



# Food Science and Culinary Techniques - FSCT

**Notes for the course NFOK13004U, at the University of  
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# Chapter 1

## Course Description

### 1.1 Content

The aim of the course is to use a basic understanding of food chemistry and physics to obtain a scientific approach to cooking when various culinary techniques are applied during processing of foods.

The course includes a series of lectures giving a scientific description of foods as a chemical and physical system. It relates to proteins, lipids, carbohydrates as well as topics within general chemistry (inorganic and organic), acids and bases, and interactions of these components. The course provides an understanding of the culinary techniques used in the production of foods and highlights the effects of food processing on the chemical reactions leading to changes of flavour/taste and colour as well as the physical properties of the food in relation to changes in structure and functionality.

Practical kitchen exercises in preparation of foods will be used as a learning tool to the understanding of culinary techniques. The use of ingredients in various recipes will be evaluated and thereby demonstrate important experimental aspects of food processing and preparation. This will include an introduction to experimental design where recipes and preparations are varied, and the methods of evaluation are identified. The following afterlab discussions will reflect on the outcome of the experiments and correlate it to the scientific principles of the exercise.

The lectures and theoretical exercises will demonstrate how food components contributes to the functional properties in dry systems, crystalline states, emulsions, foams and other real food systems. During the practical kitchen exercises students will evaluate the different preparations in relation to texture, flavour/taste and colour, and explain the outcome according to the theory.

### 1.2 Learning Outcome

A student who has fulfilled the aim of the course should be able to:

### 1.2.1 Knowledge

- Describe important chemical reactions and physical changes during processing of foods
- Describe carbohydrates, lipids and proteins and their basic functions and characteristics in food and point out the effects of culinary processes on physical, chemical and sensory conditions of food components
- Describe the effect of physical processes on the structure of food during cooking
- Identify factors of relevance for detection, perception and loss of aroma and flavour compounds in different solvents.

### 1.2.2 Skills

- Work in a gastronomic laboratory with specific culinary techniques and follow instructions to obtain a well-defined product
- Explain the changes in foods taking place during preparation of food from a chemical and a physical point of view
- Predict the outcome of various preparation methods and recipes based on a simple experimental design
- Evaluate a complex food and communicate the compositional structure of the product
- Evaluate the effect of various culinary techniques on the food structure and flavour
- Ability to perform simple statistical analyses using Excel or other related software
- Ability to give and receive peer feedback
- Ability to communicate scientific topics within food science and culinary techniques in (academic) English.

### 1.2.3 Competences

- Plan experiments related to the effect of a culinary technique on the sensory properties of food
- Integrate scientific disciplines (food chemistry and food physics) in planning and evaluation of practical experiments
- Cooperate with other students on planning and performing practical exercises including written and oral evaluation of the theoretical outcome through afterlab discussions at plenary sessions.

## 1.3 Literature

See Absalon for a list of course literature.

## 1.4 Recommended Academic Qualifications

A basic knowledge of chemical reactions involving carbohydrates, proteins and lipids as well and basic statistics is highly recommended.

Academic qualifications equivalent to a BSc degree is recommended.

Table 1.1: A table with an overview over the workload for the course.

Category	Hours
Lectures	43
Preparation	110
Theory exercises	28
Practical exercises	21
Exam	4
Total	206

## 1.5 Teaching and Learning Methods

The teaching use a general understanding of food chemistry and physics in combination with practical kitchen exercises in a gastronomical laboratory to examine the influence of various processing methods on the food components. The practical kitchen exercises set the frame for group work and will be evaluated by afterlab discussions, problem-based learning and answering questions from the lecturers. The course also includes mandatory written assignments with peer feedback (student-student) based on the practical exercises. Specific practical exercises might be organised as take-home exercises where ingredients and tools will be provided.

## 1.6 Remarks

It is recommended to follow the course on the first year of the MSc Programme in Food Innovation and Health.

## 1.7 Workload

## 1.8 Feedback Form

- Oral
- Collective
- Continuous feedback during the course of the semester
- Peer feedback (Students give each other feedback)

## 1.9 Sign Up

Self Service at KUNet

<http://www.science.ku.dk/english/courses-and-programmes/>

<https://www.science.ku.dk/english/continuing-and-professional-education/single-subject-courses/practical/>

## 1.10 Exam

Table 1.2: The table shows the details of the course exam, as defined from the website of the University of Copenhagen.

Category	Details
Credit	7.5 ECTS
Type of assessment	On-site written exam, 4 hours under invigilation
Type of assessment details	Individual written 4 hour exam on specific topics based on the course curriculum. The on-site written exam is an ITX exam. See important information about ITX-exams at Study Information, menu point: Exams -> Exam types and rules -> Written on-site exams (ITX)
Exam registration requirements	Approval of all assignments for all practical kitchen exercises.
Aid	All aids allowed. The University will make computers available to students at the ITX-exam. Students are not permitted to bring digital aids like computers, tablets, mobile phones etc. Students are, however, allowed to bring a calculator. Books, notes, and similar materials can be brought in paper form or uploaded before the exam and accessed digitally from the ITX computer. Read more about this at Study Information.
Marking scale	7-point grading scale
Censorship form	No external censorship. Several internal examiners.
Re-exam	Same as ordinary exam. Possibility to edit and re-submit all non-approved assignments from the practical kitchen exercises two weeks before the re-exam. If 10 or fewer register for the re-examination the examination form will be oral. The oral exam will be 20 minutes in the course curriculum, no preparation time and all aids allowed.

**Criteria for exam assessment** See Learning Outcome.

# Chapter 2

## Basic Knowledge Recap

This section of the course notes is designed to streamline access to the key findings from each reading material (RM), providing a concise and accessible overview of essential information. Created through experimentation with various AI platforms, this chapter also serves to enhance my prompt engineering skills, exploring diverse methods of note-taking for maximum efficiency and clarity. The procedures for creating these summaries have varied, but all methods share a common approach: each RM has been fully read, with summaries and notes prepared after completing each respective subsection. By using these AI-co-op'ed approaches, these notes aim to be both a reliable reference and a resource for continuous improvement in capturing complex microbiology concepts.

### 2.1 1<sup>st</sup> RM

#### Introduction

Chemistry evolved over a millennia, merging with biology to form diverse fields like **food chemistry**, which focuses on sustenance and nutrition. This chapter outlines chemistry's relation to food sciences and its educational context, addressing challenges like increased teaching loads and exploring new opportunities [1].

#### On the Need for Chemistry

**Food chemistry** studies the composition, structure, and properties of food and their transformations. It builds on general chemistry, including **organic**, **physical**, and **inorganic** branches. This chapter surveys these areas and introduces key terms for future topics [1].

#### Organic Chemistry

**Organic chemistry** focuses on carbon compounds and **covalent bonds** with hydrogen. Hydrocarbon nomenclature (e.g., **alkanes**, **alkenes**, and **alkynes**) introduces systematic naming. Topics include bonding theories, **valence**, and molecular conformation constraints [1].

#### Functional Group Chemistry

Organic compounds belong to families like **alkanes**, **alcohols** (R-OH), and **carboxylic acids** (R-COOH). Functional groups have consistent behaviour, e.g., **hydroxyl** groups act similarly across compounds. Their reac-

tivity may vary with the R group, as in alcohol vs. phenol [1].

## Aromatic Compounds

**Aromaticity** in compounds like benzene involves **electron delocalisation** and resonance. Conjugated double bonds in unsaturated lipids and fat-soluble vitamins contribute to their color and oxidative sensitivity. Free radicals drive polymerization of natural monomers like **isoprene** [1].

## Organic Reaction Mechanisms

Organic reactions include **addition**, **substitution**, and **rearrangement**, often occurring in raw and processed foods. **Free radical** reactions drive polymerization and impact **lipid oxidation**, photochemical processes, and ageing-related deterioration [1].

## Stereochemistry

**Stereochemistry** studies chiral compounds, often with asymmetric carbons attached to four groups. Molecules with N stereogenic centers yield ( $2^N$ ) stereoisomers. Chirality includes helices lacking stereogenic centers. Chiral molecules rotate plane-polarized light, but **racemic mixtures** show no net optical activity [1].

## Physical Chemistry

**Physical chemistry** explores material transformations, focusing on three key themes: **thermodynamics**, **chemical kinetics**, and **quantum mechanics** [1].

## Thermodynamics

**Thermodynamics** examines energy forms, transformations, and efficiency. The **first law** states energy is conserved, expressed as ( $U = Q + W$ ). The **second law** highlights entropy increase, with **Gibbs free energy** ( $\Delta G$ ) predicting spontaneity. Applications include **reaction calorimetry** and energy content in food [1].

## Chemical Kinetics

**Chemical kinetics** studies reaction rates, influenced by factors like concentration, temperature, and catalysts. Reaction rates follow Equation 2.1.

$$\text{rate} = k[A]^x[B]^y \quad (2.1)$$

With ( $k$ ) described by the **Arrhenius equation** which can be seen from Equation 2.2

$$\ln k = \ln k_0 - \frac{\Delta E^\#}{RT} \quad (2.2)$$

The **Eyring theory** relates  $k$  to  $\Delta G^\#$ ,  $\Delta H^\#$ , and  $\Delta S^\#$ , emphasizing transition states [1].

## Inorganic Chemistry

**Inorganic chemistry** covers non-carbon elements, including metals, nonmetals, and metalloids. Periodic trends, such as **atomic radii**, **ionization energies**, and **electronegativity**, arise from effective nuclear charge and electron shielding [1].



## Chemical Bonding

**Chemical bonding** can be described with **Lewis structures** which illustrates electron sharing or transfer. The **octet rule** explains covalent bonds, while differences in electronegativity lead to polarized or ionic bonds. **Resonance** applies to compounds like nitrate, where multiple structures describe electron distribution [1].

## The Shapes of Molecules

Molecular shapes are predicted using the **VSEPR model**, based on repulsions between electron pairs. Geometries like **linear**, **trigonal planar**, **tetrahedral**, and **octahedral** depend on bonded atoms and lone pairs, as seen in molecules like  $H_2O$  and  $NH_3$  [1].

## Valence

**Valence-bond theory** explains covalent bonds through orbital overlap. Some valencies require **hybrid orbitals** (e.g.,  $sp^1$ ,  $sp^2$ ,  $sp^3$ ), formed via electron promotion and orbital mixing. Orbital shapes are influenced by electron repulsion [1].

## Molecular Orbital Theory

**Molecular orbital theory** explains bonding via atomic orbital combinations forming equal numbers of bonding  $\sigma$  and anti-bonding  $\sigma^*$  orbitals. Molecular orbitals follow **Pauli's exclusion principle** and fill singly before pairing. Diatomic oxygen illustrates these principles [1].

## Food Chemistry

### Definition and Scope

**Food chemistry** applies chemistry principles to food systems, studying macroconstituents (e.g., **water**, **carbohydrates**) and microconstituents (e.g., **vitamins**, **additives**). Post-WWII advances improved **shelf-life**, **packaging**, and analysis of toxicants. Food sciences ensure nutritious, safe, and affordable food [1].

### Areas of Expertise Required by the Institute of Food Technology

The **Institute of Food Technology** identifies five core competencies for food scientists: **chemistry**, **analysis**, **nutrition**, **microbiology**, and **engineering** [1].

### Chemistry and the Food System

**Food chemistry** encompasses all levels of the food system, from **soil pH** in agronomy to the effects of **pasteurization**. Its scope includes **harvesting**, **processing**, **packaging**, and **distribution**, as well as studying **ingredient behaviour** during manufacture [1].

## 2.2 2<sup>nd</sup> RM

### Osmosis and Osmotic Pressure

**Osmosis** involves water moving to solute-rich areas across membranes. **Osmotic pressure** drives this process, dehydrating microbes in salted foods. Preservation methods like salting meats and sugaring jams rely on this principle, as seen in **beef jerky** and jellies [1].

### Carbohydrates

#### Foods High in Carbohydrates

**Carbohydrates**, including sugars, starches, and fibers, primarily originate from plants. Sources include **grains**, **legumes**, **fruits**, and **vegetables**. Exceptions are **milk**, containing lactose, and animal muscles, storing glycogen. Table sugar comes from **sugar cane** and **sugar beets**, while honey is floral nectar [1].

#### Composition of Carbohydrates

**Carbohydrates** consist of **carbon**, **hydrogen**, and **oxygen**, following the formula  $C_n(H_2O)_n$ . Synthesized via **photosynthesis**, they form saccharides classified as **monosaccharides**, **disaccharides**, **oligosaccharides**, and **polysaccharides** based on saccharide units [1].

# Chapter 3

## Lecture Notes

### 1<sup>st</sup> Lecture - Plants and Food Colours

#### Lecture Goals

After this lecture, the students will be able to:

- Describe the structures of fruits and vegetables
- Identify structural carbohydrates in plants & changes they undergo during ripening and processing
- Describe important factors responsible for texture, colours, flavours, and taste of plants

#### Plant Organs

Plants have different organs, each serving a specific function. Table 3.1 shows some plant organs and examples of fruits and vegetables which has the following trait.

#### Hemicelluloses

- Hemicelluloses contain a variety of sugars in their long chains—unlike starch and cellulose  
They contain both pentoses and hexoses
- Hemicelluloses, matted with pectic substances, serve as a connection between fibrillar cellulose
- Alkaline medium has a strong effect—vegetables cooked with baking soda added become flaccid & mushy  
Baking soda also has a destructive effect on thiamine

Xylan and arabinan are two particularly common hemicelluloses with glucuronic acid attached, which is a common feature of pectic. Figure 3.1 shows the structure of these.

#### Pectic Substances

- Pectic substances is a general term for member of this family of polygalacturonic acid compounds  
Protopectin, pectin and pectic acid
- Contained in the primary cell wall and the middle lamella (the outer region of the cell wall)
- Pectic substances in the middle lamella change form during the maturation process

Table 3.1: A table showing plant organs and examples

Organ	Function	Plant material and cell type	Example
Roots	Anchor plants into ground, absorb nutrients	Tough fibrous material – cells have thick, cellulose-rich cell walls.	Inedible
		Some roots swell up with storage cells full of <i>amyloplasts</i>	Carrots, parsnips, radishes, sweet potatoes
Stems, stalks	Conduct nutrients to roots and leaves, gives structural support	Fibrous material (stems, stalks) - cells have thick, cellulose-rich cell walls	Asparagus stems, cellery stalks
Tubers, rhizomes		Some stems swell up with storage tissue (tubers rhizomes) -cells are full with <i>amyloplasts</i>	Potato, turnip, ginger
Leaves	Produce sugar molecules by photosynthesis	Plant material is thin so gases can penetrate/escape. Almost no structural support—cell walls are thin and flexible. Cells have many chloroplasts and large air pockets between them for gases.	Spinach leaves, lettuce leaves
Flowers	Reproduction	Contain reproductive organs, Often colorful to attract pollinators	Cauliflower, broccoli
Fruits	Seed dispersal	Fleshy or dry structures, Contain seeds	Apples, oranges
Seeds	Germination	Contain embryo and nutrients, Protected by seed coat	Peas, beans

- Combine with hemicellulose in the primary cell wall to form the "cement" surrounding the cellulose fibers

Protopectin is water-insoluble, and occurs in immature fruits and, to a lesser extent, in vegetables. Pectin is water-soluble, and is found in ripe fruits and vegetables. Pectic acid is formed when pectin is heated in an acid medium. Figure 3.2 shows the structure of these.

## Starchy Vegetables and Texture

When vegetables are raw, their starch granules are hard and give a chalky feeling when chewed. When cooked, the starch granules begin to soften around 60°C, when cell membranes are also affected. Starch granules absorb water which disrupt their structure and they swell, forming a gel. Vegetables becomes tender but dry. When cell walls are weak, the gel-filled cells pull away from each other as separate particles giving a mealy impression.

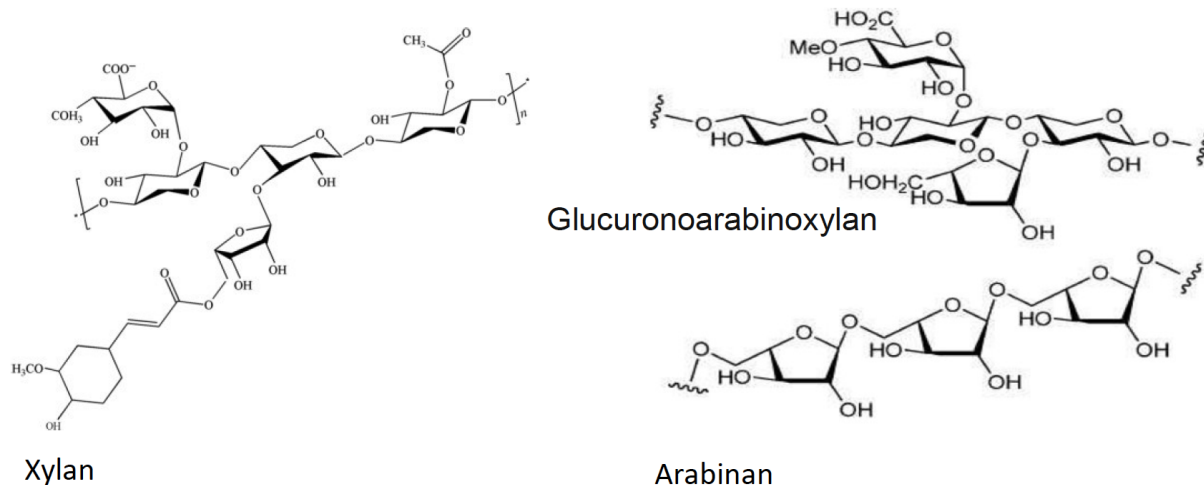


Figure 3.1: Structure of hemicelluloses

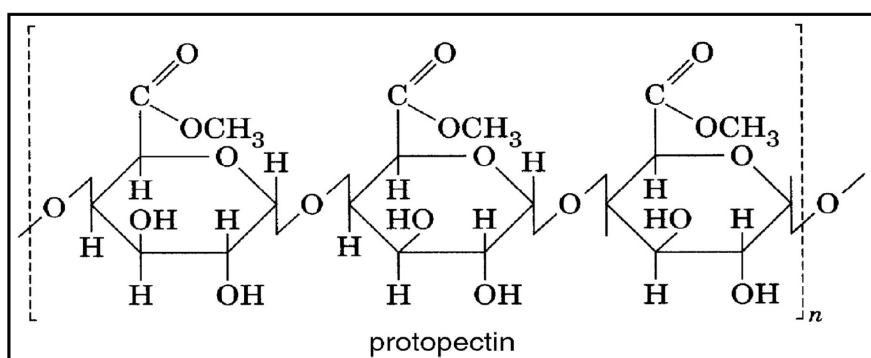


Figure 3.2: This form is a methylated (methyl ester groups), very long polymer of galacturonic acid

### Important Factors During Precessing of Potatoes

- Boiling - Pectin crosslinking promoted by enzyme activity at 55-60°C for 20-30 min  
Firm potato. According to McGee, enzyme in the cell wall alters cell well pectins - more easily cross-linked by calcium ions (activated around 50°C and inactivated around 70°C)
- Frying - Starch leaks out of granules and glues outer cell walls together when initial frying temperature is kept low (120-160°C) - crisp crust
- Grayish discolouration: caused by a pigmented complex formed by chlorogenic acid, oxygen and iron ions  
Minimized at low pH
- Leftover potatoes get a stale, cardboard flavour, due to membrane lipids being oxidized
- Salt speeds up softening (Sodium ions destabilize cell wall)
- Ca<sup>2+</sup> slows down softening (stabilizes cell wall)
- High pH soften hemicellulose and open starch structure

## 2<sup>nd</sup> Lecture - Carbohydrates I

### Carbohydrates in food

In foods various carbohydrates are present. Some examples are listed in Table 3.2.

Table 3.2: Carbohydrates in food with classification based on their molecular size

Monosaccharides	Di-	Oligo-	Poly-
Glucose	Sucrose	<b>Digestible:</b>	<b>Digestible:</b>
Fructose	Lactose	Maltotriose	Starch
Galactose	Maltose	Maltotetrose	(Amylose, amylopectin)
Mannose	Cellobiose	Maltopentose	
Ribose	Trehalose	<b>Non-digestible</b>	<b>Non-digestible</b>
Xylose	...	Rafinose	<u>Soluble:</u> agar, gum arabic, carrageenan, pectin, ...
...		Stachyose	<u>Insoluble:</u> cellulose, protopectin, chitin, ...

### Anomeric Carbon and Reducing Sugar

The anomeric carbon originates from the carbonyl group in the open-chain form of a sugar and becomes a stereocenter in the cyclic form, capable of forming alpha and beta isomers. Reducing sugars can switch back to the open-chain form, exposing the reactive carbonyl group, key in reactions like the Maillard reaction. Non-reducing sugars, like sucrose, have their anomeric carbon locked, preventing such reactivity. An example of an open-chain and cyclic form of a monosaccharide is shown in Figure 3.3 where the anomeric carbon is highlighted in red. The term "masked oxo-group" refers to the carbonyl group (C=O) in the open-chain form being hidden in the ring structure.

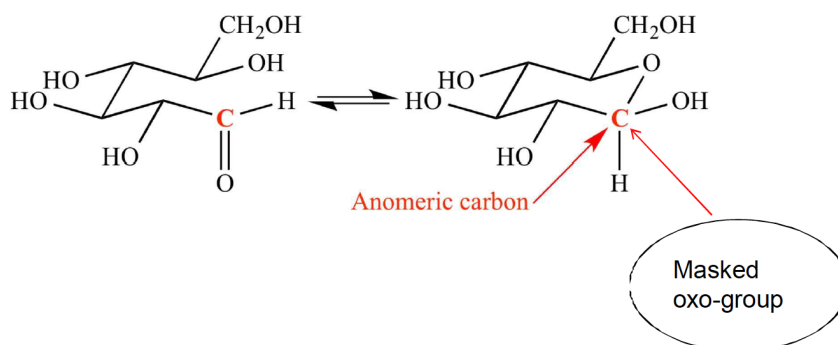


Figure 3.3: An example of an open-chain and cyclic form of a monosaccharide

# Chapter 4

## Lecture Exercises

### 4.1 19.11.24 - Exercise 1 - Carrot Soup

You are working in a company that produces frozen soups, ready to heat and eat. You are in the process of developing a new product, a carrot soup with an orange flavour. The basic recipe looks like this:

**a.**

Describe the structure of the cell wall of the carrot.

**b.**

Name the three major polysaccharides in the cell wall of the carrot and describe what happens with these polysaccharides during cooking.

**c.**

The orange you have used for the soup is fairly ripe, what kind of pectic substances do you think predominate in the orange? Explain also briefly the changes that the pectic substances undergo during ripening. Explain also whether you think the pectic substances extracted from the orange will contribute to gel formation in the soup, and why /why not.

Table 4.1: Basic Recipe for Carrot Soup

Ingredient	Preparation
Oil	<ul style="list-style-type: none"><li>• Heat a large saucepan over medium heat. Add oil. Cook the onion, stirring occasionally, for 3 minutes or until soft. Add carrot and cook, stirring often, for 5 minutes or until just soft.</li><li>• Add stock. Bring to boil. Peel 2 strips of rind from the orange. Add to pan. Reduce heat to medium-low. Simmer for 20 min. or until carrot is tender. Remove and discard orange rind.</li><li>• Set aside for 5 minutes to cool. Use a blender to puree until smooth. Juice orange. Add to soup. Place over medium heat and cook for 2 minutes or until heated through. Top with parsley.</li></ul>
1 Onion, finely chopped	
1 kg carrots, finely chopped	
1L chicken stock	
1 Orange	
1 tbsp parsley	

**d.**

Name the pigment that gives a nice orange colour to the soup and explain where it is found in the plant cell and describe its solubility properties.

**e.**

You consider improving flavour by adding lemon juice to the soup as well as orange juice. To make it a little simpler you want to add all ingredients at the onset of cooking. How do you think that addition of citrus juice might affect the softening of the carrots, if the juice is added at the onset of cooking? Explain why.



# Chapter 5

## Literature résumés

This section of the course notes is designed to streamline access to the key findings from each reading material (RM), providing a concise and accessible overview of essential information. Created through experimentation with various AI platforms, this chapter also serves to enhance my prompt engineering skills, exploring diverse methods of note-taking for maximum efficiency and clarity. The procedures for creating these summaries have varied, but all methods share a common approach: each RM has been fully read, with summaries and notes prepared after completing each respective subsection. By using these AI-co-op'ed approaches, these notes aim to be both a reliable reference and a resource for continuous improvement in capturing complex microbiology concepts.

### 5.1 1<sup>st</sup> lecture

#### 5.1.1 Article 1 - Fermented Foods as Experimentally Tractable Microbial Ecosystems

##### Introduction

# **Chapter 6**

## **Exam**

# Chapter 7

## Abbreviations and Explanations

Topic	Abb.	Description
<b>16S ribosomal RNA</b>	<b>16S rRNA</b>	<i>A component of the 30S subunit of prokaryotic ribosomes, commonly used in phylogenetic studies to identify bacteria and archaea.</i>

# Bibliography

- [1] Richard Owusu-Apenten. *Introduction to Food Chemistry*. Boca Raton, FL: CRC Press, 2004.

# **Chapter A**

## **Appendix**

### **A.1 Appendix 1 - Principles for isolation of microorganisms from fermented food and beverages**