)			
g (m/s^2)	*9.81*	*9.81*	*9.81*

Questions

12. *Calculate the speed v at which the glass bead reaches the bottom using a and t in table 1 and note this in table 2.*
13. *Rewrite the formula from the text so that you get η_m on the left of the = sign.*
14. *Using the formula from question 13, calculate the viscosity of the mayonnaises and note these in table 2.*
15. *On the basis of the calculated viscosities determine the concentrations of oil of the three mayonnaises using the given calibration curve.*
16. *What is the relationship between the concentration of oil and the viscosity of the different mayonnaises?*
17. *Why did you measure the time twice and take the average?*

Table 2: Calculations			
	mayo A	**mayo B**	**mayo C**
V_g (ml)			
ρ_g (kg/m^3)			
ρ_m (kg/m^3)			
v (m/s)			
η_m (Pa.s)			

Part 2: The Kitchen

Now that you know more about emulsions, you can adapt a traditional emulsion recipe. This experiment is best performed in the kitchen, but can also be done in the laboratory.
In this experiment you will make mayonnaise with a fresh taste and colour, namely orange mayonnaise. This experiment is intended as a final assignment bringing together all the theory from this section on emulsions. At each step, think carefully about why you are doing it. At the end, you will write a report giving an in-depth analysis of the recipe.

How to make orange mayonnaise

Equipment

- pan (2x)
- sieve
- ladle
- zester/grater
- magnetic stirrer
- stirrer
- 300 ml glass beaker
- orange
- sunflower oil
- egg yolk
- mustard
- salt
- pepper
- sugar
- hand-held blender

Method

1. Grate all the skin from an orange and put it in a pan.
2. Add 120 ml oil to the orange peel in the pan. Heat the oil gently until bubbles appear. Remove the pan from the heat and leave the orange peel to steep in the oil for about 30 minutes.
3. Squeeze the juice from 3 oranges and put the juice along with 3 tablespoons of sugar into another pan.
4. Heat the juice until it is reduced to a thick syrup and then leave it to cool.
5. Using a sieve drain the orange peel and collect the oil. Use a ladle to press any remaining oil from the peel.
6. Keep about 10 ml of the orange oil and juice to taste later.
7. Mix the rest of the reduced juice with egg yolk, salt, pepper, and half a teaspoon of mustard in a glass beaker on the magnetic stirrer.
8. Gradually add 70 ml ‘orange oil’.
9. Add the rest of the orange oil in two lots and mix well each time using the hand-held blender.
10. **Taste** the mayonnaise, the orange oil and the orange juice. Do you taste any difference?

Assignment

Each step of this recipe is based on molecular gastronomic theory. For example, step 4 is performed to concentrate the flavourings in the orange juice, but chemical, taste-improving reactions are also taking place, such as the Maillard reaction and caramelisation.
Describe the molecular gastronomic theory behind each step of this experiment.

Write a report on this recipe, endeavouring to explain every action in the recipe in relation to physics and/or chemistry. Explain also what could go wrong during each of the various steps. Try to explain why this goes wrong and how you can prevent it. Give answers to the following questions in the report:

1. *Why do you steep the orange peel in oil and not in water?*
2. *Why do you use grated peel and not big pieces of peel?*
3. *Why do you heat the oil?*
4. *What happens to the sugar while the juice is being reduced?*
5. *Why do you have to let the oil and orange juice cool before adding it to the egg yolk?*
6. *Why do you add mustard and egg yolk?*
7. *Why do you add the oil gradually?*
8. *What would happen if you added the oil all in one go?*
9. *Explain the differences in taste between the orange oil, the orange juice and the orange mayonnaise.*
10. *What is the purpose of adding salt and pepper to the mayonnaise?*