Oral Digestion 2: Food Breakdown during Oral Digestion

Overview

The main enzyme present in saliva is ______________________________

- Important in the digestion of ________________________
- Only found in animals that eat foods with considerable starch content
- Highest prevalence in saliva of ______________________, but the activity/amount varies considerably
- Evolution suggests that…

The other enzyme found in saliva is _________________________, which hydrolyzes

________________________________ to ____________________________________

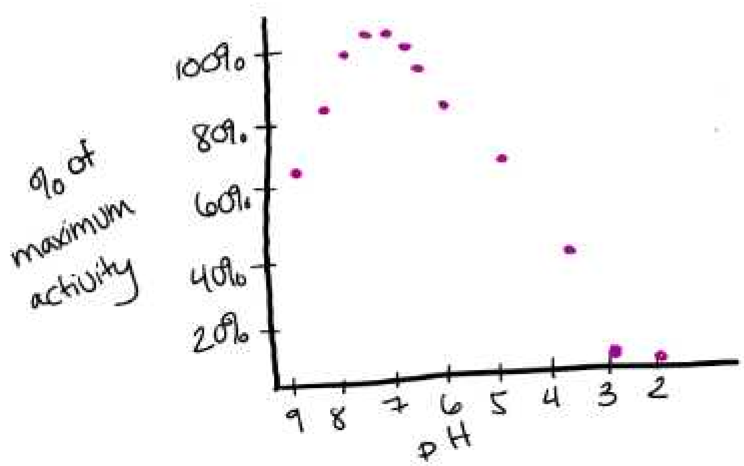
- In humans, lingual lipase activity has been found to be ____________________
- In other species, such as _________, lingual lipase has a high lipolytic activity, which results in significant lipid hydrolysis

Salivary Amylase

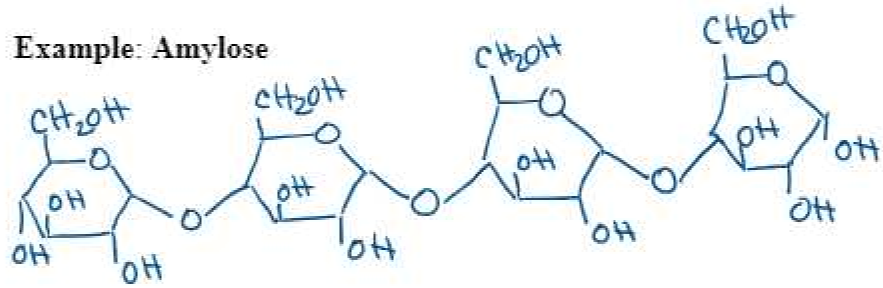
Salivary amylase breakdown down _________________________ into smaller molecules such as: ____

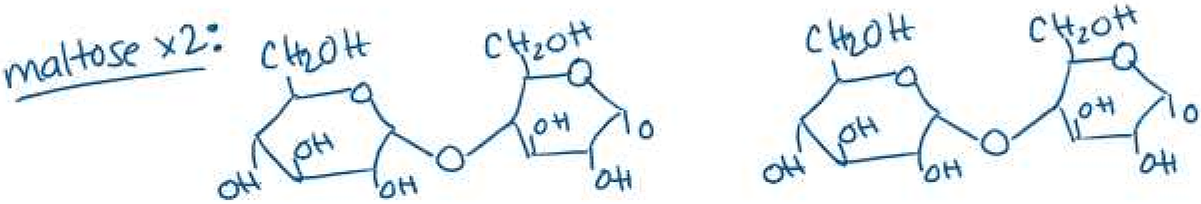
Optimal pH: _____________

Active pH range:



Example: Amylose





Simplified view: Amylose vs. Amylopectin Hydrolysis

Salivary Amylase Hydrolysis Products

<u>Importance of Salivary Amylase in Carbohydrate Digestion</u>

Historically, α-amylase was considered ________ __ ____ in carbohydrate digestion

Why?

However, recent studies have contradicted this belief and shown that α-amylase may be more important in carbohydrate digestion than previously considered. Why?

- Evolutionarily, why do omnivores have an enzyme (not present in obligate carnivores) if it is not necessary?
- α-amylase results in _ ____ __ in several minutes
- α-amylase reduces bolus __ __________ in a very short time → impacts on ________ ___
- Breakdown of starch into maltooligosaccharides may change ________
- Starch digestion products may be detected in the oral cavity and begin to elicit ___________

Salivary amylase may also be result in gastric starch hydrolysis

- Studies have shown that meal gastric pH may remain high (_______) allowing α amylase to continue starch hydrolysis in the stomach
- α-amylase retained activity during gastric digestion in vitro and using in vivo animal models

<u>Food Mechanical Breakdown during Mastication</u>

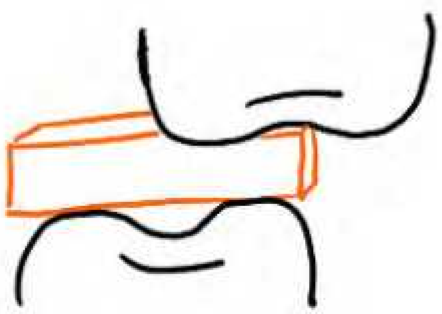
In addition to softening and enzymatic hydrolysis by salivary amylase, foods are also

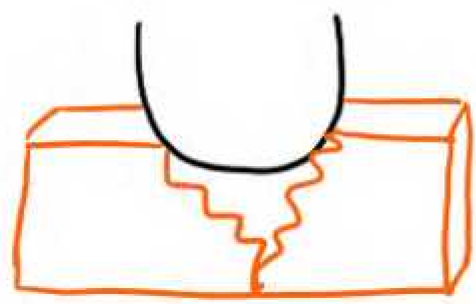
_______________________ down by the _____________ during mastication.

The biological objective of food breakdown is to increase___________________________,

facilitating enzymatic and acid hydrolysis

If we take a very simplified view of (solid) food particle breakdown by the teeth, we can imagine 2 different mechanisms:





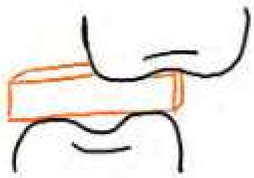
The specific breakdown and resulting particle size distribution are influenced by the solid food physical properties, such as:

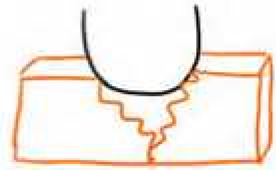
The overall solid breakdown process of foods during mastication can be described similar to any comminution process, which is made up of 2 separate events.

- <u>Selection function (S):</u>

- <u>Breakage function (B):</u>

How do we relate the particle breakdown processes with food properties?





E = elastic or Young's modulus of food

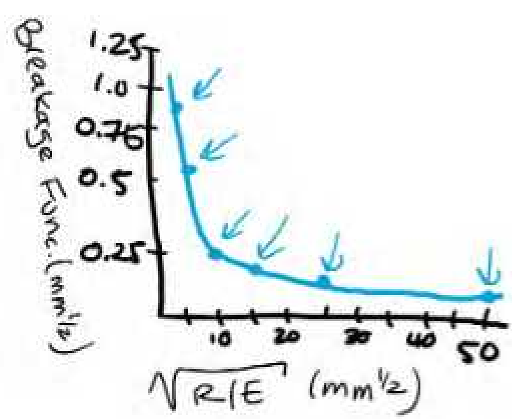
R = toughness of food (energy dissapated in crack formation)

Exceptions to the $(R/E)^{0.5}$ criterion:

- Very thin particles:
- High forces:

What does this look like for actual foods?

Example Food Property Values (Agrawal et al., 1997)			
Food Product	**R, Toughness, J/m²**	**E, Young's Modulus, MPa**	**$(R/E)^{0.5}$**
Feta cheese	88.7	0.47	13.7
Cheddar cheese	123.3	0.89	11.8
Parmesan Cheese	254.9	2.26	10.6
Raw carrot	440	4.57	9.8
Potato	210.9	2.68	8.9
Almond (blanched)	245.8	21.57	3.4
Cashew	174.8	11.08	4.0
Peanut (roasted)	255.5	23.9	3.3



<u>How to determine particle size reduction during mastication?</u>

A common technique in mastication trials is to employ the "chew and spit" methodology. These types of tests generally include the following steps:

1. Give subject certain amount of food to be chewed

2. Practice chews
3. Have subject masticate (chew) food for: (1) (2)
4. Expectorate (spit) chewed food pieces/bolus
5.

Factors that may be changed or controlled in mastication studies are:

1.
2.
3.
4.

Measurements commonly taken in mastication trials

1. Number of chews/chewing time (if food chewed until swallow triggered)
    a.
    b.
2. Jaw movements
    a.
3. Electromyography (EMG) activity of the jaw
    a.
4. Saliva secreted
    a.

5. Particle size distribution of chewed food

    a.

    b.

    c.

    d. **x50** quantified:

<u>How to determine the x50 from a distribution of particles?</u>

One commonly used equation to describe the particle size distribution after mastication, the **Rosin-Rammler equation**:

$$C(x) = 1 - e^{-(x/x_{50})^{b} \cdot ln(2)}$$

$C(x)$ = cumulative fraction of particles with a size smaller than x

x = particle size

x_{50} = size of a sieve that 50% of the particle mass could pass through

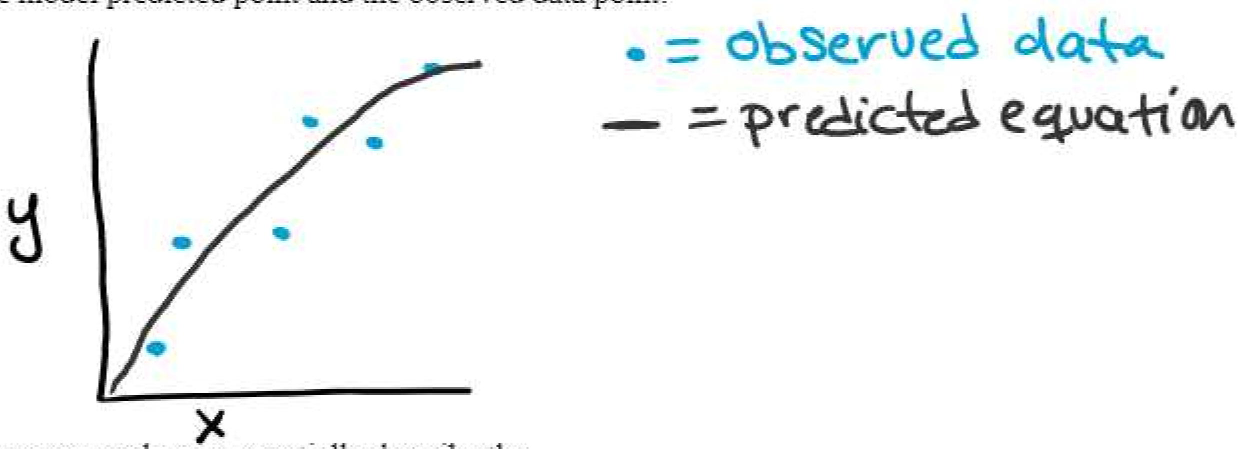
b = variable representing the spread of the distribution

The Rosin-Rammler Equation was originally used to describe particle size of

____, but works very well with mastication data.

As this is a ___________________________, to determine the x_{50} and b values, we will need to use a simple non-linear regression. To do this, we will minimize the root mean squared error (____________) using Excel solver (another tutorial will show you how to do this).

When you fit any equation to data points, you will have residuals, which are the distance between the model predicted point and the observed data point:



The root mean squared error essentially describe the______________________________________, and is a common way to describe the error associated with a model.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_{i,predicted} - y_{i,observed})^2}{n}}$$

RMSE = root mean squared error

n = number of observations

$x_{i,predicted}$ = predicted value i

$x_{i,observed}$ = observed value i

We will minimize the RMSE to fit our Rosin-Rammler parameters →

<u>When is a Swallow Triggered??</u>

There are 2 ways to think about when a swallow would be "triggered"

1) Degree of lubrication, structure, and time
2) Optimal cohesive forces

1) Degree of lubrication, structure, and time

Three conditions must be met before a food can be swallowed:

A) Degree Lubrication: amount of saliva

The degree of lubrication will be influenced by

B) Degree of Structure: size of food particles

C) Time: each food will have a certain minimum time required in the mouth

To see how this could be applied, let's look at two contrasting foods:

Juicy steak

Degree of Lubrication:

Degree of Structure:

Time:

Dry piece of cake

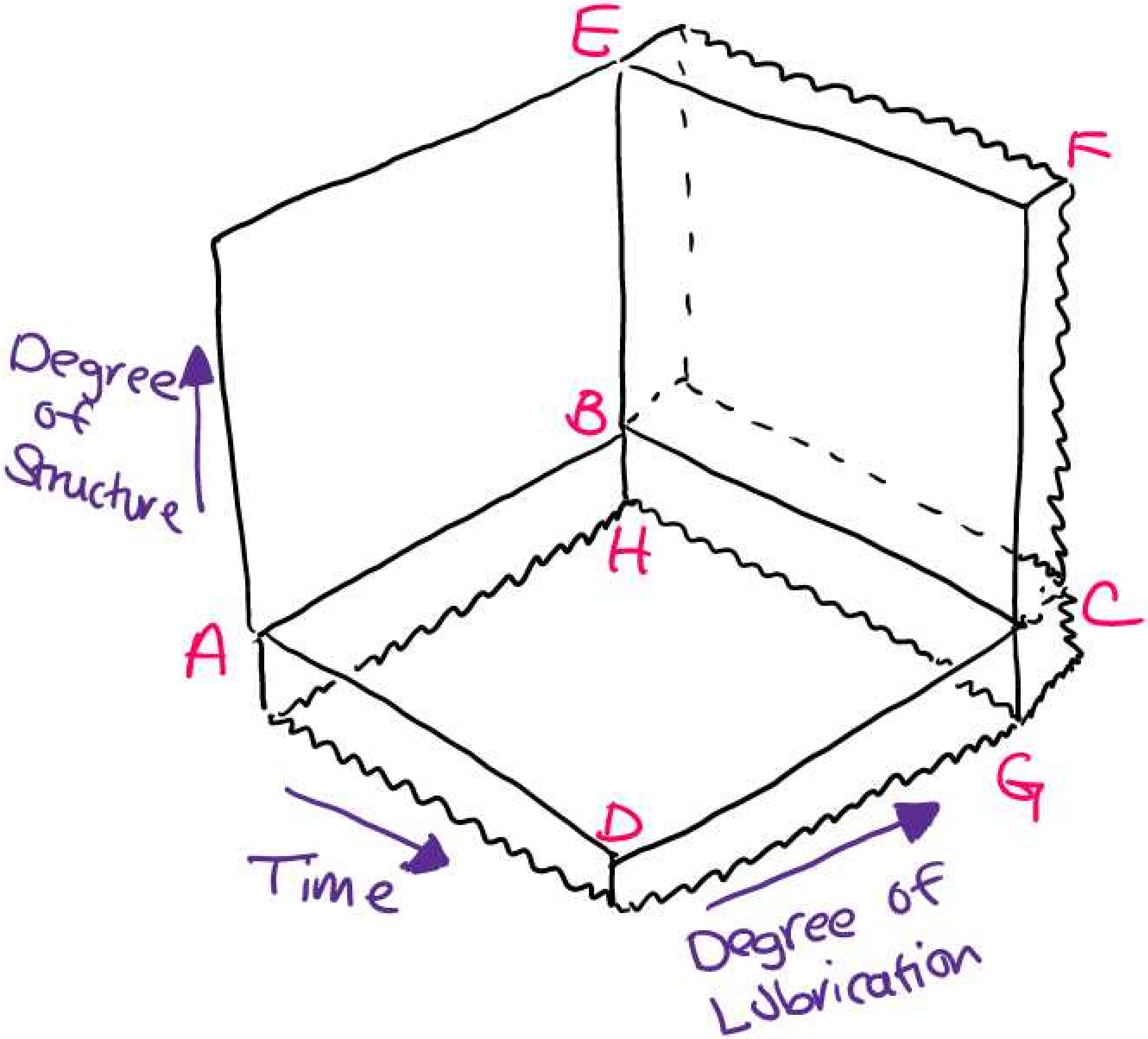
Degree of Lubrication:

Degree of Structure:

Time:

Visualization of the 3D axes of Degree of Structure (y-axis), Degree of Lubrication (z-axis), and Time (x-axis) →

This is also called the "mouth process model" →



2) Optimal cohesive forces

This way of understanding when a swallow would be triggered focuses on the bolus instead of only the food particles.

We assume that in a simplified scenario, there are two competing forces during bolus formation:

- An adhesive force between
- A viscous force between

A swallow will be triggered when the bolus cohesive force reaches a maximum.

Adhesive force between food particles and oral cavity

Food particles become coated with saliva and stick to the oral cavity or other particles

Bolus adhesive force can be calculated as:

$$F_A = 4\pi r \lambda$$

F_A = adhesive force,

r = radius of the food particle,

λ = surface tension of the oral fluid, N/m*

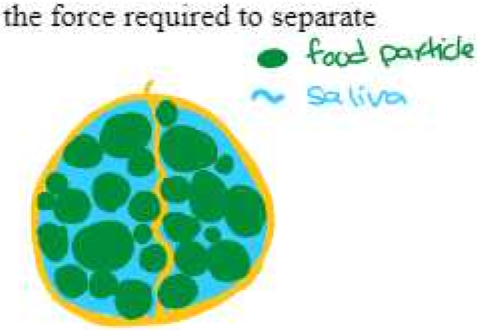
*Surface tension of normal saliva can be estimated as 0.053 N/m

Viscous force between particles within a bolus

Assumes food bolus is a spherical ball of particles with a disc-like surface on each side.

Bolus viscous force of the particles in the bolus, F_V is modeled as the force required to separate the two sides of the bolus from one another:

$$F_V = \frac{3\pi\eta R^4}{4d^2t}$$



η = the viscosity of the saliva between the food particles,

R = radius of the "disc" of particles,

t = time span when the particles are separated,

d = average distance between particles,

Bolus Cohesive Force:

The bolus cohesive force in the bolus can be described as the difference between the viscous and adhesive forces:

$$F_c = F_V - F_A$$

F_c = cohesive force within the bolus of food particles, N

F_A = adhesive force of the food particles to the oral lining, N

F_V = viscous force of the food particles within the bolus, N

What values of bolus cohesive force (F_c) mean:

- $F_c < 0$:
- $F_c > 0$:
- When F_C reaches a ___________________ , a swallow will be triggered

What do bolus cohesive forces look like during the chewing process?