FDE206 Reaction Kinetics in Food Engineering

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Purpose of class

- Define the important reactions for the quality of foods during **processing** and **storage.**
- Determine the changes of this important reaction during either **processing** and **storage at a certain temperature** applying analytical methods in lab.
- Use the appropriate kinetic models.

- Calculate the kinetic parameters such reactions (***k*, $t_{1/2}$ and D values**), which show the stability of m.o.'s, enzymes and quality factors.

- Calculatee kinetic parameters such reactions (**E_a, *z* and Q_{10} values**), which show the effect of temperature on the inactivation/degradation of m.o.'s, enzymes and quality factors.

- Calculate the **shelf-life** of foods using the calculated kinetic parameters.

Class programme

- 1st week :: Reactions affecting the quality of foods during processıng
- 2nd week: Graphical presentation of experimental data, constructing of arithmetic graphs (determination of slope)
- 3rd week: Graphical presentation of experimental data, constructing of semi-log graphs (determination of slope)
- 4th week: Calculation of linear regression for arithmetic and semi-logarithmic equations

- 5th week: Reaction rates, Order of reactions in foods (zero-, first- and second-orders)
- 6th week: Calculate the ***k*** value for zero-order reactions
- 7th week: Calculate the ***k*** values for first- and second-order reactions
- 8th week: Midterm
- 9th week: Calculate the $t_{1/2}$ **and D** values for first-order reactions

- 10th week: Collision theory
- 11th week: Factors affecting reaction rates in foods
- 12th week: Activation energy (E_a) and Q_{10} values
- 13th week: Calculation of E_a and Q_{10} values for important reactions in foods
- 14th week: Calculation of shelf life in various foods

Suggested readings

1) Toledo RT. 1994. ***Fundamentals of Food Process Engineering***. 2nd ed., Chapman & Hall, New York, N.Y., U.S.A.

Chapter 1: Review of mathematical principles and applications in food processing, p.1-50.

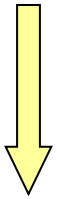
Chapter 8: Kinetics of chemical reactions in foods, p 302-314.

2) Earle R, Earle M. 2003. ***Fundamentals of Food Reaction Technology***. 2nd ed., Leatherhead Food International, United Kingdom.

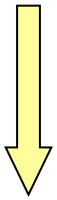
3) Özkan M, Cemeroğlu B, Kırca Toklucu A. 2010. ***Gıda Mühendisliğinde Reaksiyon Kinetiği***. Bizim Grup Basımevi, Ankara.

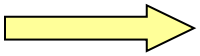
Food processing

raw material



Processing (pasteurization and sterilization)



Storage  **Consumer**

Purposes of food processing

- To produce products safer, more attractive and easier to eat,
- To build desirable constituents (formation of lactic acid in pickle fermentation) and removes undesirable ones (oxygen, causing oxidation of ascorbic acid and lipids)
- To encourage enzymes to develop desirable flavors and color (PPO, oxidizing the phenolics in black tea production)

- To inhibite enzymes causing undesirable changes (PPO and pectolytic enzymes in fruit juice production)
- To grow m.o.'s to create desirable flavor (yogurt production),
- To destroye m.o.'s to prevent harm to the consumer (pasteurization of juices, sterilization of canned vegetables, meat and fish).

Food processing

- Aims to preserve foods for a long time,
- How?

  Apply various methods, such as heat processing (pasteurization and sterilization)
- **Heat processing**;
  - Primary purpose in to inactivate the **pathogen and/or spoliage m.o.'s** causing the spoilage of foods stored at commonly used storage temperatures
  - Inactivate **enzymes** causing the loss of quality of foods (such as lipase and lypoxygenase).

Heat processing

depending on the temperature and time, important losses of foods occur in;

- **Sensorial properties (losing aroma)**
- **Nutritional value (losing ascorbic acid and thiamine)**

- Choose **HTST** to minimize the quality losses.

Table 1 Changes in food materials during processing

- **Chemical:** Hydrolysis (sucrose), oxidation, polymerization (starch, cellulose and pectin), denaturation, browning
- **Physical:** Gelation (freezing of gelatine), hardening (ice-cream), softening (ripening pf fruits), color loss/gain
- **Biological:** Growth and death of microorganisms, glycolysis, physiological changes during ripening (ethylene and CO_2 production, chlorophyll degradation)

- **Nutritional:** Loss of vitamins and amino acids

- **Sensorial:** Aroma and flavor loss, texture changes, color bleaching and darkening

Reaction	Typical sensorial changes	Typical nutritional Constituent loss	Environmental factor affecting these reactions
▲ Non-enzymatic browning	• Loss of dissolution of proteins • Browning • Stale and cooked type of off-flavor	• Loss of some essential amino acids • Loss of ascorbic acid	• Temperature, water activity and composition of gaseous in packaging
▲ Lipid oxidation	• Rise in fat viscosity • Rancid off-flavor • Browning	• Loss of A and E vitamins • Loss of essential fatty acids	• Temperature and water activity
▲ Forming of cross-links in polymers such as proteins and polysaccharides	• Hardening in texture • Loss in water holding capacity	• Loss of protein digestion	• Temperature, water activity and composition of gaseous in packaging
▲ Enzymatic changes in fruits and vegetables stored at refrigerated temperatures	Off-flavor formation	• Loss of vitamins	• Temperature, water activity and composition of gaseous in packaging

Changes in foods can be measured through

- Chemical analysis
- Phyisical analysis
- Microbiological analysis
- Sensorial analysis

Shelf-life (End point of food)

Time that a food lasts as an **acceptable and safe** during storage, distribution and home.

(Food is no longer to be consumed due to loss of **quality** or **safety**)

Shelf-life determination

√ Determine **the critical product attributes** and **their acceptable levels** **(toughest part!!!)**

√ Find out the reactions causing these changes

√ Determine the changes of product attribute with time (**Process** or **store** the food at a **certain temperature**)

√ Calculate the rate of this reaction at this temperature (Determine the **Slope**!)

- **Quantitative data** obtained from the lab measurements are fitted to **mathematical equations**. ($y = ax + b$)

- These equations are used to predict changes (or to determine shelf life) during **processing** and **storage**.

Identify the critical attributes of orange juice

- ??????
- ??????

Identify the critical attributes of orange juice

- Aroma and flavor (depends on temp., O_2 and rind-oil)
- Inactivation of pectin methyl esterase
- Pathogenic microorganisms (5 log cyle)

- Ascorbic acid
- Browning
- Carotenoids

Which quality attribute should be chosen to determine the shelf-life of orange juice ?

Inactivate the pathogens by a factor of 5 log cycle

- Legal regulation requires that the **packed orange juice** must be subjected to a process sufficient to **inactivate the pathogens** in the finished product by a factor of **5 log cycles**.

- To obtain this inactivation, either **heat processing** (pasteurization or sterilization) or **non-thermal methods.**

Factors affecting the reactions in foods

- **Temperature,**
- **Water activity,**
- Gas composition in packaging or storage.

Storage variables affecting the shelf life of foods

Food materials	Environment	Packaging
Microbial quality	**Temperature**	**Permeability**
Pathogens, Spoilage bacteria, yeasts and molds	**Water activity**	water vapor, O_2 and CO_2
Composition	**Gas composition**	**Light transmittance**
Moisture, Acidity/pH, Salt content, Preservatives	**Light**	**Product/packaging interaction**

Reaction kinetics

- Deals with the reaction's mechanism as well as the **rates** of chemical reactions.

- Investigates how different experimental conditions (temp. or a_w) can influence the **rate** (speed) of chemical reaction.

- Constructs mathematical models that can describe the characteristics of a chemical reaction.

In food science, reaction kinetic calculations are used to determine for:

- Degradation or formation of food constituents (vitamins, pigments, etc.)
- Inactivation or growth of m.o.'s
- Inactivation or activation of enzymes

Reaction mechanism

- To determine the rate of reaction, net reaction is important and intermediate products are mostly not taken into consideration.

- An intermediate is a compound that is produced from the preceding reactants and is then reacted with another reactant to form a final product.

- Life-time of intermediates are very short.

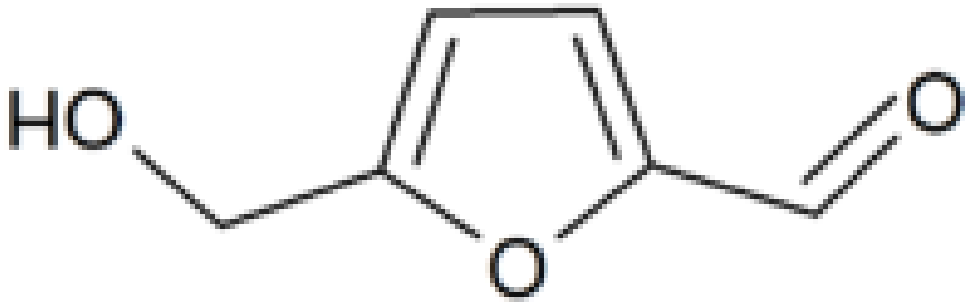
- Mostly, intermediates cannot be measured analytically and are not very important for reaction kinetic calculations.

- However, in some cases, the formation of intermediate products can be very important in foods. For example:

  ✓ HMF (intermediate) formation indicates browning formation (final product)

  ✓ Formation of HMF indicates that foods are exposed to high processing or storage temperature.

Hydroxymethyfurfural



Difference of reaction kinetics between chemical and food eng:

- Chemical engineers are interested in increasing the yield for the production of chemical compounds (product side)

- Food engineers aim to preserve the quality (reactant side).