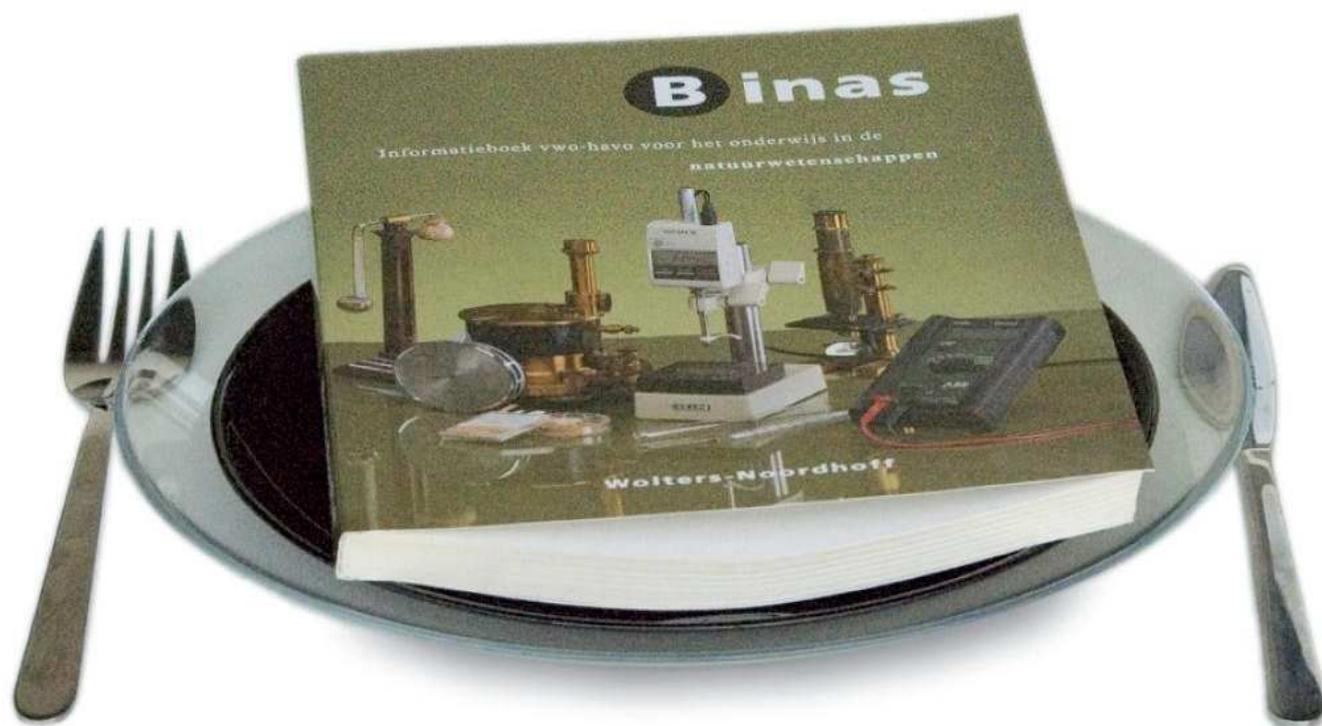


# MOLECULAIRE GASTRONOMIE



## Practical Course On Foams



NLT module voor het VWO



WAGENINGEN UNIVERSITY  
WAGENINGEN **UR**

---

## Practical Course on Foaming

Molecular gastronomy is a field of science aimed at improving existing recipes by, for example, looking into the causes of the problems that occur most frequently 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 the stability of beer foam, looking in particular at the underlying processes that cause the foam to sag. In the second part you will make meringues according to various recipes. In the third part you will dive into the molecular gastronomy kitchen with your class to make some espumas.

After performing the experiments you will write a report containing the answers and calculations to the questions. This report will count for 25% of your final mark in the module.

### Learning goals

- You will learn how to calculate the half-life of beer foam.
- You will learn that the stability of foam depends on three physical processes.
- You will learn what effect the solubility of a gas has on the stability of the foam.
- You will learn what role carbohydrates, proteins and air play in foam.
- You will learn more about various types of foams, fluid and solid.
- With the knowledge on molecular interactions you will learn how to understand the micro-level changes in foams, which result in molecular gastronomic foaming.
- You will learn how to calculate the volume fraction of gas as a function of time.
- You will learn what effect sugar has on drainage speed.
- You will learn what happens in the oven when a meringue is baking.
- You will learn how to prepare espumas with proteins and carbohydrates, using gases that are converted into foam with the help of a gourmet whip.

### Skills

- Working with a microscope
- Working with a magnetic stirrer
- Working with a burette/foam column
- Making a protein foam
- Making a milk foam
- Working with a gourmet whip
- Critical analysis and calculation of your results

## Part 1: Beer foam

### The stability of beer foam

Beer drinkers attach a lot of importance to a nice head of foam on their beer. When beer is poured into a glass, this foam head forms. Unfortunately the foam does not last long, gradually sinking into the beer. The dispersed phase of beer foam usually consists of CO<sub>2</sub> (Heineken), but sometimes of nitrogen (Guinness). In the experiments below we are going to investigate the stability of beer foam.

#### **Here are a few tips for pouring your beer in order to get a nice foam head:**

- First pour a little deeper into the glass so that the necessary foam forms.
- Don't pour too fast, because this causes air bubbles instead of carbon dioxide bubbles to appear, and these disappear faster.
- Pour in the beer along the side of the glass.
- Make sure that the glass is approximately the same temperature as the beer.

### **Experiment 1: The half-life of beer foam**

The stability of a foam head can be expressed as the half-life value. The half-life of beer foam is the 'Number of seconds that pass before the volume of the foam has decreased by half.' In a tall glass that is the time that passes before the height of the head has sunk by half.

#### Equipment

- 2 glass cylinders (250 ml)
- Guinness beer (cold and luke-warm)
- Heineken beer (cold and luke-warm)
- Stopwatch
- Ruler
- Thermometer

#### Method

Perform the experiment for each beer twice, in order to increase the accuracy of your results (you will end up with 8 measurements in total). Make sure that when carrying out the experiment you always pour the beer in the same way.

1. Measure the temperature of your beer with the thermometer. Make a note of this.
2. Pour the beer in a thin stream into the glass cylinder up to about 150 ml, so that you get a lot of foam and only a little beer.
3. Wait until the biggest bubbles have burst and start the stopwatch.
4. Use a ruler to measure the height of the foam head every 30 seconds.  
(Careful of the foam that sticks to the side, make an estimate of the height)
5. Take these measurements over a period of 10 minutes (600 seconds).
6. Enter the measured values (a) in the table below.

Time (s)	Length of foam (cm)
t	a
0	
30	
60	
....	
570	
600	

Questions

1. Calculate the normalised length by deducting the last measurement (b) from all previous measurements (a).
2. The time it took for the foam head to sink is an exponential function. That means that the same percentage of the height decreased every second: the decrease in height/sec is proportional to the height itself. For example, if we start with 10 cm and after 10 sec there is still 5 cm left, there will be 2.5 cm left after 20 sec and 1.25 cm left after 30 sec, etc. In mathematical terms this means that the natural logarithm of the height (ln x) decreases proportionally with time. Calculate the value of ln (x) using your calculator.

Time (s)	Length of foam (cm)	Normalised length (cm)	Ln(x)
t	a	X= a-b	
0			
30			
60			
....			
570			
600			

b = The length of the foam head after 300 seconds.

3. Draw a graph with the time on the x-axis and ln(x) on the y-axis and determine the slope (K).
4. Calculate the half-life ( $t_{1/2}$ ) using the formula below:
 
$$t_{\frac{1}{2}} = \frac{\ln(1/2)}{K} = \frac{-0.693}{K}$$
5. What does the half-life value say about the stability of the beer foam?
6. Which 3 processes take place while the foam is collapsing. Use drawings to explain what happens in these processes.
7. Which beer foam has a higher stability without looking at your results. Guinness or Heineken?
8. Does the answer to question 7 correspond to the results from question 4? If not, explain why not.
9. What is the effect of temperature on the foam head?
10. While carrying out the experiment, there was a visible pattern consisting of 3 different layers in the cylinder (figure 1). From bottom to top these layers look as follows: the lowest layer consists of fluid (beer). Layer 2 consists of fine foam and layer 3 of rougher bubbles. Explain the structure of the different layers. Which process from question 6 plays an important role here?

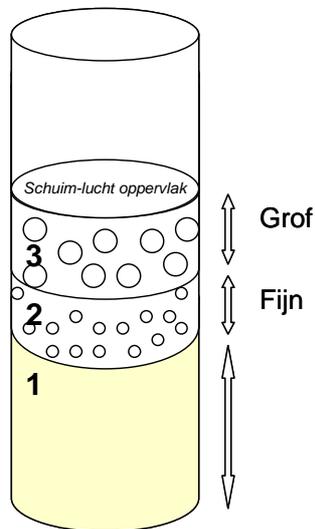


Figure 1. Beer foam pattern in a cylinder.

[translation of words in diagram to be transferred: foam-air surface/coarse/fine]

## Experiment 2: The stability of beer foam

Another way to determine foam stability is to measure the volume of the gas phase as a function of time. The volume fraction of the gas can be calculated using the following comparison:

$$\phi(t) = \frac{h_{\text{tot}}(t) - h_0}{h_{\text{tot}}(t)}$$

With:

$h_{\text{tot}}(t)$ : Total height of the foamed beer (height of the beer + foam at time t)

$h_0(t)$ : Height of the beer before foam forms.

### Equipment

- Burette/foam column with ruler
- Set up with clamps for the burette
- Beer
- Carbon dioxide tank
- Nitrogen tank
- Rubber/plastic hose
- Stopwatch
- Glass beaker
- Stirrer
- Magnetic stirrer

### Method

Perform the experiment twice for each gas, to increase the accuracy of your results (this will give you a total of 4 measurements).

1. Rinse out the burette with cold water.
2. Pour flat beer into the burette and measure the height of the liquid (up to  $\pm 10$  cm).
3. Create a foam in the first cylinder by attaching the CO<sub>2</sub> hose to the bottom of the burette and opening the tap very carefully.
4. Close the tap when the foam layer has reached a thickness of 30 cm and leave the gas hose in place.
5. Measure the height of the foam and the height of the liquid-foam interface as a function of time for 15 minutes (see table below).
6. Rinse out the glass cylinder again with cold water.
7. Repeat the experiment using nitrogen.

### Questions

1. Enter the measured values in the table below.

Type of gas	CO <sub>2</sub>			Nitrogen			
	Time (min)	Interface (cm)	Foam (cm)	Volume fraction (-)	Interface (cm)	Foam (cm)	Volume fraction (-)
Before foaming			0	0		0	0
0							
2							
4							
6							
8							
10							
12							
14							
15							

2. Calculate the volume fraction of the gas (CO<sub>2</sub> or nitrogen) for the time.
3. Draw a graph with time on the x-axis and volume fraction on the y-axis.
4. What can you deduce from the graph? Explain your observation.
5. Would it be possible to make a nice head of foam from air? Which gas, air or CO<sub>2</sub> forms the smallest bubbles and why?
6. Why can't you use air to replace the CO<sub>2</sub>?
7. What would happen to the beer foam if you sucked away the air directly above the foam head with a water jet pump, like a vacuum cleaner?

### Experiment 3: Cleanness of the glass

The stability of the foam head is also determined by the cleanness of the glass. In this experiment we are going to take a look at the effect that the cleanness of the glass has on the stability.

### Surface tension

Surface tension is a natural phenomenon in which the surface of a liquid in a liquid-gas transition behaves like a resilient layer. The fact that a fly can walk on water, and the reason why you cannot blow bubbles from normal water, are all because of surface tension. You can see the tension in a glass of water. The surface is not totally flat, but is a little convex. This is because Van der Waals forces between the molecules in the water head towards the liquid's surface. In the water the force is exercised from all sides, which causes them to lift each other. Some substances, for example soap, can reduce the surface tension of a liquid.

Thus, surface tension also plays a role between the gas and liquid phase in beer foam. This tension is required to keep the air bubbles intact.

### Equipment

- 3 beer glasses
- Milk
- Detergent
- (Demi)Water
- Beer
- Stopwatch

### Method

1. Take three beer glasses:
  - a. Clean one in water with detergent.
  - b. Clean one by rinsing with (demi)water.
  - c. Rinse one with a milk
2. Fill the glasses with beer and using a stopwatch measure how long a foam head stays on the beer. Fill in the table below:

Beer glass	Time (seconds)
Cleaned with detergent	
Cleaned with water	
<i>Rinsed with milk</i>	

3. Leave one of the glasses that contained beer in the sun for 15 minutes and watch what happens.

### Questions

1. *In which of the three glasses did the foam head stay longest?*
2. *Explain what this has to do with surface tension?*
3. *After rinsing it is better to let a beer glass drain than dry it with a tea towel. Why?*
4. *Why is it unwise to serve fatty snacks like cheese and sausage with beer?*
5. *What happens to the glass that is left to stand in the sun? Explain.*
6. *A real beer drinker does not want his glass washed each time he has emptied it. Why not?*

## Part 2: Meringue

### Experiment 4: Meringue from egg foam

#### Equipment

- 6 eggs
- 300 g sugar
- 3 tsp vinegar
- Whisk
- Weighing scales
- Grease-free bowl
- Microscope
- Glass plate
- Cover glass
- Pasteur pipette
- Oven preheated to 100°C

#### Method

<b>Ingredients</b>	<b>Recipe 1</b>	<b>Recipe 2</b>	<b>Recipe 3</b>
Eggs	2	2	2
Sugar (g)	50	100	150
Vinegar (tsp)	1	1	1

1. Carry out steps 2 to 10 for the above recipes in the table.
2. Separate the eggs into egg yolks and egg whites. (Make sure that you only use the egg white)
3. Whisk the egg whites until stiff.
4. Then gradually add the sugar until stiff peaks form.
5. Next add the vinegar and whisk thoroughly.
6. Use half the meringue foam and with 2 spoons place ovals of mixture on a baking tray covered with grease-proof paper.
7. Label the baking tray recipe '1', '2' and '3'.
8. Bake the meringue for about 1 hour in an oven preheated to 100°C. (Extend the baking time by 20 minutes for bigger meringues)
9. The meringues are properly cooked if the outside is dry and if they can be easily removed from the grease-proof paper.
10. Place a piece of the cooked meringue (recipe 2) under the microscope and draw what you see in figure 1.
11. Using a pipette place a drop of the foam from recipe 2 (other half of step 5) on a slide and cover it with a cover glass.
12. Look at the foam under the microscope and draw what you see in figure 1.

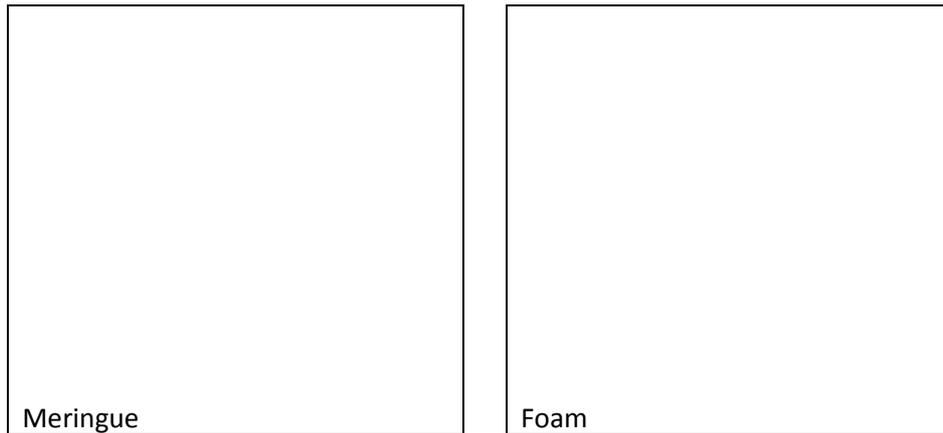


Figure 1: Microscope drawings

### Questions

1. Why do liquid egg whites change into a foam when whisked? Explain what happens to the egg whites.
2. What is the role of water here?
3. Explain why you shouldn't keep whisking indefinitely. What would happen?
4. Why does the bowl have to be grease-free?
5. Why do we add vinegar?
6. What is the effect of the added sugar on the drainage speed? See formula:

$$Q = \frac{2 \cdot \rho \cdot g \cdot 0.4 \cdot d \cdot \delta}{3\eta}$$

7. What happens while the meringue is baking?
8. What is the continuous phase and what is the dispersed phase of both structures (indicate in figure 1)?
9. What is the difference between the two foams in figure 1?
10. Fill in the table below on the basis of your observation (experimenting and whisking). Explain your observation.

Viscosity	Recipe (foam)	Taste	Recipe (meringue)
High		Sweeter	
Low		Sweet	

### Experiment 5: Meringue from milk foam

Milk foam is usually made to put on top of a cappuccino. In section 4 you read about the research Wageningen University carried out to show that milk foam can be used to make meringues without egg whites.

### Equipment

- Fresh low-fat milk
- Fresh full-fat milk

- Sterilised low-fat milk
- Sterilised full-fat milk
- Sugar
- Vinegar
- Whisk
- Grease-free bowl
- Hot plate
- Thermometer
- Oven
- Baking tray lined with grease-proof paper
- Ingredients to make a tasty meringue

### Method

Carry out steps 1 to 4 for all four types of milk.

1. Pour 500 ml milk into a grease-free bowl.
2. Whisk the milk until it forms a foam.
3. Gradually add the sugar and vinegar.
4. Do you get a stable foam? Fill in the table.

Carry out steps 5 to 8 for all four types of milk.

5. Heat 500 ml milk in a bowl to 75°C on a hotplate.
6. While heating, whisk the milk to a foam.
7. Gradually add the sugar and vinegar.
8. Do you get a stable foam? Fill in the table.

Carry out steps 9 to 10 for all four types of milk.

9. Heat 500 ml milk in a bowl to 90°C on a hotplate.
10. While heating, whisk the milk to a foam.
11. Gradually add the sugar and vinegar.
12. Do you get a stable foam? Fill in the table.

Type of milk	Cold (fridge)	75°C	90°C
Fresh low-fat milk	<i>Stable/unstable</i>	<i>Stable/unstable</i>	<i>Stable/unstable</i>
Fresh full-fat milk	<i>Stable/unstable</i>	<i>Stable/unstable</i>	<i>Stable/unstable</i>
Sterilised low-fat milk	<i>Stable/unstable</i>	<i>Stable/unstable</i>	<i>Stable/unstable</i>
<i>Sterilised full-fat milk</i>	<i>Stable/unstable</i>	<i>Stable/unstable</i>	<i>Stable/unstable</i>

Now it's time to experiment with your knowledge. In section 1.6 chapter 4 you read that you can add a flavour when you make foam from milk, just like you can with ice-cream. Let's do this. Use the milk and temperature that created the best foam from the previous steps.

13. Perform the steps again to make a stable foam (step 1 to 3 or step 5 to 7 or step 9 to 11).
14. While making the foam add the flavouring of your choice! It shouldn't contain too much water. For example, if you have brought orange juice along, reduce it first, so that the water can evaporate.

15. Use 2 spoons to make ovals of mixture on a baking tray covered with grease-proof paper.
16. Bake the meringue for about 1 hour in an oven preheated to 100°C. (Extend the baking time by 20 minutes for bigger meringues)
17. The meringues are properly cooked if the outside is dry and if they can be easily removed from the grease-proof paper.

### Questions

1. *Explain why you can also make a meringue with milk.*
2. *Explain the results from table 1.*
  - a. *Which temperature makes the best foam? Why?*
  - b. *Why is it more difficult to make a stable foam at the other two temperatures?*
  - c. *What sort of milk gives the best foam? Why?*
3. *If you whisk cream, it doesn't work if the room is too warm. Explain why.*
4. *Why is it easier to add all sorts of flavourings to milk foam than to egg foam?*
5. *Did you succeed in making a meringue with a 'new' flavour?  
If so, why? If not, why not?*
6. *What is the difference between cappuccino foam, cream foam and meringue foam?*
7. *Why is low-fat milk often used to make cappuccino foam?*
8. *Why is light, fluffy food so delicious?*

### **Part 3: Making espumas**

Espumas is Spanish for foams or mousses. You can make espumas using a gourmet whip (see section 1.6.2.). A gourmet whip is a sort of cream dispensing can, with which you can make different flavoured foams. You fill the gourmet whip with the desired ingredients and a foam is created by means of a gas cartridge. In groups you are now going to make various fillings to go in the gourmet whip. Then you will make, test and analyse the foams with the lecturer:

- How does the foam remain stable?
- Why do you take certain actions when preparing the recipe?
- Why do you heat/cool the foam?

#### ***Group 1: Cucumber espuma***

##### Equipment

- 1 cucumber
- 4 egg whites
- 1 tsp salt
- Hot plate
- Hand-held mixer/blender
- Thermometer
- Bowl + pan to make a bain-marie
- Glass beaker

##### Method

1. Cut the cucumber into pieces and puree it to a liquid with the hand-held mixer/blender. You will need a total of 4 dl juice.
2. Mix the juice with the egg whites and whisk it into a foam.
3. Heat the mixture in a bain-marie to 68°C.
4. Sieve the mixture and fill the gourmet whip with it.
5. Place the gourmet whip in the bain-marie to keep it warm until ready for use.
6. Use 2 gas cartridges to make the foam.

#### ***Group 2: Peanut butter espuma***

##### Equipment

- 350 g milk
- 75 g peanut butter
- Sugar
- Weighing scales
- Hot plate
- Hand-held mixer/blender
- Thermometer
- Small pan
- Spoon

##### Method

1. Heat the milk and the peanut butter in a pan to 60°C.
2. Add the sugar and mix until it is all dissolved.
3. Fill the gourmet whip with the mixture. Use 1 gas cartridge to make the foam.

### ***Group 3: Strawberry espuma***

#### Equipment

- 450 g strawberries
- 55 g sugar
- 2.5 leaves of gelatine
- Hand-held blender
- Fine sieve
- Hot plate
- Small pan
- Bowls
- Whisk

#### Method

1. Let the gelatin swell in cold water.
2. Cook the strawberries with the sugar.
3. Puree the strawberry mixture and sieve.
4. Heat 200 ml of the strawberry puree to 60°C and stir in the gelatin.
5. Add the rest of the puree and leave the mixture to cool.
6. Mix the mixture again with a whisk, before pouring it into the gourmet whip.
7. Pour the puree in the gourmet whip and use 1 gas cartridge to make the foam.

### ***Group 4: Chocolate espuma***

#### Equipment

- 250 ml milk
- 250 ml cream
- 35 g sugar
- 50 g chocolate

#### Method:

1. Weigh all the ingredients.
2. Put the cream and milk in a pan.
3. Then add first the chocolate and then the sugar.
4. Now heat everything until the chocolate has melted and the sugar is dissolved. (don't let it cook).
5. Then leave the mixture to cool to 40°C.
6. Fill the gourmet whip with the mixture.
7. Let it cool in the fridge for 2 hours.
8. Use 2 gas cartridges to make the foam.