UNIVERSITY OF COPENHAGEN
FACULTY OF SCIENCE

Sustainable Innovation in Food Science NFOK20003U

Notes taken during the course, including lectures, exercises, curriculum, and practicals

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Link to Git repo.: https://github.com/DanishUnicorn/sifs_notes

Course Description

Content

The course aims to provide the students with an understanding of sustainable innovation in the food chain and sector; e.g. gentle food processing technologies and circular business models that result in reduced environmental footprints. The students will be introduced to key aspects such as:

- Life Cycle Assessment (LCA): In-depth exploration of the four steps of LCA— goal and scope definition, inventory analysis, impact assessment, and interpretation.
- Sustainable Innovation and Systems Design: Exploration of circular business models and sustainable production systems designed for resource efficiency and environmental impact reduction.

The students will work theoretically with identifying potential solutions to current challenges in the food chain and sector. The student will work in a group on a relevant challenge that is linked to the teaching on a weekly basis.

Students will apply theoretical knowledge to practical challenges divided in portfolio parts. They will reflect on real-world restrictions and opportunities, including IPR, food regulation, and data security considerations.

Learning Outcome

Knowledge:

- Describe the four steps of Life Cycle Assessment (LCA), including system boundaries and functional units
- Explain key concepts of sustainable innovation and circular economy in food systems design.
- Identify environmental impacts and potential improvements in food processing and production systems.
- Basic insight into IPR, regulation, ethics, and consumer preferences

Skills:

- Ability to conduct and interpret comparative LCA, including mass balance calculations for the chosen challenges.
- Ability to critically reflect on bottlenecks in the implementation of sustainable innovation in the food chain
- Ability to apply theoretical LCA knowledge to practical challenges.
- Ability to identify business expansion opportunities for sustainable innovation in the food chain.

Competences:

- Ability to collaborate effectively in interdisciplinary groups to address complex sustainability challenges.
- Ability to analyse environmental performance and propose improvements based on LCA results.
- Ability to communicate findings and solutions effectively using LCA data and theoretical frameworks.
- Ability to contextualize system and product environmental footprint within the broader frameworks addressing the grad societal challenges of UN's SDGs and planetary boundaries in the course challenge.

Chapter 0

Litterature

See Absalon for a list of course literature

Recommended Academic Qualifications

Academic qualifications equivalent to a BSc degree is recommended.
We recommend the students have a Windows based operating system for the LCA calculations.

Teaching and Learning Methods

Lectures, exercises and group work. The student will work in a group on a relevant challenge documented by a portfolio addressing the key aspects of the course.

Remarks

The course is identical to the discontinued course NFOK20004U Short Thematic Course in Food Science and Technology. Therefore you cannot register for NFOK20003U - Sustainable Innovation in Food Science, if you have already passed NFOK20004U Short Thematic Course in Food Science and Technology.
If you are registered with examination attempts in NFOK20004U Short Thematic Course in Food Science and Technology without having passed the course, you have to use your last examination attempts to pass the exam in NFOK20003U - Sustainable Innovation in Food Science. You have a total of three examination attempts.

Workload

Table 1: *A table with an overview over the workload for the course.*

Category	Hours
Lectures	54
Preparation	42
Theory exercises	30
Project work	73
Guidance	6
Exam	1
Total	206

Feedback format

Written Oral Collective Continuous feedback during the course of the semester

Exam

Table 2: *A table with an overview over the the examination for the course.*

Category	Hours
Credit	7,5 ECTS
Type of assessment	Oral examination, 15 minutes
Type of assessment details	The exam is an individual oral exam (15 minutes) without preparation time based on both previous submissions and the course curriculum. Written assignments are done in groups and consist of multiple parts with deadlines throughout the course. In order to access the oral exam the submissions (written assignments) must be submitted during the course.
Examination prerequisites	Use of AI is only allowed for the written assignments as described in the challenge guidelines provided on the course.
Aid	Only certain aids allowed (see description below) The student can bring a paper version of the challenge portfolio parts to the oral exam.
Marking scale	7-point grading scale
Censorship form	External censorship
Re-exam	Same as ordinary exam. In order to access the oral exam the submissions (written assignments) must be submitted two weeks before the oral examination. Any previously submitted submissions (written assignments) will be reused.

Contents

Synposis for Question 09

1 Introduction

Milk is an important nutritional source for humans, and serves as the basis for a variety of dairy products. As the main ingredient in dairy products, the microbiological and compositional quality of the raw milk is of great importance and is directly correlated with the quality of the final dairy product [1].
Proteins play an essential role in determining texture, flavour, and functional properties. If the proteins present in milk are degraded, either enzymatically or due to microbial activity, product quality can suffer significantly [2]. Upholding a high standard for milk is therefore not only of importance with respect to consumer acceptance, but also of economic relevance [1].

2 Milk Composition

Milk is a complex liquid whose composition includes a variety of dilute salts, the simple sugar, mainly lactose, and vitamins where fat is emulsified as globules [3]. Proteins in milk is mostly present in the form of casein micelles, which are colloidal aggregates of thousands of molecules [4].

Though the protein content (approximately 3.2% [5]) of milk is relatively low, compared to that of fat globules [4], this synopsis will focus on proteins and their degradation in milk.

The milk protein content and composition is influenced by various factors, such as breed, lactation stage, genetic variants, and cell count [6]. Furthermore, the protein content of milk is divided into two major groups: caseins and whey proteins. Caseins make up approximately 80% of the total protein content, while whey proteins make up the remaining 20% [6]. The composition of milk casein proteins consists of α_{s1}-casein, α_{s2}-casein, β-casein, and κ-casein, in respective order [6]. The casein proteins are present in structures of micelles and are relatively hydrophobic fibrous proteins [4]. Of the existing whey proteins in milk, the major constituents are α-lactalbumin, β-lactoglobulin, bovine serum albumin, immunoglobulins, and enzymes, in respective order [6].

3 Protein Degradation

While the somatic cell count (SCC) in milk is an important indicator of udder health, it is used to monitor the presence of mastitis in dairy cows [7]. Mastitis is an inflammation of the mammary gland, and is a major problem for dairy producers, as an increase in SCC corresponds to an increase in the proteolytic potential in milk [2]. This protein degradation in milk can have negative effects on yield and quality of dairy products, such as cheese [2].

3.1 Reasons for Protein Degradation

There are various reasons for the degradation of proteins in milk, e.g. microbial proteases, endogenous proteases, and heat treatment [2].

Microbial Proteases Some psychotropic bacteria can survive pasteurization, as they can produce heat-stable proteases [8]. These proteases will be active, even after heat treatment, and can initiate the degradation of the

casein- and whey proteins in milk by proteolysis [9]. This is predominantly the case for psychotropic gram-negative bacteria [8]. If *Pseudomonas fluorescens* is present, normal pasteurization will be insufficient and the bacterias extracellular proteinases will degrade the proteins by proteolysis [8].

Endogenous Proteases There are many enzymes with milk at its natural habitat, such as plasmin, cathepsin D, and cathepsin B, which can degrade the proteins in milk [2]. Plasmin is the most important and predominant protease in milk, and is largely responsible for the degradation of casein proteins. The quantity of plasmins is correlated with mastitis, analysis of the raw milk is therefore imperative [2].

Heat Treatment Though the primary objective of heat treatments as pasteurization and ultra high temperature pasteurization (UHT-pasteurization) is to kill pathogenic and spoilage bacteria, the temperature does not differentiate by microorganisms, it kills/inactivates all microorganisms which is not sufficiently heat resistant [9].

3.2 Susceptible Proteins

Microbial Proteases The proteins most susceptible to microbial derived enzymes, resulting in proteolysis are the caseins, as their high proline content makes them more susceptible to proteolysis [10].

Endogenous Proteases The most susceptible proteins to endogenous proteases are the caseins $\alpha_{s1} - casein$, β-casein and the whey protein α-lactalbumin. The decrease for these three proteins are percentagely the same (26-75%), but the content of the caseins is approximately 10 times higher, therefore, the overall quantitative loss is greatest for caseins [7].

Heat treatment Caseins have a high content of proline, for α_{s1}-, α_{s2}-, β-, and κ-casein, the proline content is 17, 10, 35, and 20 residues per mole, respectively [10]. The high proline content in the caseins results in a low content of α-helix or β-sheet structures make them structurally more prone to denaturation and aggregation under heat treatment [10].

4 Consequences of Proteolysis in Milk Products

Severely heat treating milk can result in degradation of proteins in milk which in turn can have negative effects on the quality of the final dairy product, e.g. cheese not ripening properly due to high moisture and excessive syneresis in yogurt [9]. Another consequence of heat treating milk is Maillard reaction which can result in a brownish color and a cooked taste [11]. Enzymatic activity from plasmin has also been shown to have a direct impact on both bitterness, gellation and shortens shelf-life [11]. A combination of high enzymatic activity, resulting in more available amino acids, and high temperature treatments can result in a more pronounced Maillard reaction [11].
If there is a reduced amount of casein proteins in milk, leading to reduced cheese yield, since caseins are the primary proteins responsible for curd formation [2]. The reduction in casein proteins will also affect the cheese ripening process, as the endogenous proteinases contribute to the cheese ripening process through casein hydrolysis [2].

5 Methods for Analysis

5.1 Determining Protein Degradation

SDS-PAGE, a gel electrophoresis method, has been shown to indicate protein degradation in milk [2]. By staining the gel, degraded proteins apear as distinct bands on the plate. Smaller peptides travel further through the gel matrix, allowing differentiation of the protein size, depending on the travel length [2].
The fluorescamine method is another technique for analysing protein degradation in milk. It is based on the reaction of fluorescamine with primary amines, which produces a fluorescent product. The emitted fluorescence can be measured by spectrometry, and the intensity is proportional to the quantity of primary amines present in the sample, giving an indication of protein degradation in milk [2].
Other spectrometrical methods, such as seize-exclusive chromatography HPLC (SEC-HPLC), reverse-phase HPLC (RP-HPLC), and liquid chromatography-mass spectrometry (LC-MS) can also be used to analyse protein degradation in milk [12, 13]. An optimized version of LC-MS HPLC has been suggested to provide a novel insight in the complexity of the main milk proteins [13].

5.2 Preventing Protein Degradation

Good raw milk quality is essential for any use. When focusing on preventing protein degradation raw milk must be collected at farms that uphold strict hygienic standards and ensure immediate storage at low temperatures. This creates an unfavourable environment for bacteria, particularly psychotropic species [11]. Before the raw milk is being processed at the dairy plant, microbiological testing should be performed to ensure low bacterial counts and low somatic cell levels. After passing microbiological control, the milk should be pasteurised promptly to inactivate native and microbiological enzymes before further processing [11].

6 Conclusion

Several factors can be responsible for protein degradation in milk, including microbial proteases, endogenous proteases, and heat treatment. To ensure milk of high quality, it is imperative to monitor both protein content, composition, and somatic cell count. Preventive measures must be implemented at both the farm and dairy plant levels to maintain milk quality and reduce proteolysis potential.
For quality control, SDS-PAGE, fluorescence assays, and HPLC-based techniques can be implemented to detect signs of degradation. If any anomalies are detected, prompt action is necessary to prevent further protein breakdown. In severe cases, the milk may need to be discarded to avoid excessive economic losses.

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