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Texture and sensory properties of modified fish products for dysphagia patients

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Contents

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Abstract

The Statistics Norway (SSB) population projection indicates that the people aged 70 years and above will double in three decades, from nearly 600,000 today to around 1.2 million. During ageing, many elderly people undergo problems with normal swallowing process. This causes swallowing disorder, medically termed as dysphagia. Dysphagia leads to undernutrition and malnutrition that may be followed by prolonged hospital stay and convalescence. Few food products categorized with a specific texture level are available in the retail market or institutions for dysphagia patients.

The main objective of this thesis was to develop two texture modified fish products of soft and pureed consistency of level 4 as per the International Dysphagia Diet Standardisation Initiative (IDDSI) with high protein content and appealing sensory properties. Fatty fish (salmon) and lean fish (haddock) were used as raw material. Heat treated fish muscle was blended and a new product was reconstructed using texture modifiers, whey and casein proteins, and in addition, enzymatically derived fish hydrolysate. Texture analyses were performed to analyze the effect of modifying the raw material with proteins on the firmness of product. The qualitative aspect after modification was analyzed using qualified sensory panels at Stavanger and Ås.

After a satisfying product was developed, a shelf-life study was performed, intended for a chilled chain distribution for >30 days. The products were pasteurized and packaged in plastic trays with modified atmosphere (100% N_2) and autoclaved to a core temperature of 95°C for 15 mins, chilled in ice slurry and stored at 4°C for 4-6 weeks. Texture analyses, sensory analyses and microbiological analyses (aerobic plate count, aerobic and anaerobic spore-formers) were carried out during this storage period. Both salmon and haddock products were compared with the commercially available dysphagia products.

The texture analyses showed that the modified salmon and haddock products with fish protein hydrolysate were softer in texture compared to the products without fish protein hydrolysate, and softer than the commercial reference product. The objective instrumental analyses were compared with the standard test methods described in the IDDSI. Similar results for softness were obtained with a simple IDDSI fork test method. The qualitative descriptive analysis of salmon products and the reference product showed that the attributes within odour (spice and fish odour), appearance (uniformity, dotted and glossy), taste (spiciness and fish taste) and texture (softness, fattiness, granularity, cohesiveness and adhesiveness) were significantly

different ($p<0.05$). The haddock products and the reference product showed significant difference ($p<0.05$) in the attributes within odour (milk and fish odour), appearance (uniformity, dotted and glossy), taste (saltiness, milky taste, spiciness and fish taste) and texture (hardness, fattiness, fibrous, juiciness, cohesiveness and adhesiveness). The shelf life study of salmon and haddock products at 4°C indicated a good microbiological quality product and safety in 43 days.

Abbreviations

ANOVA	Analysis of variance
cfu/g	Colony-forming unit per gram
cP	Centipoise
D-value	Decimal reduction time
F_{max}	Maximum force
FPH	Fish protein hydrolysate
GLM	General linear model
H	Texture modified haddock product without fish protein hydrolysate
HFP	Texture modified haddock product with fish protein hydrolysate
HDPE	High-density polyethylene
IDDSI	International Dysphagia Diet Standardisation Initiative
mPa.s	Millipascal-second
N	Newton
NDD	National Dysphagia Diet
NMKL	Nordisk Metodikkomité for Næringsmidler
PCA	Plate count agar
PEM	Protein energy malnutrition
QDA	Quantitative Descriptive Analysis
RDA	Recommended Dietary Allowance
S	Texture modified salmon product without fish protein hydrolysate
SFP	Texture modified salmon product with fish protein hydrolysate
TCATA	Temporal Check-All-That-Apply
TMF	Texture modified food
TPA	Texture profile analysis
WPC80	Whey protein concentrate 80% protein

Dedicated to the memory of my beloved late father, Nathu Shinde.
Your eternal love and belief helped me in pursuing my dreams.

1 Introduction

The world population across the globe is ageing dramatically (He, Goodkind, & Kowal P., 2015). On the world basis, the population of 60 years and above is expected to grow from 962 million in 2017 to around 2.1 billion in 2050 (United Nations, 2017b). In Norway, the Statistics Norway (Statistisk sentralbyrå, 2016) states a growth from the current 600,000 to 1.2 million in people above age of 70 years by 2030. Due to the medical development and awareness, more and more ageing people are inclined to stay healthy and food conscious. However, this is not the case for everyone.

The ageing process increases vulnerability to various diseases and illnesses because of the physiological and anatomical changes (Humbert & Robbins, 2008). The protein reserve and the dietary protein intake diminishes with advancing age and leads to the loss of muscle mass. This puts older population at a higher risk of undernutrition. This can be avoided by increasing dietary protein intake. Evidently, older people need more dietary protein than the younger adults to regain the muscle loss (Bauer et al., 2013). The Norwegian directorate of health, reports that nearly 45% of the institutionalized elderly are at the risk of undernutrition (Nasjonalt råd for ernæring, 2017).

Another concern of the ageing process is the disruption of the normal chewing and swallowing process. The medical term for this disorder is dysphagia, which is estimated to affect around 8% of the global population (Cichero et al., 2016; Sura, Madhavan, Carnaby, & Crary, 2012). Due to their reduced ability to swallow, the dysphagia patients are restricted to consume specific foods and liquids with modified textures. Lack of such food can negatively impact the nutritional status and may lead to severe protein and energy malnutrition.

The management of dysphagia through food texture and liquid modification occurs throughout the world. However, the number of texture modification levels and characteristics across and within the countries are different and increase the risk to patient safety. A need of international standardized terminology is thereby crucial for consistent communication among health professionals, care providers, researchers and industry partners to facilitate safety of patients and improve quality of care. This led to the formation of the International Dysphagia Diet Standardisation Initiative (IDDSI) (Cichero et al., 2013). The aim of this global collaboration was to develop international standardized terminology and definitions of the texture modified

food and liquid for individuals with dysphagia. Based on the severity of the dysphagia, the IDDSI has developed eight consistency levels of food and liquids (Cichero et al., 2016).

Appropriate food texture and protein enrichment can play a key role in overcoming the problem of nutritional risk (Ney, Weiss, Kind, & Robbins, 2009). However, providing soft, palatable and healthy texture modified foods and liquids for elderly, especially with dysphagia has been a major challenge for both food industries and institutions (Aguilera & Park, 2016).

The main challenge lies in developing a texture modified food of a specific consistency level that not only has a suitable texture but is also nutritionally dense. Currently, in Norway a limited range of texture modified products aimed for dysphagia patients are available in chilled condition. To our knowledge, the only commercial series of dysphagia products with defined consistency available today are frozen products. These are supplied in bulk quantities to the institutions by the retailers or are available online. Storage facility for such frozen products is also a challenge (Puaschitz & Reigstad, 2010). The non-availability of these products in the grocery stores or supermarkets makes it less accessible and less practical for the home-staying elderly group. Many institution kitchens cater their own texture modified food. But the method and the level of texture modification and nutritional enrichment is not standardized. Hence, it may lead to variations in nutrients, consistency, appearance and acceptability (Keller, Chambers, Niezgoda, & Duizer, 2012).

The aim of this thesis was to develop texture modified and protein enriched fish products for the dysphagia group with extensive swallowing problems and study the various challenges underlying in their development. A pureed, homogenous, cohesive and non-elastic consistency of level 4 as described in the IDDSI framework was desired (IDDSI, 2016a). The food should be easy to swallow without any need of biting or chewing. The product should be suitable for cold chain (4°C) distribution with a minimum shelf life of 4-6 weeks and should hold its shape during pasteurization, storage and reheating.

The thesis is a part of Nofima' s strategic project "VårMat" (project no.12234) that focuses on the use and development of the personalized food in different stages of human life. It is an interdisciplinary project which involves several other divisions of Nofima AS.

2 Theory

2.1 Status of 'elderly' population in the world and Norway

The world's population aged 60 years or over is rising rapidly at an unprecedented rate of 3 percent per year, owing mainly to the decline in fertility and increase in the life expectancy. This global phenomenon of rise in a population above a certain age is termed 'population ageing' (United Nations, 2017a, 2017b). This substantial increase in the number of people aged 60 years and over is expected between 2017 to 2050 in almost every country in the world. According to the data from United Nations (2017a), on world basis there was an estimated 962 million people aged 60 or over in the year 2017 comprising 13 percent of the global population. This number is projected to double by 2050 and probably more than triple by 2100, with an inevitable increase from 962 million in 2017 to 2.1 billion in 2050 and probably 3.1 billion in 2100 (United Nations, 2017b). The majority of these countries with old age population lies in Europe making 25 percent of European population aged 60 or over (United Nations, 2017b).

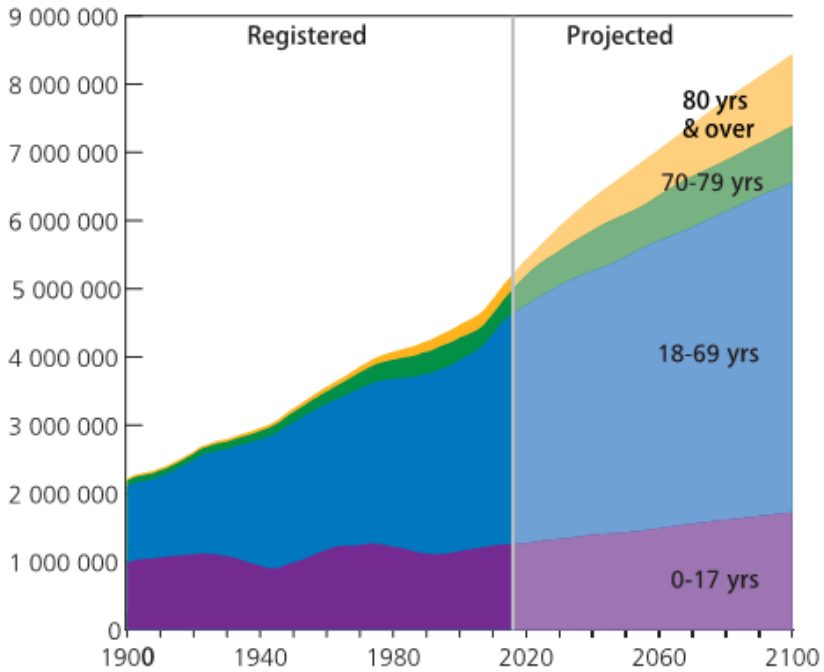


Figure 2.1 Registered and projected population of four age groups in Norway (in millions). The projection is based on development in four demographic components fertility, lifespan, domestic migration and immigration. In this graph median-growth is used for all components. Source: SSB «Befolkningsframskrivinger 2016-2100» Hovedresultater»

Due to the inconsistent geographic distribution of age and varying life expectancy, the definition and the use of term "elderly or older person"[1] differs across the world (He et al., 2015). Most developed western countries refer to chronological age of 65 as older population which is set by the World Health Organization (WHO). This age criteria may not be suitable for some countries where life expectancy is relatively low (e.g. Africa) compared to other developed countries. Therefore, the United Nations (UN) refers to age 60 years or over as older population (United Nations, 2017a; World Health Organization, 2000). Generally, the definition of age in developed or developing countries is associated with the retirement or pension age set by their respective government (World Health Organization, 2000).

In Norway, it correlates to the age when one starts receiving pension which is generally the age of 67 years. This may certainly change in the near future due to new pension reforms. The old age norm can also change on a global basis if people are living longer and healthier life. The Statistics Norway (SSB) population projection indicates that the people aged 70 years and above will double in three decades, from nearly 600,000 today to around 1.2 million (Figure 2.1). Also, in just over two decades, the number of 80 years and above will double from today's 220,000 to 440,000 (Statistisk sentralbyrå, 2016).

There are large individual differences but statistically ageing leads to some vital changes in a person that diminishes their physical, sensory, cognitive and immune functions. These poses increasing risks to diseases such as chronic respiratory diseases, diabetes, cancer, stroke and dementia. The age-related health issues also include challenges such as oral health, frailty, malnutrition, undernutrition and swallowing impairment. (Beard, Officer A., & Cassels A., 2015). The ever-increasing old population and the challenges associated with it needs to be managed effectively. This ageing boom will have an immense effect on the socio-economic growth, especially the food, healthcare, welfare and infrastructure sector.

2.2 Dysphagia: A swallowing disorder

The anatomical and physiological changes due to ageing tends to alter and slow down natural swallowing abilities of a healthy old adult. Such characteristic changes in swallowing mechanism of a healthy old adult is termed as presbyphagia (Humbert & Robbins, 2008; J. Robbins, Hamilton, Lof, & Kempster, 1992). With time, this condition can deteriorate even more due to acute illnesses, certain medication and several other age-related conditions, leading

[1] For this thesis, the term "elderly or older person" refers to those above 67 years and over, unless otherwise specified.

to severe swallowing impairment termed dysphagia. Globally, around 8% of the population is affected by dysphagia (Cichero et al., 2013).

Swallowing is a complex neuromuscular process involving around 50 muscle couples regulating the sensory-motor events starting right from sight and smell of food to moving it from the mouth further into oesophagus and finally down to the stomach (Humbert & Robbins, 2008; Mertl-Rotzer, 2009). Normal swallowing process consists of four phases (Figure 2.2).
(1) ***Preparatory phase***- The first phase involves mastication of a food and mixing it with saliva. The resulting soft and moist mass of food is termed as bolus. Saliva helps to soften the food, aiding the mastication process and passage of bolus through the pharynx. **(2)** ***Oral phase***- During this phase the bolus is propelled from the oral cavity into the pharynx with the help of the tongue. **(3)** ***Pharyngeal phase***- The bolus is transported from the pharynx further into esophagus (food pipe). During this the soft palate elevates and prevents the food entering nasal cavity. Simultaneously the epiglottis blocks the larynx (trachea) preventing the aspiration of food or liquid. And **(4)** ***esophageal phase***- Finally, the bolus is propelled from esophagus to the stomach for digestion (Clave, Terre, Kraa, & Serra, 2004; Dodds, Stewart, & Logemann, 1990; Humbert & Robbins, 2008).

Dysphagia or swallowing disorder can occur in any phase of swallowing. Based on the anatomical location of the problem, dysphagia can be classified into either oropharyngeal or esophageal (Clave et al., 2004). Oropharyngeal dysphagia occurs when there is difficulty in moving the food from the oral cavity to pharynx and thereby esophagus. In esophageal dysphagia problem arises several seconds after initiating a swallow leaving a sensation of stuck food in throat or chest and difficulty passing the food down through the esophagus (Garcia & Chambers, 2010).

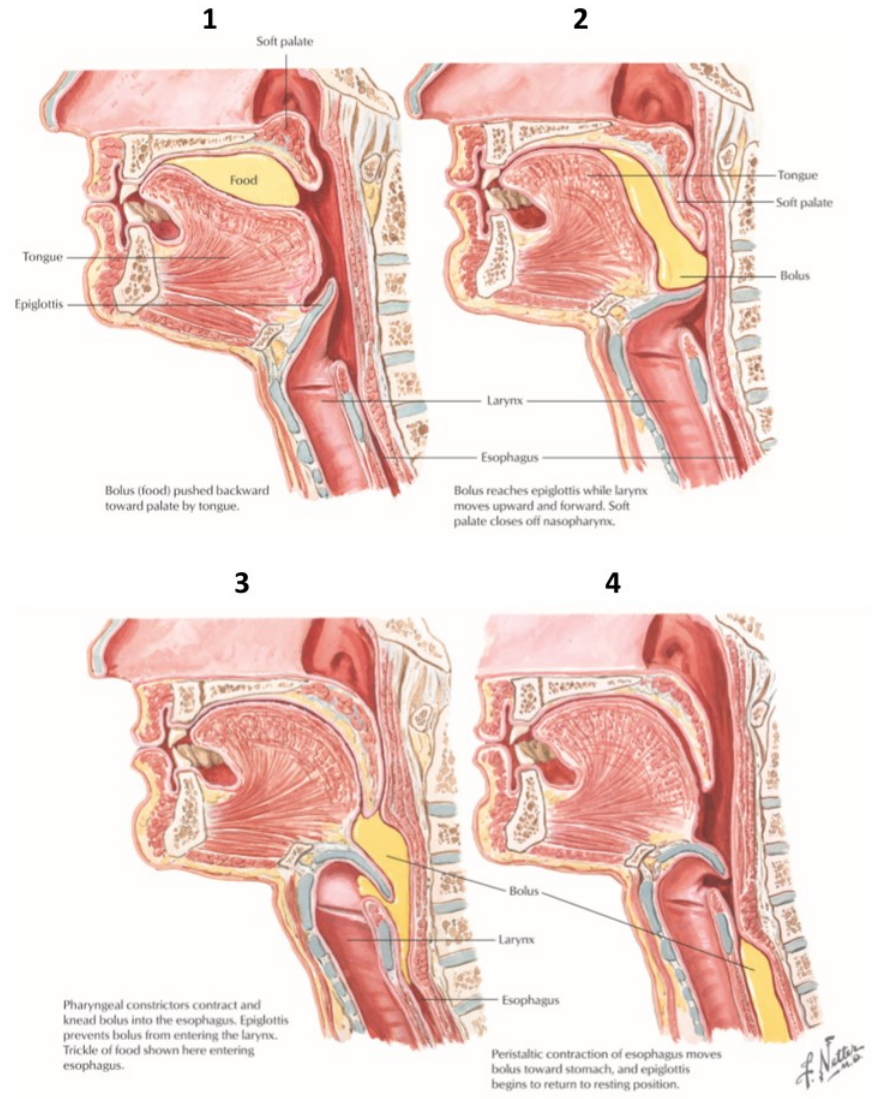


Figure 2.2 Four stages of normal swallowing process in a healthy person. (1, 2) The food is masticated and the bolus moves from mouth to pharynx. (3, 4) It is further propelled to esophagus which then moves the bolus towards the stomach. The picture is adapted from Garcia and Chambers (2010).

Esophageal and oropharyngeal dysphagia can occur due to several motor or mechanical disorders (Figure 2.3). The oropharyngeal dysphagia is widespread in patients with neurological diseases such as stroke, brain injury, dementia and Parkinson's desease (Clave et al., 2004; Ney et al., 2009). But it is most commonly followed by stroke. (Marik & Kaplan, 2003). It is estimated that incidence of dysphagia ranges from 40%-60% in acute phase of stroke (Sura et al., 2012). Dysphagia can also be a consequence of sarcopenia, an involuntary loss of skeletal muscle mass and strength which may already start by the age 65 years (Aguilera & Park, 2016). As shown in Figure 2.3, if unmanaged, dysphagia can give rise to complications such as dehydration, malnutrition, respiratory infections and eventually morbidity and mortality (Ekberg, Hamdy, Woisard, Wuttge-Hannig, & Ortega, 2002; Sura et al., 2012). Around 68% of

elderly in nursing homes, up to 30% of admitted elderly patients, 64% of post-stroke patients and 13%-38% of elderly living independently are affected by dysphagia (Sura et al., 2012).

Similarly, 30% of patients having had a cerebrovascular accident (CVA), 52-82% patients with Parkinson's disease, up to 84% of patients with Alzheimer's disease, 60% of patients with amyotrophic lateral sclerosis (ALS) and up to 44% of patients with multiple sclerosis develop oropharyngeal dysphagia (Clave et al., 2004; Rofes et al., 2011). Dysphagia is also a symptom and comorbidity of many age-related diseases and/or their treatments. Head and neck injury, carcinoma, diabetes, brain tumor can also lead to intermittent or chronic dysphagia. Several medications and treatments like chemotherapy or radiotherapy can increase the risk of dysphagia (Ney et al., 2009; Sura et al., 2012).

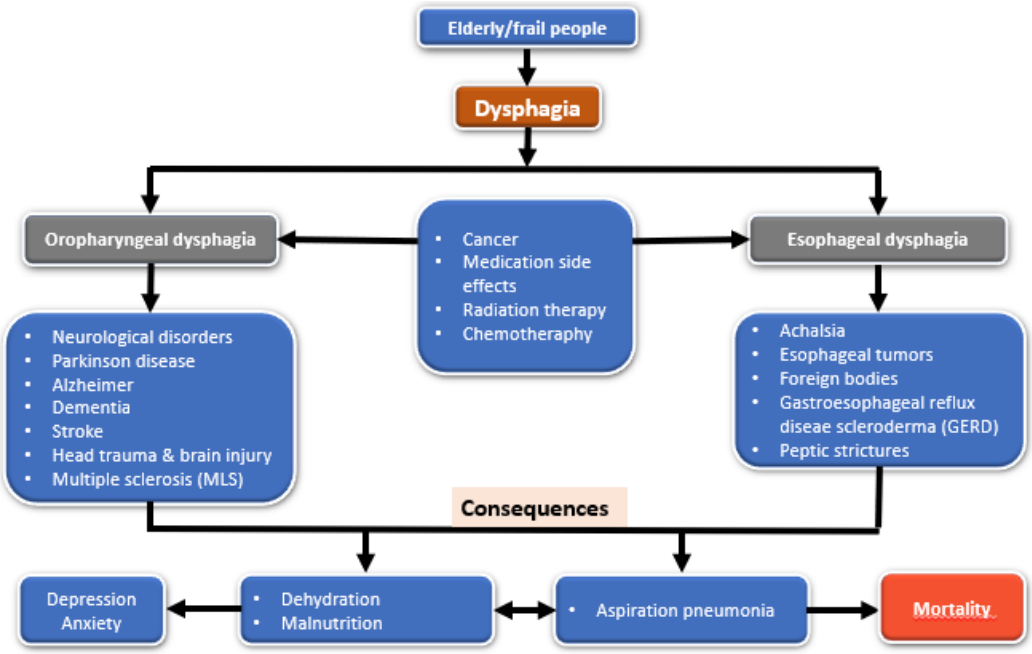


Figure 2.3 Two types of dysphagia (oropharyngeal and esophageal) based on anatomical classification, their etiology and consequences. The figure is based on the information from Aslam & Vaezi, 2013; Ney et al., 2009; Sura et al., 2012.

Inability to swallow properly and fear of choking initiates anxiety and panic among dysphagia patients during mealtimes. It can lead to reduced or complete loss of appetite. The embarrassment of not being able to seek the basic pleasure of eating could affect patient's dignity and self-esteem (Ekberg et al., 2002). This has a tremendous social and psychological impact abstaining an individual from the social pleasure of eating and drinking. This accelerates depression and anxiety, influencing their quality of life. (Ekberg et al., 2002; Ney et al., 2009). According to Ekberg et al. (2002) around 36% of patients avoided eating and 41% experience anxiety or panic during mealtimes because of dysphagia.

2.2.1 Dysphagia management through diet modification

The modification of the diet holds the key in the dysphagia management. To facilitate easy swallowing in dysphagia patient, the texture of the food should be modified depending on individual's chewing and swallowing capability (Garcia & Chambers, 2010). Texture-modified food (TMF) for individuals with chewing and swallowing difficulties refers to food that is altered to achieve a soft, moist and cohesive texture. Such foods can be processed by less or no chewing (Cichero et al., 2013; Cichero, 2015). Progressive research is constantly being conducted with regards to the various type of dysphagia treatment. Yet, TMF is emerging as a major breakthrough for dysphagia patients, where mastication and swallowing disabilities can be fatal (Cichero et al., 2013). For example, a soft and cohesive modified diet that can merely be disintegrated with tongue could make swallowing safe and prevent choking (Aguilera & Park, 2016). Decreased food intake in dysphagia patients also exposes them to various nutritional deficiencies. Factors such as special nutritional demands during ageing should also be considered while designing a TMF (Aguilera & Park, 2016). Based on the information from a review by Aguilera & Park, 2016, some key health and nutritional aspects of the elderly people that needs to be considered while developing and designing texture modified food are summarized in Figure 2.4.

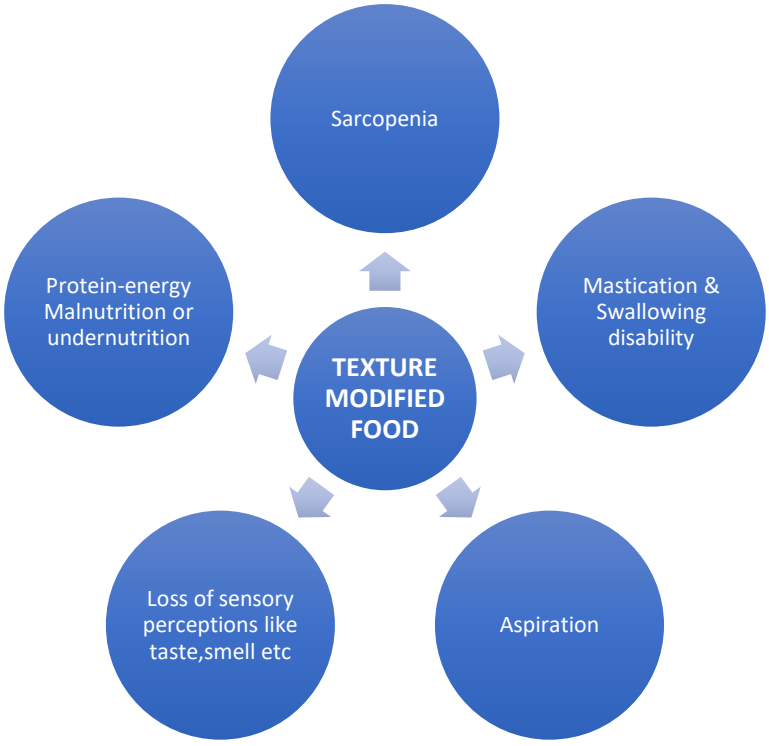


Figure 2.4 Some important factors to be considered while designing a texture modified food for elderly people with increasing swallowing disability. Diagram is adapted from Aguilera and Park (2016).

2.3 Nutrition requirement for elderly

Research suggests that the nutritional requirement of aged people is unique. The energy requirement decreases with advancing age in healthy elderly in contradiction to the protein need which increases due to age related changes in protein metabolism and declined anabolic response to protein intake. The vitamins and minerals requirement may either remain the same or increase (Bauer et al., 2013; Ney et al., 2009). Diminished sensory perceptions and sarcopenia in elderly conjunction with dysphagia can lead to loss of appetite and result in severe protein-energy malnutrition (PEM). Consequences of PEM includes dehydration, weight loss, fatigue, osteoporosis which has an adverse effect on the nutritional and functional status (Ney et al., 2009). Majority of elders need higher dietary protein intake to overcome these conditions.

Proper nutrition through food is key to good health and wellbeing. Proteins constitute 15-20% of the entire human body and are built from a total of 20 essential and non- essential amino acids that are crucial for several cellular functions of the body (Nordic Council of Ministers 2014, 2014). The WHO (2007) and European Food Safety Authority (EFSA 2012) specifies a recommended daily allowance (RDA) of 0.83 grams protein per kilogram of body weight each day (g/kg BW/d) for all healthy adults, irrespective of age and sex (Bauer et al., 2013). This intake might represent *lower intake range* and would not support the older adults with declining health followed by other illness and functional failures (Nordic Council of Ministers 2014, 2014).

Moreover, the consumption of protein can often be less in the older people than young people. A scientific study conducted by an international group, PROT-AGE (2013), revealed that recommended protein intake of 0.83 g/kg BW/d is very low for elderly people. The study recommends an average RDA of 1.0-1.2 g/kg BW/d to maintain the physical functions in older people which corresponds to the intake range of 1.1–1.3 g protein/kg BW/d suggested by Nordic dietary habits (Bauer et al., 2013; Nordic Council of Ministers 2014, 2014). Ideally, a healthy adult weighing 70 kg should therefore have a protein intake ranging from 70-91g/d. Furthermore, this study also indicated that the protein requirement in elderly people with severe illness or injury can be as much as 2.0 g/kg BW/d.

Dysphagia and other age-related problems such as loss of appetite and sensory perceptions, dryness of mouth (Xerostomia), aspiration problems, poor dentition or loss of teeth may drastically reduce the swallowing process. Dysphagia also limits the intake of food with certain

textures, e.g. hard texture. More likely, meal is consumed in much smaller portion. This in turn would not suffice the adequate nutrient intake putting them at high risk of nutritional deficiencies. Because of this dysphagia patients are exposed to further undernutrition or malnutrition. The National Nutrition Council of Norway (Nasjonalt råd for ernæring, 2017) estimates that every third patient in Norwegian hospital is either undernourished or on the verge of undernourishment. To meet the nutritional demand the required diet should be more energy and protein rich than the regular diet. The meals are generally preferred or consumed in smaller portions by the elderly and hence they should be as nutrient dense as possible (Aguilera & Park, 2016; Puaschitz & Reigstad, 2010). A clinical trial performed by Munk et al. (2014) showed that the protein-enriched food had a positive effect on the protein intake of the undernourished hospitalized patients.

2.4 The need for development of different consistency levels

The treatment of dysphagia does not involve modification of diet alone. It also involves modifying the diet in different levels. Modification level is a requirement of dysphagia patients and depends upon the severity of the dysphagia (Garcia & Chambers, 2010). A person can suffer from mild to advanced dysphagia. The degree of dietary modification should therefore be based on each patient's swallowing capacity and should be constantly evaluated. Modifying the fluids to appropriate consistency as per patient's abilities to swallow will ensure that they are not receiving overly modified liquids that are unappealing. Similarly, patients with advanced dysphagia receiving extremely thin liquid can put them at risk of aspiration (Garcia & Chambers, 2010). Patients suffering from mild dysphagia with intact chewing ability do not necessarily need pureed food. Lack of texture in food can make it a less enjoyable experience. This may lead to reduced food intake and consequently to undernutrition. They could rather be served with minced and moist food.

2.5 Standardized terminologies of modified dysphagia diets

The texture of food and liquid is often modified into different levels of consistency based on severity of dysphagia and patient's oral motor control (Garcia & Chambers, 2010). These consistency levels are described through various terminologies generated either by hospitals or national guidelines (Cichero et al., 2013). Many countries including USA, Canada, Japan and Sweden have compiled their own national lexicon of descriptors. However, these descriptors remain inconsistent within countries and throughout the world (Brook, 2015; Cichero et al., 2013).

For example, some countries have three levels of texture modified foods (Australia) while some have up to five (Canada) in addition to the regular food. In contrast to USA where food texture is characterized based on the particle size of the food, Japan has numbered them with the provision of nutritional information. For modified liquid diets, where it may seem obvious to differentiate them only as 'thin and thickened', there are multiple levels based on the increasing thickness or viscosity. Besides this, certain countries like USA and Japan express the liquid consistency in rheological measure centipoise (cP) and millipascal-second (mPa.s) respectively at a shear rate of 50 s^{-1}. Australia on the other hand uses dual system of number and descriptive text. It is also quite common to use color coding and terms such as 'honey' that resonates familiarity to a particular food (Cichero et al., 2013).

In Norway, descriptors are inconsistently used in various health institutions and industries.

The Norwegian Directorate of Health (Helsedirektoratet) has issued "National guidelines on preventing and treatment of malnutrition" (Helsedirektoratet, 2013) and a diet book, "Kosthåndboken", comprising of a chapter regarding texture modified food dedicated to people with dysphagia (Helsedirektoratet, 2012). A comparison of national descriptors used to characterize different consistency levels of texture modified foods and liquids in Norway and some other countries have been summarized in the Table 2.1 and Table 2.2 (Cichero et al., 2013).

Table 2.1 Different terminologies used to describe texture modified food in five countries including Norway. The diet ranges from regular to extremely modified diet. Colour coding is used in countries like United Kingdom and Japan. The chart is adapted from Cichero et al. (2013).

International terminology for texture-modified food

Country	← Regular food				Extensively texture modified food →	
USA (NDD)	Regular	Dysphagia Advanced (bite sized, < 2.5cm)	Dysphagia mechanically altered (0.6cm)	Dysphagia pureed		
United Kingdom		Texture E Fork mashable dysphagia diet (1.5cm)	Texture D Pre-mashed dysphagia diet (0.2cm)	Texture C Thick Puree Dysphagia Diet	Texture B Thin Puree dysphagia diet	
Australia	Regular	Texture A Soft (1.5cm)	Texture B Minced + Moist (0.5cm)	Texture C Smooth pureed		
Japan	Level 5 Normal diet	Level 4 Soft food	Level 3 (Dysphagia Diet) Paste containing meat/fish	Level 2 (Dysphagia Diet) Jelly food with protein [Rough jelly surface]	Level 1 (Dysphagia Diet) Smooth Jelly food with protein, except for meat and fish	Level 0 (Test Food) Smooth Jelly food without protein
Norway		Level 3 Regular soft/easy to chew **"Lett tyggelig kost"**	Level 2 Minced & pureed (homogenous) **"Findelt (puré)"**	Level 1 Soft & pureed (homogenous & non-elastic) **"Geleringskost"**		

Table 2.2 Different terminologies used to describe texture modified or thickened liquids in five countries including Norway. The consistency ranges from "water-like" to "pudding-like". Japan and USA characterize the consistency level using mPa s and cP respectively. The chart is adapted from Cichero et al. (2013).

International terminology for thickened liquids

Country	← "Water-like"				"Pudding-like" →
USA (NDD)	Thin (1-50 cP[a])		Nectar-Like (51-350 cP[a])	Honey-like (351-1750 cP[a])	Spoon-thick (>1750cP[a])
United Kingdom	Thin	Naturally thick fluid	Thickened fluid Stage 1	Thickened fluid Stage 2	Thickened fluid Stage 3
Australia	Regular	-	Level 150 Mildly thick	Level 400 Moderately thick	Level 900 Extremely thick
Japan	Less mildly thick (< 50 mPa.s[a])	Mildly thick (50-150 mPa.s[a])	Moderately thick (150-300 mPa.s[a])	Extremely thick (300-500 mPa.s[a])	Over Extremely thick (> 500 mPa.s[a])
Norway	Level 1 Thin liquid **"Tyntflytende"**	Level 2 Thickened fluid **"Tyktflytende"**			Level 3 Creamy, spoon-thick **"Krem"**

[a] Shear rate 50 s^{-1}; both cP and mPa s are used in the literature as the unit of viscosity, 1 cP = 1 mPa s

As the world is shrinking due to technology and global community travelling more than ever, this variations in definitions across the globe can mislead and pose serious threat to patient's safety. Thus, the need to develop globally recognized terminologies arose in attempt to safeguard the therapeutic needs of dysphagia patients and persistent inter-professional

collaboration (Cichero et al., 2013). To resolve this an International Dysphagia Diet Standardization Initiative (IDDSI; www.iddsi.org) was established.

2.6 The International Dysphagia Diet Standardization Initiative

The International Dysphagia Diet Standardization Initiative (IDDSI) was established in 2013 with an aim to develop international standardized terminology and definitions describing texture modified foods and thickened liquids for individuals with dysphagia irrespective of age, care settings and culture (Cichero et al., 2013). It provides guidelines for use in the public sectors and institutions.

IDDSI is an independent and non-profit organization that comprised of board members representing ten countries which are Canada, Australia, China, Brazil, United Kingdom, Japan, United States & territories, South Africa, Belgium and Germany. It has thrived on the financial support from numerous organizations, institutions and companies. The IDDSI framework draft was conceptualized based on the existing standard terminology across the world, stakeholder survey and a systematic review. The responses from the survey indicated disparity in the use of terminologies across different countries with common use of ≤5 levels of food texture (54 different terms) and liquid thickness (27 different terms). The initial draft framework featured colour code, numbering scheme and number of levels for better understanding. This was subjected to review by the international stakeholder consultation. Certain amendments were made with respect to colour, number of levels etc. based on the feedback received by respondents (Cichero et al., 2016).

Subsequently the final IDDSI framework with a total of 8 levels (including regular diet and drink) of texture modified food and thickened liquid was composed using a twin pyramid design (Figure 2.5). For better understanding, the draft pyramid design is also enhanced with the colour code, numbers and the levels are highlighted with 8 distinguishable colours that are suitable to colour blinded people. An additional sidebar category termed ‘transitional foods’ across the levels 5-7 on the inverted pyramid was added. This category includes regular foods (level 7) (e.g. wafers or cheese puffs) with special textural properties (hard and chewable) that change their texture rapidly once moisture (e.g. water or saliva) is applied, or when temperature change occurs (e.g. heating) and can be manipulated between levels. ‘Liquidized foods’ and ‘Moderately Thick fluids’ overlap at level 3 and ‘Pureed food’ and ‘Extremely Thick fluids’ overlap at level 4 (Cichero et al., 2016).

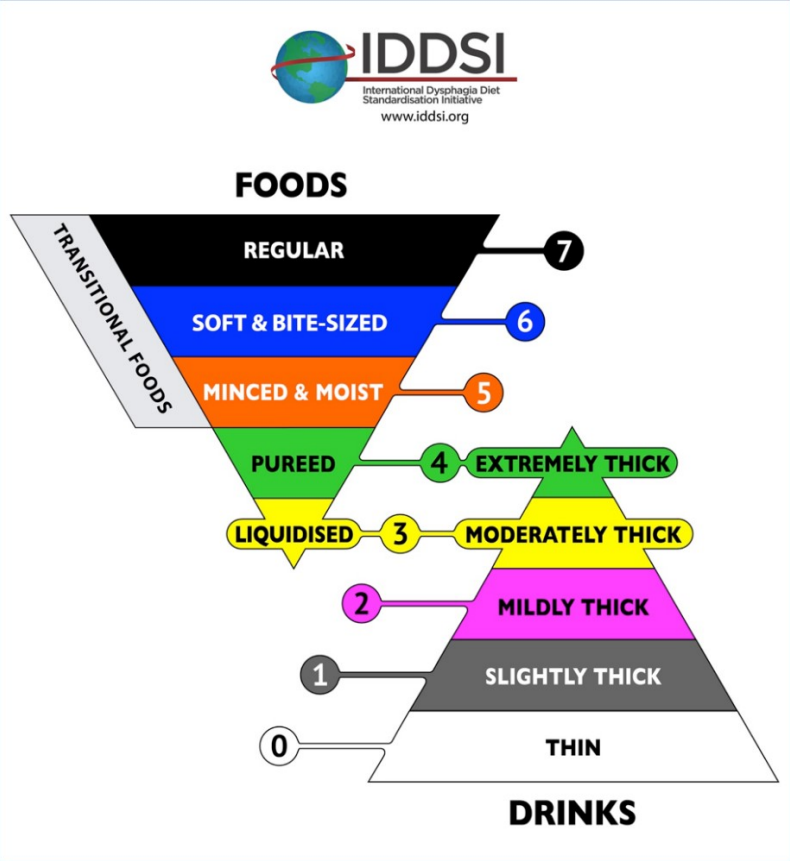


Figure 2.5 The IDDSI framework pyramid representing 8 levels of foods and liquids, highlighted with different colours and denoted with a level number. An additional transition level sidebar is placed on the left-hand side of inverted pyramid. Picture is retrieved from ©The International Dysphagia Diet Standardisation Initiative 2016 (IDDSI, 2016a).

However, to check if the developed framework is feasible as intended, it is important to study the implementation logistics in various care facilities around the world. To execute this, IDDSI has proposed the use of MAPA model (Monitor-Aware-Prepare-Adopt) to aid the Food and catering industries and health care providers. One such pilot study was conducted in July 2015 at a hospital in Kempen, Germany (Lam, Stanschus, Zaman, & Cichero, 2017). This study demonstrated a successful implementation of the framework in a span of 6 to 12-month period. This establishes a promising future for application of IDDSI at other sites in the world. In addition, the IDDSI framework and testing methods have been translated into some languages including Norwegian to make the implementation easier around the globe. The translation work is in progress for many other languages including Japanese, German and Arabic.

Many countries have initiated the use of IDDSI standards by replacing their internal standards. The Norwegian Directorate of Health has also approved the use of the IDDSI standard for dysphagia treatment and management (Helsedirektoratet, 2018).

2.6.1 Measurement of different texture and consistency levels

The extensive use of modified food and liquids with different levels in various hospitals, institutions, commercial kitchens etc. also depend on the ability to measure and differentiate the consistency. The scientific assessment of texture modified foods and liquids, based on its texture, consistency and particle size requires expensive equipment such as food texture analyzers and viscometers. This can be impractical for the institutions, home-nursing, commercial and industry kitchen, catering personnel due to lack of access to such instruments (Cichero et al., 2016). This restricts some kitchens to use fewer levels such as cooked, minced or pureed foods because of this limitation of measurement. (Rosnes, J.T., Rognså, G.H., & Brierley, M, 2018). This challenge was overcome by the IDDSI committee by developing practical quantitative methods to distinguish liquid thickness, food texture and particle size in various categories (IDDSI, 2016a, 2016b). An illustration with simple methods, figures and images is provided that can be used by clinics, institute kitchens or even dysphagic people at home. To designate a modified food of a specific texture or consistency to a certain level, it must qualify the respective test or tests. These tests could be performed easily using basic available tools such as forks and spoons. In addition, finger tests and chop sticks were also introduced for countries where testing with forks and spoon might not be an option (Cichero et al., 2016).

Some tests to mention are *Gravity flow test* for levels 0-3, *Fork drip test* for level 3 and 4, *spoon tilt test* for level 4 and 5. *A fork pressure test* can be used to assess foods that falls into IDDSI levels 5–7 and transitional foods. The fork is set on to sample and the pressure is applied by placing the thumb onto the bowl of the fork, just below the prongs. It is pressed just hard enough until the thumb nail blanch to turn white (Figure 2.6). This pressure corresponds to approximately 17 kilopascal (kPa) and is close to the tongue pressure applied during swallowing (IDDSI, 2016b). There is a need to couple the objective instrumental method and the practical fork test together to standardize the measurement.

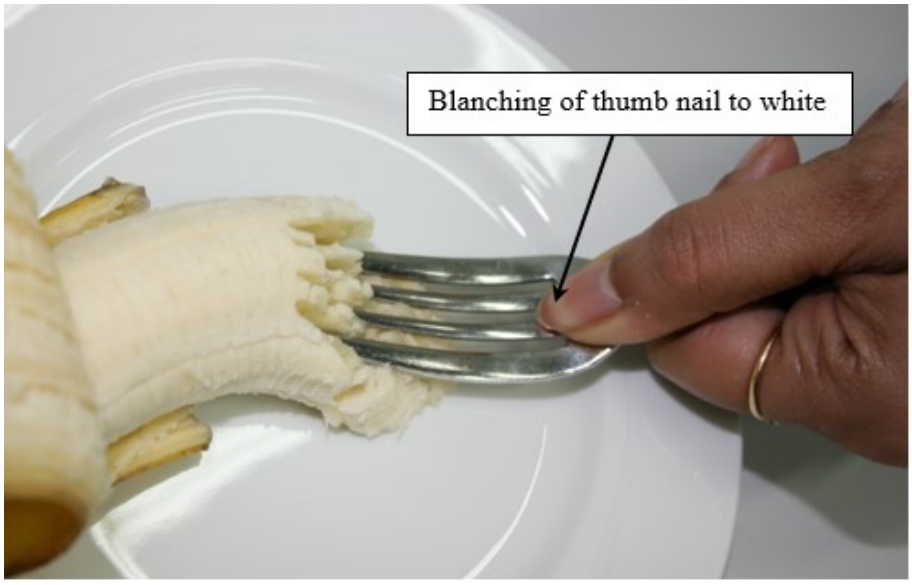


Figure 2.6 IDDSI fork pressure test applied to food sample by placing thumb onto the bowl of the fork (just below the prongs) until blanching is observed. The blanching of the thumb nail is demonstrated by the arrow in the image. Photo courtesy: JanThomas Rosnes, Nofima AS

2.7 Fish as raw material

Fish is mainly composed of water, protein and fat. It is also a good source of essential amino acid and micronutrients. The consumption of fish is considered healthy and nutritious and is recommended by the health authorities.

Cooked fish is generally elastic and soft in texture and could be easily consumed by most older adults. But this soft texture is perceived differently by the people with chewing and swallowing difficulties. Numerous restructured products based on minced or ground fish are readily available in today's market. But most of them have firm and elastic texture which makes it difficult for the people with dysphagia to chew and swallow it. Food for dysphagia patients must be soft and non-elastic in consistency. There are not many modified dysphagia products based on fish that are available in the commercial retail market or health institution sector.

Two different kinds of fish were chosen as a basic protein source in the development of the texture modified product for dysphagia. Atlantic salmon (*Salmo salar*) as a fatty fish and Haddock (*Melanogrammus aeglefinus)* as a white lean fish. The fresh, raw fish quality available for fish products can change with catch, time of the year and storage period. To obtain a stable quality, frozen fish was used for processing. Raw salmon and haddock have a protein content of about 19-20% and 16.6% respectively (Norwegian Food Composition Database, 2018).

2.8 Protein enrichment

The texture modification of a dysphagia diet requires some mechanical alteration of the original food to prevent choking and promote safe and easy swallowing (Cichero, 2015; Keller et al., 2012) . This modified diet must also be moist and cohesive (Cichero, 2015). This modification process involves addition of some liquid (e.g. milk, water, broth) during alteration. This in turn dilutes the nutrient density of the final product, thus increasing the potential risk undernourishment (Cichero, 2015; Keller et al., 2012). Protein enrichment is therefore necessary to compensate these reduced levels of nutrients in the product.

For this purpose, fish protein hydrolysate (FPH), caseinate and whey protein concentrate 80 (WPC80) were used for the enrichment of the modified products. Enrichment with proteins has limitations. High protein content can lead to harder products in contrast to desired softer products. An appropriate amount of protein is thus important to enrich the modified product simultaneously obtaining a desirable texture and taste.

2.8.1 Fish protein hydrolysate

The fish processing industry produces tons of protein- rich byproducts that are discarded or underutilized every year. To utilize these proteins more effectively and sustainably towards human health and consumption, several biotechnologies have been developed. Enzymatic hydrolysis of native protein is one such technology that results into protein hydrolysates. Protein hydrolysates can be defined as proteins that are chemically or enzymatically broken down into peptides of varying sizes (Adler-Nissen, 1986). These fish protein hydrolysates (FPH) are good sources of amino acids and contains small fragments of biologically active peptides. These peptides make amino acid source readily available for human physiological functions (Aspevik, 2016; Kristinsson & Rasco, 2000; Richardsen, Nystøyl, Strandheim, & Marthinussen, 2016).

It was a logical to use a fish-based protein source for enrichment because the modified products were based on fish raw materials. The functional properties of FPH includes good water solubility and water holding capacity (Kristinsson & Rasco, 2000). The latter is of great importance in texture modified food for elderly as it may help retaining the moisture and thereby improving the texture. Other properties such as gelling activity, foaming capacity and emulsification ability may also prove helpful in developing texture modified foods. Several studies have also indicated antioxidant activity in FPH (Kristinsson & Rasco, 2000; Nordic Innovation Centre, 2009). This anti-oxidant activity can prove beneficial in the production of

oxidatively stable fatty fish products (Nordic Innovation Centre, 2009). Owing to its easy digestibility and assimilation of these peptides, FPH can be introduced in elderly diet to overcome malnutrition.(Aspevik, 2016; Nordic Innovation Centre, 2009).

Despite their well-documented functional abilities, their use is still limited. Expensive enzymes and high processing cost are a setback in production of FPH towards human consumption. But the major drawback lies in its bitter taste. This unpalatable bitter taste may be attributed to the hydrophobic amino acids of peptides that are exposed as a result of hydrolysis process (Aspevik, 2016; Kristinsson & Rasco, 2000). A strenuous effort in research area is being made to overcome this challenge.

2.8.2 Milk proteins

Milk constitutes an important part of human diet due to its high nutritional value. Among dietary proteins, dairy proteins are one of the nutritionally complete protein due to high content of essential amino acids and good digestibility. Milk proteins are essentially composed of two groups of proteins; casein and whey protein. The casein is the most abundant representing 80% of milk protein and whey protein representing 20% of milk protein. These two are characterized by precipitation at pH 4.6 at a temperature of 20 °C. Due to their superior amino acid profile, similar to human milk, whey proteins are considered superior to casein (Sindayikengera & Xia, 2006).

Casein and whey protein can be processed further using various technologies to produce more concentrated forms with enhanced functional qualities. Casein and whey proteins react very differently under various conditions. It is therefore necessary to outline the application and choose the protein accordingly.

The utilization of whey protein as value added food ingredient has increased due to its nutritional and functional properties (Jeewanthi, Lee, & Paik, 2015). The two common whey protein ingredients are whey protein concentrates (WPCs, 35-80% protein) and isolates (WPIs 90-96% protein (Jeewanthi et al., 2015). Due to their superior amino acid profile, similar to human milk, whey proteins are considered superior to casein (Sindayikengera & Xia, 2006). Whey proteins has good solubility that makes it suitable for protein enrichment in beverages. Its water binding and adhesion properties helps improving the moisture and homogenous texture of food products. Besides they are good emulsifiers. Whey protein concentrate do not

impart any off-flavors and can improve the sensorial properties of food by creating a richer and fuller flavor (Jeewanthi et al., 2015).

Being low-lactose milk products, lactose-intolerant people can tolerate casein and WPC 80 (Sindayikengera & Xia, 2006). Both types of proteins are applied in many different applications from dairy products, baked products, nutrition bars, confections, soups, sauces, beverages, processed meats and even desserts. They are used for nutritional enrichment of food with perceived health benefits. Such diets can help recover muscle loss, especially in old people (Bauer et al., 2013).

2.9 Texture modification using texture modifiers

Texture modification of food into various consistency level, depending on the severity of the dysphagia is fundamental in dysphagia management. Processes technologies such as mincing, pureeing and thickening (liquids) to various extents can be used to achieve desirable soft texture (Cichero et al., 2016). These mechanical alterations are not enough on its own. Often to achieve a desired texture and increase functionality of food, a binding agent or additive is required.

The building blocks of food consists of proteins, carbohydrates and lipids. Their interaction forms structural network of small and large molecules that influences the texture and structure stability of the product (Figure 2.7). In this thesis, hydrocolloids have been used as texture modifiers. The interactions between the proteins present in food and added hydrocolloids can give rise to different textures (Van Nieuwenhuyzen, Budnik, Meier, & Popper, 2006) and it is important to study their effect on the binding process during the texture modification process.

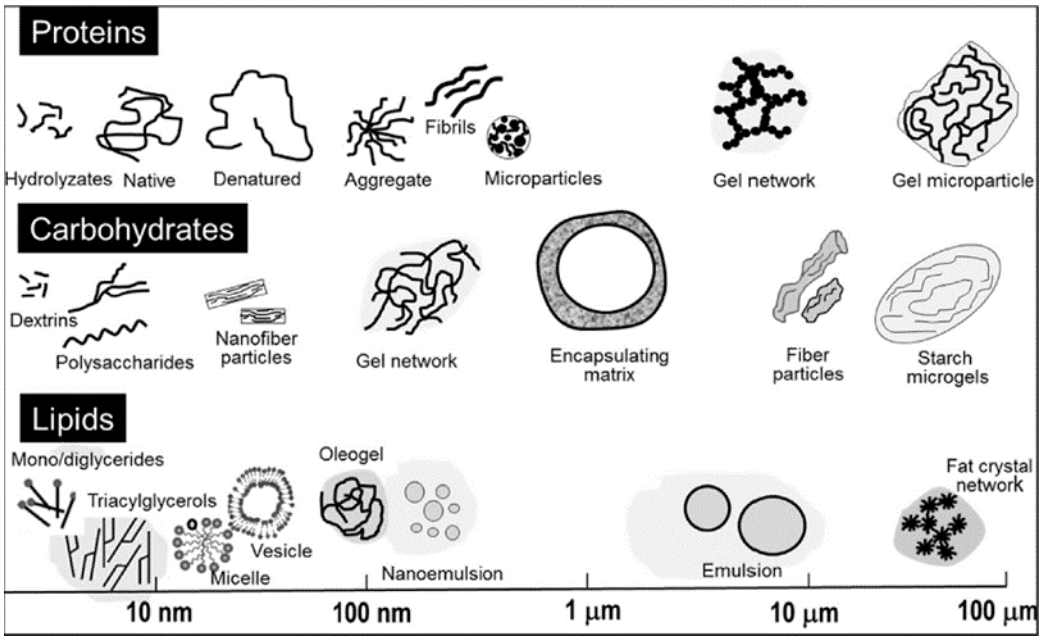


Figure 2.7 Three basic building blocks which are important in designing texture modified foods and the approximate dimensions of their important molecular components, structural elements and food matrices (Aguilera & Park, 2016).

A ***hydrocolloid*** is *defined* as a colloid system wherein the colloid particles are dispersed in water whose key function is to control texture and organoleptic properties by enhancing viscosity and gel characteristic (Williams & Phillips, 2003). Additionally, they are also potential emulsifiers, stabilizers which tend to improve quality and shelf life of the food products (Van Nieuwenhuyzen et al., 2006). The classification of hydrocolloids can be ambiguous. Some authors use the term “hydrocolloids and starches", indicating that starches are a separate class of soluble colloidal thickening agents. While some include starches under the hydrocolloid definition (Van Nieuwenhuyzen et al., 2006). With respect to this thesis, starch is included under hydrocolloids.

Hydrocolloids such as starch, xanthan, guar gum, locust bean gum, tara gum and cellulose derivatives are used commonly as thickeners. Gelatin, agar, pectin, alginate, carrageenan, gellan are some important gelling agents (Table 2.3) (Saha & Bhattacharya, 2010). These can be ranged from cheap to highly priced depending on their source and processing methods. Expensive thickeners and gelling agents are not cost effective for hospitals and commercial kitchens who cook for larger groups. Corn starch and locust bean gum are therefore actual texture modifiers in the development of modified foods.

Table 2.3 Source and application of some food grade hydrocolloids. Modified table from Van Nieuwenhuyzen et al., 2006; Williams & Phillips, 2003.

Hydrocolloid	Source	Function	E-number	Application
Botanical				
Modified starches	Corn, potato, etc.	Thickener Gelling	E1404-E1452	Soups, sauces, bakery products
Pectin	Citrus peel Apple pomace	Gelling	E440 a-b	Jams, jellies, fruit preparations
Locust bean gum	Seed endosperm *Ceratonia siliqua*	Thickener Stabilizer	E410	Dairy and desserts
Guar gum	Seed endosperm *Cyamopsis tetragonoloba*	Thickener Gelling Stabilizer	E412	Petfoods, ready-to-eat meals, sauces
Algal Red seaweeds				
Agar	*Gelidium, Gelidiella* and *Pterocladia*	Thickener Stabilizer Firm brittle gelling	E406	Confectionery, dairy and desserts, puddings
Carrageenan *Kappa*	*Euchema cottonii* and *Chondus crispus*	Gelling	E407	Cocoa drinks, syrups, petfoods, sugar confectionery
Carrageenan Iota	*E. spinosum*	Gelling	E407	
Brown seaweeds				
Alginate	*Laminaria hyperborea, Macrocystis pyrifera*	Thickener Gelling Stabilizer Emulsifier	E400-E404	Dairy and desserts, bakery products, petfoods
Microbial				
Xanthan gum	*Xanthomonas campestris*	Thickener Stabilizer	E415	Ready-to-eat meals, sauces and dressings
Gellan gum	*Sphingomonas elodea*	Gelling	E418	Beverages, jelly drinks
Animal				
Gelatin	Animal collagen (pigs, fish)	Gelling	Food	Mousses, whipped cream
Milk proteins	Cattle	Gelling	Food	Bakery products, dairy and desserts, confectionery

2.9.1 Thickening and gelling - functional role of hydrocolloid

The two-functional role of food hydrocolloids involves thickening and gelling. Thickening arises due to non- specific entanglement of conformationally disordered polymer chain due to which the movement of molecules is restricted. This transition from the free moving molecules to an entangled network leads to thickening. Gelling occurs when two or more polymer chains form specific inter-chain association regions, called ‘junction zones. These junction zones form three-dimensional network that holds solvent in the interstices (Saha & Bhattacharya, 2010). Any single food hydrocolloid cannot meet all requirements in food modification. It must be carefully selected depending on the functions required. Blending of suitable multiple

hydrocolloids showing synergistic effects can help developing an optimal modified product (Funami, 2011). The interaction between hydrocolloids and proteins can result into soft product. However, the degree of modification in food depends on the severity and levels of dysphagia (see IDDSI chapter). This can be challenging to achieve solely with traditional functional protein alone. Advantage of hydrocolloids over functional proteins is that they can effectively change the rheology of food at a low concentration of about 0.2 percent (Van Nieuwenhuyzen et al., 2006).

2.9.2 Starch

Starch is the most commonly and abundantly used hydrocolloid thickener and gelling agent. It is also relatively cheaper (Saha & Bhattacharya, 2010), which promotes its use in the small kitchens and institutions. It is derived commercially mainly from corn and potato but also produced from rice, tapioca, pea, waxy corn and sago to a lesser extent. Figure 2.8 shows the starch granule consisting of two polysaccharides, namely amylose (α-1,4-linked glucose polymers) and amylopectin (α-1,4/1,6-linked glucose polymers). The ratio of these polysaccharides varies depending on the source (Van Nieuwenhuyzen et al., 2006; Williams & Phillips, 2003). Starch is used in both its native and modified forms. Native forms are labelled as food while the modified are classified at E-additives. Modified starches are used extensively in soup, sauces, dressings and confectionary (Van Nieuwenhuyzen et al., 2006). Insoluble in cold water, the starch granules burst and release the amylose on heating that leads to thickening of liquids (Saha & Bhattacharya, 2010; Williams & Phillips, 2003). Their excellent cooking properties permits their use in pasteurized and sterilized products (Van Nieuwenhuyzen et al., 2006). Some starch- based thickeners such as “Thicken up” (NESTLE) and “Nutilis” (NUTRICIA), are commercially available in Norway directed towards dysphagia patients (Puaschitz & Reigstad, 2010).

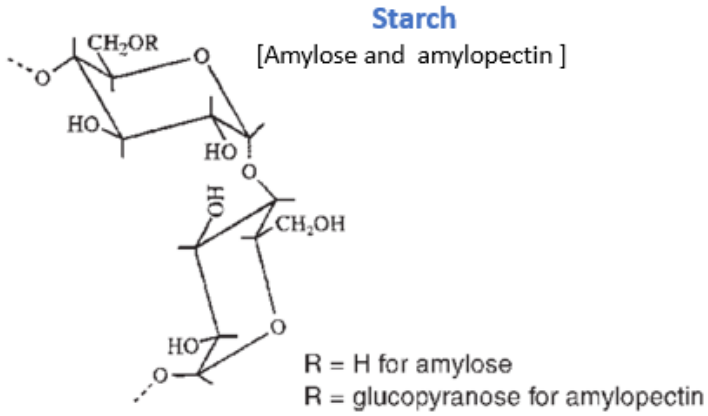


Figure 2.8 Primary structure of starch consisting of two polysaccharides; amylose and amylopectin (Williams & Phillips, 2003).

2.9.3 Locust bean gum

Locust bean gum (LBG) is a galactomannan obtained from the endosperms of leguminous seeds of Ceratonia siliqua. It consists of a linear main chain of (1 → 4) linked β-d-mannose residues and the side chain of (1 → 6) linked α-d- galactose (Figure 2.9). The mannose to galactose ratio, (M/G), is approximately 4.5:1. The LBG needs to be heated to dissolve it completely (Williams & Phillips, 2003). LBG, different hydrocolloids, starches or proteins can be blended to prevent syneresis, the unwanted exudation of water from the product (Saha & Bhattacharya, 2010; Williams & Phillips, 2003).

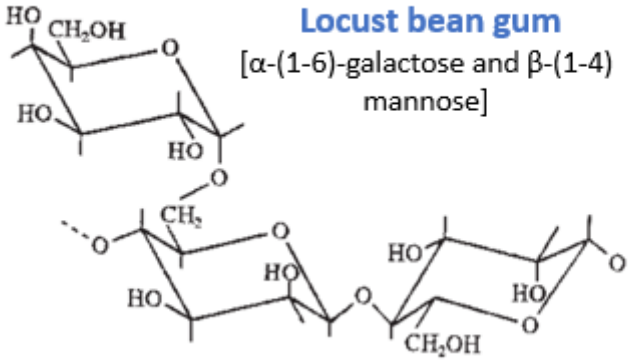


Figure 2.9 Primary structure of locust bean gum with a linear main chain of (1 → 4) linked β-d-mannose residues and a side chain of (1 → 6) linked α-d- galactose.

2.10 Protein denaturation and gel formation

Protein denaturation is a biochemical modification of its structure (secondary, tertiary or quaternary) without necessarily breaking their primary structure. This denaturation can be induced by physical means like temperature and pressure, or chemical agents like using a strong acid or base, concentrated inorganic salts or organic solvents. The denaturation can be reversible (renaturation) or irreversible. Thermal denaturation leads to transition of a protein from its folded to its unfolded state, exposing their hydrophobic core. Subsequently they begin to interact with other hydrophobic regions on the same protein (intra) or with other denatured proteins (inter). Further on, protein-protein interaction leads to aggregation, leading to binding and gelling mechanism. Aggregation of protein governs the structure, flavor, texture, and other nutritional qualities and physical stability of food, especially during cold storage (Berg, Tymoczko, & Stryer, 2001).

The denaturation process plays an important role in innovation of texture modified food using hydrocolloid technology. Food hydrocolloid supposedly act as filler and interact with denatured protein, inducing crosslinking and intra-protein reaction. This helps in even better gel formation (Ramírez, Uresti, Velazquez, & Vázquez, 2011). The possible interaction between the hydrocolloids and proteins is depicted in Figure 2.10.

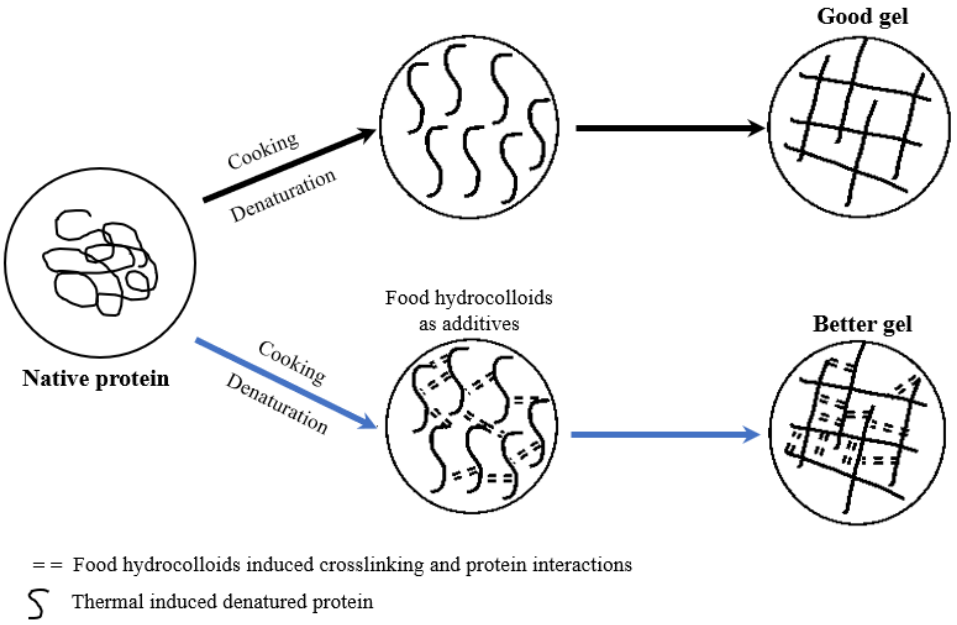


Figure 2.10 Suggested interaction between proteins and food hydrocolloids. Adaptation from (Ramírez et al., 2011).

2.11 Texture properties of food

Texture is one of the fundamental characteristics of food which can be defined as, “the sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinesthetics” (Szczesniak, 2002). Both sensory (subjective) or instrumental (objective) analyses can be applied to measure the texture of food.

The notion of food texture starts from the moment we first place food in mouth to the first bite, through chewing process and finally as we swallow it. It is an interplay between the several physical attributes which profoundly influences the food palatability by more than 30% (Field & M. Duizer, 2016; Funami, 2011; Szczesniak, 2002). Therefore, texture is of utmost importance when it comes to food cognition, intake and acceptance in both healthy and frail older adults (Field & M. Duizer, 2016; Funami, 2011).

The declining oral and swallowing mechanism, reduced saliva and bite force due to ageing can induce change in texture perception. Hardness in foods for example is perceived more strongly in older adults than in younger people in contradiction to creaminess which is generally less recognized by older adults. Foods with textural attributes such as hard or crunchy (carrot), sticky (candy), dry (bread) are often avoided by older group due to difficulty in processing them. For people with dysphagia, where pureed food with soft and smooth texture is the only option, may not be the ultimate choice either. This can be due to lack in taste, indistinguishable nature or unpleasant feel in mouth (Field & M. Duizer, 2016). IDDSI has classified texture modified food in several levels based on the severity of dysphagia. Developing a modified diet with suitable texture, based on the dysphagia level is crucial to increase food acceptability and promote safe and healthy swallowing. Some of the important mechanical attributes of texture, essential when designing a texture modified food for dysphagia patients includes hardness, adhesiveness and cohesiveness (Aguilera & Park, 2016; Garcia & Chambers, 2010). It is important to measure the texture of modified food instrumentally to regulate and standardize the texture. This will help in developing a consistent product every time. Over the years, various instruments and analysis have been developed, depending on the type of the product and the parameters of interest that need to be examined. Test methods as simple as penetration test to complex test of Texture profile analysis (TPA) can be performed using texture measuring instrument to test solids or semi-solid food.

TPA is a multifaceted analytical method used to characterize food in an objective manner. (Funami, 2011; Rosenthal, 2010). The analysis, also known as 'two bite tests' mimics the human mastication process by compressing the sample twice. Five primary mechanical characteristics such as hardness, cohesiveness, adhesiveness, viscosity and elasticity as well as three secondary characteristics (brittleness, chewiness, and gumminess) can be assessed through this test (Szczesniak, 2002).

A penetration test using a TA. XT plus analyzer can be applied to measure the firmness (in newton) of the texture modified salmon and haddock products. This penetration method gives maximum positive force (F_{max}) as a measurement of the firmness. The higher the force required to penetrate the sample, the firmer the sample. The analytical settings used are an adaption of sample project provided by stable micro systems.

2.12 Sensory perception of the modified diet

Sensory perception is one of the key factors that influences our food preferences consumption and satiation. It is perceived by our sense to see, touch, smell, taste and hear which are connected to sensory cells. The sensory cells located in our sensory organs (eyes, nose, ears etc.) responds to stimuli by transmitting an impulse via nerve cells to brain for further interpretation (Sensorisk studiegruppe, 2015).

There is a discussion on how much the elderly loose the taste or sensory perception. The systematic review by Methven et. al (2012) justifies this age-related decline in the sensory perception and sensitivity, especially taste perception. This occurs at varying extent and significance. The sensory decline is influenced by several factors including nutritional status and dentition, dry mouth feeling (Xerostomia). Texture modification of food for people with dysphagia can significantly alter the sensory properties of food. Often due to the modification process, the food does not relate to the original form of food and lacks sensory appeal. Use of thickeners for example can also modify the taste to a less pleasant one. These factors may lead to disliking of the products and minimize food consumption among the elderly and could lead to malnutrition and affect their health drastically (Field & Duizer, 2016).

It is thus vital to consider this decline of sensory abilities during development of texture modified food for the older generation, to compensate for sensory losses. There should be focus

on making a nutritious modified diet that will help in stimulating sensory perception. Their food preferences and liking can be evaluated by sensory methods (Methven, Allen, Withers, & Gosney, 2012). Sensory evaluation is a scientific approach used to evoke, measure analyze and interpret these sensory responses towards a product. This objective analysis of food is done using human as measuring "instrument" (Lawless & Heymann, 2010). In combination with analyses such as physical, chemical and microbiological, sensory evaluation can generate large data. Statistical analysis of such data can help describe a product and its attribute scientifically. It has therefore proven to be a versatile tool in both industrial and research area for product development, innovation, quality and safety (Sensorisk studiegruppe, 2015).

Descriptive analyses (DA) are the most sophisticated tools used in the field of sensory. Several different descriptive analysis techniques (Flavor profile, Quantitative Descriptive Analysis, Texture Profile and sensory spectrum) can be used for specification of the sensory attributes of a single product or a comparison of the sensory differences among several products. These techniques are usually ideal for shelf-life testing (Lawless & Heymann, 2010).

Quantitative Descriptive Analysis (QDA), developed in 1970 is one of the most versatile DA methods, based on the independent judgments of panelists and statistical testing. It can be used to profile the changes in product over time with respect to its overall attributes or limited attributes such as texture descriptors (Lawless & Heymann, 2010; Sensorisk studiegruppe, 2015). The analysis involves multiple steps including assessor selection and training, vocabulary development, testing and statistical analysis. It is done in accordance with ISO 13299:2016(E).

In addition to the QDA, texture modified salmon can also analyzed using a new dynamic method, Temporal check-all-that-apply (TCATA). The perception of sensory attributes and its intensity changes from the moment to moment. TCATA is a novel temporal sensory method that has been recently introduced for tracking and describing these multidimensional sensations in the product as they evolve over time. The attributes are selected based on its applicability to each sample at each time slice rather than its dominance. This method is applied by checking the attributes at times whenever applicable, and to uncheck whenever not applicable. Assessors are also permitted to leave them without checking whenever not applicable. The sensations that arise either sequentially or concurrently can thus be described by selecting multiple attributes simultaneously (Castura, Antúnez, Giménez, & Ares, 2016).

3 Materials and methods

The aim of the experiment was to develop and optimize a process for composing a texture modified, protein-enriched minced fish product. Different combinations of starches, hydrocolloids and proteins were examined to achieve a texture corresponding to IDDSI level 4 (soft and pureed). The development of products involved mainly of preliminary experiments (Chapter 3.5) and pilot production (Chapter 3.6). The workflow of the pilot production process is presented in Figure 3.1.

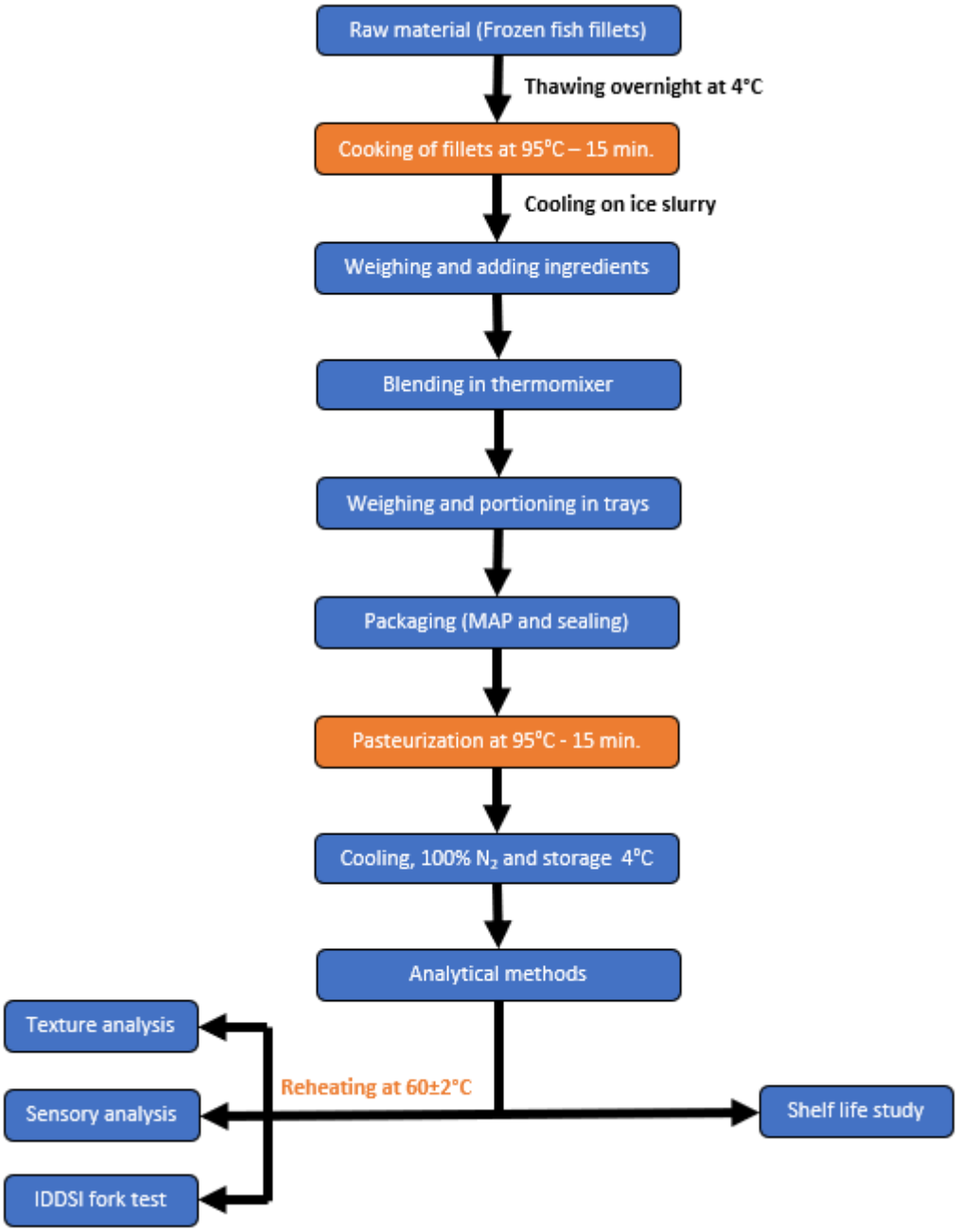


Figure 3.1 Workflow diagram showing pilot production of modified salmon and haddock products. The process involved three heat treatments.

3.1 Technique and process development

The general process of texture modified food production in commercial kitchen involves cooking and mincing of raw material, addition of liquid and texture modifiers (e.g. starch, hydrocolloids). The mixture is then portioned in trays or molds, before cooling (Rognså, 2015). To begin with, it was necessary to understand the process and technique of developing a basic minced fish product using ingredients such as milk, eggs, starch etc. It was also important to study the effect of particle size of minced and ground fish on texture of the end product. This insight was gained from the results obtained in the RFF-Vest project, "Konsistenstilpasset mat til eldre" [KOMAT] (Project no: 245347) with respect to generating meals with soft and pureed consistency (level 1- 'findelt purée') and / or mince and pureed (level 2- 'geleringskost') as defined by the Kosthåndboken (Helsedirektoratet, 2012).

Three recipes (I, II, III) based on the KOMAT project were used to understand how the ingredients and processes influenced the texture of the product. The products were referred to as product I, product II and product III corresponding to the recipes. Salmon was used as raw material and was processed to either minced or grounded form before mixing with the other ingredients. This gave an idea of how different particle sizes of the fish influenced the texture of the end product. The *Thermomix*®TM5 blender (Vorwerk, France) was used in the KOMAT project and the same was also utilized for this purpose (Figure 3.2). Product I was based on a basic minced fish recipe using starch as binding agent. Product II consisted of minced fish and texture modifying mixture of gellan, agar-agar and lecithin. Product III was made of ground fish where egg was used as binding agent. All three products were pasteurized to a core temperature of 90°C, where product II was pasteurized twice. This was done to break-down the elasticity of the minced fish mixture in first heat- treatment and to see how this affects the binding process in second treatment. The recipes and method of preparation for all three products are illustrated in Appendix A. The practical skills and knowledge obtained from the KOMAT project was used constructively in the development of preliminary recipes.

3.2 Raw material and ingredients

Two fish species, representing lean and fatty fish, were used as raw material in the production of texture modified fish products. Salmon represented a fatty fish source and haddock a lean

fish source. Both have different characteristics in terms of water-binding abilities and nutrient composition Table 3.1.

Table 3.1 Nutrient composition of salmon and haddock. The values are obtained from Norwegian Food Composition Database, 2018 .

Nutrients (%)	Raw farmed salmon	Raw haddock
Water	61	81
Protein	20	16.6
Fat	16	0.2
Carbohydrates	<0.1	<0.1

They also exhibit different properties because of cooking process. Besides this, salmon is regarded as healthy with healthy fatty acids, e.g. omega-3. Fatty acids are prone to oxidation during storage and when in contact with the environment. This oxidation process develops rancid off-odours and off-flavors. The oxidative rancidity has a negative effect on the sensory shelf-life of a fishery product. Since, we were looking for a product with a microbiological and sensory shelf life of more than 4 weeks, these aspects were important. It was therefore of interest to study how the composition of the recipe, processing and packaging in modified atmosphere inhibit the oxidation process. The raw material used in the preliminary experiments and pilot production are listed in Table 3.2

Table 3.2 List of raw materials and ingredients used in **1. Preliminary experiments** and **2. Pilot production** of salmon and haddock texture modified products.

1. Preliminary experiments

Materials	Producer	Country
Frozen salmon fillet without skin and bone (4x125g)	Lerøy Seafood As	Norway
Egg white powder	Myprotein®	Cheshire, UK
Locust bean gum (Art.3907)	Natur drogeriet A/S	Hørning, Denmark

Common ingredients for 1 and 2

Materials	Producer	Country
Fresh Haddock fillet without skin and bone	Domstein Sjømat	Stavanger, Norway
Whole milk 3.5% fat	Tine SA	Norway
Whipping cream 38% fat	Tine SA	Norway
Sunflower oil	Produced for Coop AS	EOL Polska, Poland
Sodium Caseinate (*KAPA™ JPR 1002)*	Armor proteines	France
Whey protein concentrate 80 (WPC80) Art. 4466	Tine SA	Norway
Endurance Salmon protein hydrolysate > 95%	Hofseth Biocare	Norway
Cornstarch (Maizena®)	Unilever AS	Norway
Fine refined salt (NaCl) CAS-no. 7647-14-5	Akzo Nobel salt	Denmark
Dry fennel powder (Art.18165) EAN13-code: 7053260181654	SAGA krydder, L.K Haaland	Sandnes, Stavanger
Ground Mustard powder (Art.18935) EAN13-code: 7053260189353	SAGA krydder, L.K Haaland	Sandnes, Stavanger
White pepper powder (Art.18745) EAN13-code: 7053260187458	SAGA krydder, L.K Haaland	Sandnes, Stavanger
Ground ginger powder (Art.18340) EAN13-code: 7053260183405	SAGA krydder, L.K Haaland	Sandnes, Stavanger

2. Pilot production

Materials	Producer	Country
Farmed and fresh salmon belly loin without skin and bone	SALMA Brand, Bremnes seashore AS	Bremnes, Norway
Locust bean gum (art. 40460)	Bohlsener Mühle, GmbH &Co.KG	Germany

3.3 Nutrient calculation

The nutrient content of the final product, especially protein content is an important aspect in texture modified food. The raw salmon and haddock have protein content of about 20% and 16% respectively (Table 3.1). Because the product is intended for people with dysphagia, it needs to be mixed with a high amount of liquid to modify the texture to a soft consistency. This dilutes the total protein content of a product. On the contrary, the protein level must be higher in these products as the elderly people (> 67 years) have higher requirement of protein than a healthy adult. Considering that they consume smaller portions, it is important that the product should be as nutrient dense as possible (Chapter 2.3). So, it was important to calculate and compare between the protein content of the final product and the raw fish.

The Norwegian Food Composition Database, 2018 (www.matvaretabellen.no) was used for the estimation of the nutrients and energy content of the raw material and ingredients of texture modified fish recipes. All the values presented in the database refer to the content per 100 grams of an edible portion of the food. Nutrient contents of some ingredients were not registered in the database. However, they were added to the database, based on the information provided on the product sheet or food labels. The diet planner tool, "Kostholdsplanleggeren 2014," was used to compile the recipes. This tool allowed to calculate and compare the sum of nutrient content in different recipes.

3.4 The development of blending method

The choice of processing method for the raw material (cutting, mincing, cooking etc.) is dependent on the structure and texture, one is after. The restructured and elastic fish product was not a criterion here. On the other hand, it should be properly minced or pureed such that it does not contain any pieces, clumps or large fibers. The same conclusion was derived from the KOMAT experiments. For this purpose, the *Thermomix*®TM5 blender (Vorwerk, France) was chosen.

It was used to make a homogenous mixture of fish by blending it with the ingredients. The mixture was blended for a fixed speed and time after addition of each ingredient (Table 3.4). *Thermomix*®TM5 is a versatile robust food processor with 12 functions. These functions can be operated through various function dials on the home screen. The maximum capacity of the stainless-steel mixing bowl is 2,2 litres. It has integrated temperature sensors that allows to heat and cook the food between 37°C to 120°C. The speed range is from 40 rpm (gentle stir) to

10,700 rpm. It consists of a single stainless-steel knife that can rotate in both clockwise and anticlockwise direction. The time dial shows mixing time in minutes: seconds.

Figure 3.2 Thermomix®TM5 blender

3.5 Preliminary process and optimization

Salmon was chosen as a raw material to conduct the preliminary experiments. The salmon was minced either in its raw form or precooked form before adding the other ingredients. The interaction of raw or cooked fish with milk proteins, texture modifiers, protein hydrolysate, along with the effect of the heat treatment process on the texture of the product was investigated. Figure 3.3 gives an overview of the development stages of product optimization. The results acquired from processing the salmon were used in the production of texture modified haddock products. In this quest of designing a modified fish product with desired texture, sensory attributes and protein composition, multiple recipes were examined in the pre-experiments. Ten recipes of salmon and five recipes of haddock were examined to compose the final recipes (Appendix B).

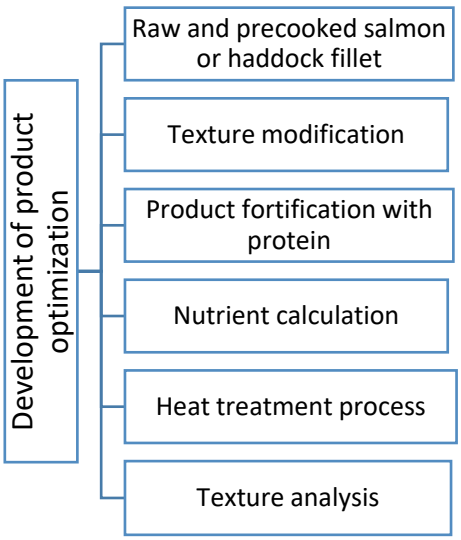


Figure 3.3. Schematic presentation of product development during preliminary experiments

3.5.1 Preparation of preliminary products

The raw material and ingredients are listed in the Table 3.2. The fish fillets (raw or precooked) and ingredients were weighed according to the recipe. In case of precooked fish, the liquid cook loss was also included with the fish weight. The mixture was blended to a homogenous mixture, after addition of each ingredient in a pre-defined sequence. Refer to Appendix B for the recipe details.

The mixture was transferred to a pastry bag (HDPE/LDPE 90my 275x550mm, NorEngros AS, Stavanger, Norway). Round Aluminium foil trays (Aluform 7112, 110ml Ø80x37mm, NorEngros AS, Stavanger, Norway) were greased with vegetable fat (Melange form Fett, Mills DA, Norway). A portion of 90±5 g was piped in each tray and covered with a plastic cling wrap. The products were then cooked in a convection oven (Metos system Intl., MSCC61, Germany) with 100% steam to a core temperature of 95°C for 15 min. The temperature was monitored with temperature probes (E-Val flex, Ellab, Denmark). After cooking, the containers were cooled immediately on an ice slurry to stop the process of further cooking. The products were refrigerated at 4°C until further use. Figure 3.4 highlights some of the preparation steps.

The products were used to develop and optimize the texture measurement method. The firmness of the products was measured in Newton (N), using various experimental settings for compression-penetration testing. These measured values were determining factor in selecting

the recipes for the pilot production. The instrument, preparation and measuring methods were the same as that of pilot products (chapter 3.8.1).

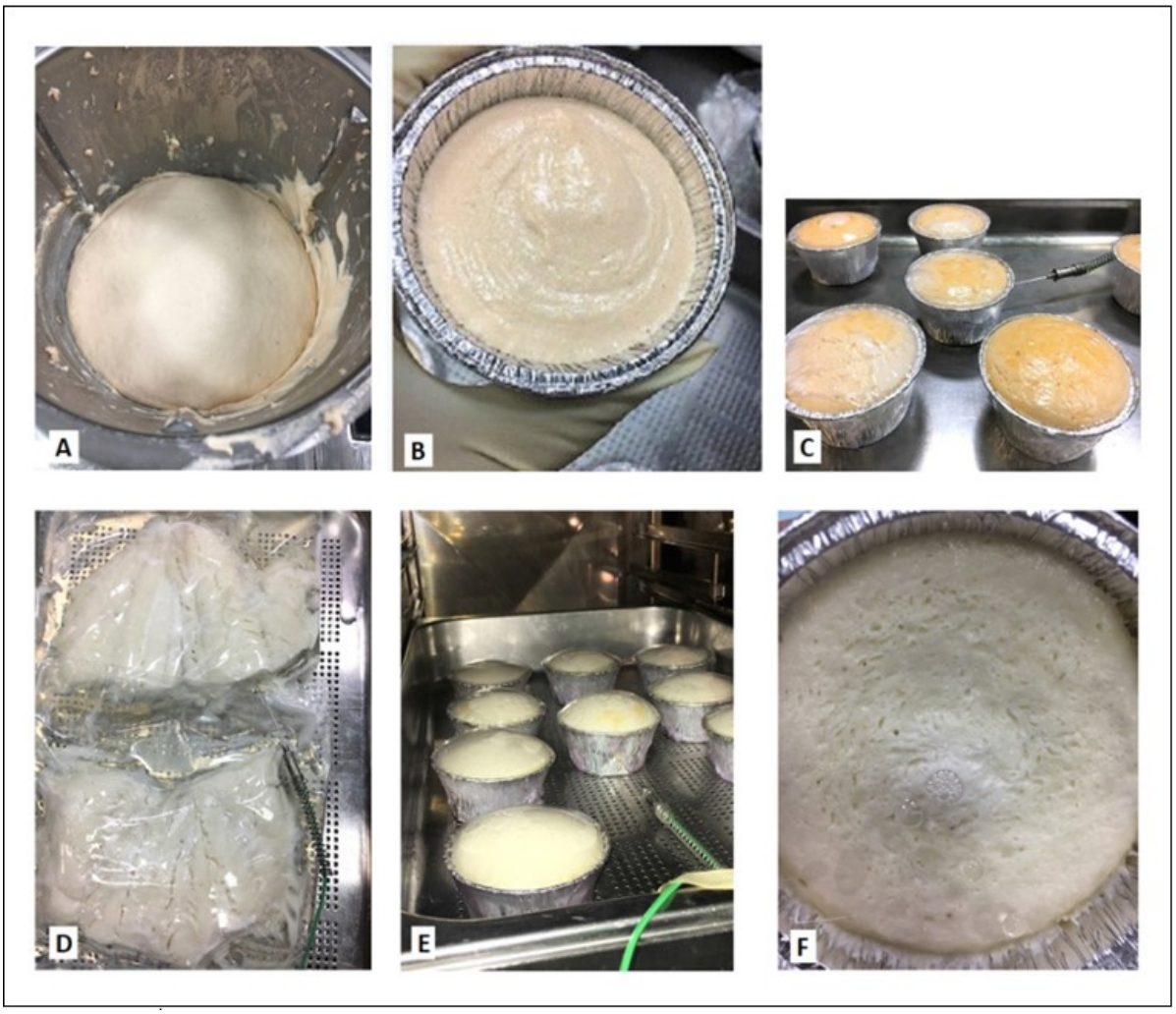


Figure 3.4 **Preliminary process of salmon product: (A)** Blended mixture in *Thermomix®*, **(B)** portioning in round aluminium tray **(C)** Heat-treatment (95°C) with temperature logging. **Preliminary process of haddock product**: **(D)** Pre-cooking of haddock fillet in vacuum bag, **(E)** Heat-treatment (95°C) with temperature logging and **(F)** haddock product after cooking.

3.6 Pilot production

After several experimental approaches in preliminary production, recipe 7a (without fish protein hydrolysate) and 7b (with fish protein hydrolysate) were shortlisted for pilot production of both salmon and haddock texture modified products. These two recipes; 7a and 7b are henceforth referred to as recipe A and recipe B respectively, in pilot production (Table 3.4). The selection of recipe A and recipe B was based on the nutrient calculation, texture measurement and basic sensory evaluation of the products. It showed that these two recipes gave an optimum protein content, texture (firmness) and mouthfeel respectively as compared

to other recipes. Both recipes were enriched with whey protein concentrate 80 (WPC80) and sodium caseinate in different proportions to increase the protein content of the end product. But only recipe B was additionally enriched with salmon fish protein hydrolysate (FPH). This was to understand whether the addition of FPH had any positive effect in terms of soft texture, fish flavor and protein content of the product. Henceforth, the salmon and haddock texture modified products is referred to as the abbreviations in the Table 3.3.

Table 3.3 The abbreviations for texture modified salmon and haddock products.

	Abbreviation	Expansion of abbreviation
Salmon	S	Texture modified salmon product without fish protein hydrolysate
	SFP	Texture modified salmon product with fish protein hydrolysate
Haddock	H	Texture modified haddock product without fish protein hydrolysate
	HFP	Texture modified haddock product with fish protein hydrolysate

The haddock products for microbiological shelf life study (43 days), sensory and texture analysis were produced on the same day. The salmon products however, were produced on three different production dates. This was done due to sampling convenience of sensory analysis in Ås. In the first production, samples for microbiological shelf life study (43 days), texture analysis and sensory analysis (26 days old) were produced. The 19 days and 5 days old samples for sensory analysis were produced in second and third production respectively. The samples from the first production were used for microbiological shelf life study (43 days) and texture analysis. To summarize this, the samples from production 1, 2, 3 were 26, 19, 5 days old on the day of assessment respectively.

3.6.1 Raw material

The raw materials used in the pilot production of both salmon and haddock texture modified products are mentioned in the Table 3.2. The possible role of the ingredients in designing a texture modified fish product is stated in the Figure 3.5.

Salmon and haddock

Farmed, skinless and boneless salmon belly loins (SALMA, Salmon brand, Norway) were purchased from Bremnes Seashore As, Norway. SALMA Belly loins were chosen to prevent the variation in the final product with respect to protein content because they have a standardized fish farming, giving raw material with more or less same distribution of protein. The loins were 24 h old after slaughtering and filleting. They were repacked at Nofima,

Måltidets Hus, Stavanger. The loins were cut and portioned into an average weight of 1±0.2 kg. These portions were packed individually in 220 x 600mm sous-vide bags (PA/PE 70my, LietPak, Lithuania). A Webomatic® (Supermax C; B055 m^3/h, Bochum, Germany) vacuum packaging machine was used to seal the bags with 99,9% vacuum. The packages were then frozen at -18°C until further use. Fresh haddock fillets were purchased from Domstein Sjømat A/S, Stavanger. The fillets were 7 days old. They were portioned, repacked, vacuumed and frozen in the similar way as for salmon fillets.

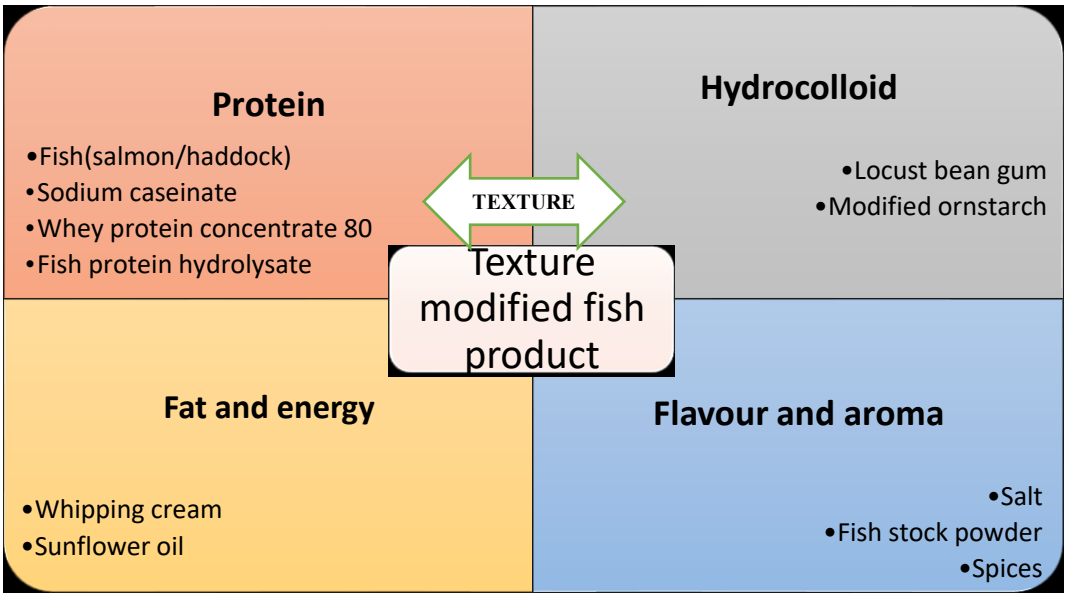


Figure 3.5. Functionality of ingredients in the enrichment and texture of the texture modified fish product.

3.6.2 Preparation of pilot-test products

The method of preparation was the same for both salmon and haddock texture modified products. The day before production, the frozen and vacuumed fish packages were thawed in large plastic containers with cold water. These containers were placed in a 4°C cooling chamber. The fish were thawed overnight for 20±2 h. On the day of production, the fish packages were placed on a rack in a preheated oven (100°C with 100% steam) and cooked to a core temperature of 95°C with holding time of 15 mins. This was monitored by the temperature probe inserted into the thickest part of the fillet. After cooking, the temperature of the fish was lowered immediately to about 30±5°C by placing the bags onto an ice slurry.

The cooled fish and the cook loss inside the bag were put into a stainless-steel bowl. A total of 1000±5 g cooked fish including the cook loss was weighed and transferred to the Thermomix® mixing bowl. The products were prepared following the two shortlisted recipes; recipe A

(WPC80 + sodium caseinate) and recipe B (WPC80 + sodium caseinate+ FPH). The ingredients were weighed, added sequentially and blended at a specific speed and time interval in the Thermomixer®, as mentioned in Table 3.4. The homogenous mixture from the mixing bowl was transferred to a pastry bag. The bags were stored at 4°C until portioning and packaging.

Table 3.4 List of ingredients in recipe A (enriched with WPC80 and sodium caseinate) and recipe B (enriched with WPC80, sodium caseinate and salmon protein hydrolysate). Different mixing speed used for this recipe corresponds between 1100-10200 revolutions/min.

Sequence of addition	**Recipe-A**	Weight in gram (g)	Mixing speed	Mixing time (mins: secs)
1	Precooked fish fillets [a)]	1000	5	01:00
2	Salt	6		
3	Whipping cream 38% fat	400	10	02:30
4	Sunflower Oil	160		
5	Cornstarch	10	10	00:15
6	Sodium caseinate	40	10	00:10
7	Whey protein concentrate 80	80		
8	Spice mix [b)]	3/4[c)]	10	00:10
9	Fish stock powder	20		
10	Locust bean gum	6	10	00:30

Sequence of addition	**Recipe- B**	Weight in gram (g)	Mixing speed	Mixing time (mins: secs)
1	Precooked fish fillets **a)**	1000	5	01:00
2	Salt	6		
3	Whipping cream 38% fat	400	10	02:30
4	Sunflower Oil	160		
5	Cornstarch	10	10	00:15
6	Salmon fish protein hydrolysate (FPH)	30	10	00:10
7	Sodium caseinate	30	10	00:10
8	Whey protein concentrate 80	60		
9	Spice mix **b)**	3/4 **c)**	10	00:10
10	Fish stock powder	20		
11	Locust bean gum	6	10	00:30

a) Indicates either salmon or haddock including cook loss.
b) Equal quantity of ground fennel powder, ground ginger powder, mustard powder, white pepper powder.
c) 3 g was used for haddock products and 4 g for salmon products.

3.6.3 Packaging and pasteurization

The food grade 562 Dynopack square trays in HDPE with dimensions 93x93x53 mm and volume of 280ml (RPC Bebo food packaging, Kristiansand, Norway) were used for packaging of the products. The tray was certified for use at a temperature range from -50°C to 121°C. It had O_2 permeability rate of 3.3 35 cm^3 / m^2 per 24 h. atm (Appendix C). Trays were greased thoroughly, at the bottom and the inner walls with the vegetable fat. A quantity of 120±2 g of the homogenized fish product was portioned in trays, using about 50% of the total tray volume. The products were packaged under modified atmosphere by flushing the trays with 100% nitrogen gas before sealing. Dynoseal ST 1575, a 90 µm sealing film (Dynopack AS, Kristiansand, Norway) consisting of 15 µm of bi-oriented polyamide and 75 µm of laminated polyethylene was used (Appendix C). It had O_2 transmission rate of < 35 cm^3 / m^2 per 24 h. atm at 25°C and 0 % RH under a pressure of 1 atmosphere. The trays were sealed using a Dynopack VGA 462 sealing machine (Ing-Buro Schmid Maschinenbay, Germany). A Steriflow Shaka® autoclave (Roanne, France) was used in a static mode to pasteurize the fish products to a core temperature of 95°C for 15 mins. The temperature was measured with temperature probes (E-Val flex, Ellab, Denmark). The products were cooled immediately in ice water bath for approximately one hour.

After cooling, the trays were sorted for different analyses and were packed accordingly in master bags. All salmon and haddock products trays were packed in 250x350mm PE/PA/PE 90 µm master bags (Norengros, Kjosavik AS, Stavanger, Norway), except for salmon products for sensory analysis. They were packed in a 460x700mm PA/PE 80 µm master bags (Norengros Kjosavik AS, Stavanger, Norway). As the HDPE trays had a weak O_2 barrier, the bags were flushed with 100% N_2 gas to obtain a better O_2 barrier for 43 days storage period. The CVP A-600 MAP packaging machine (CVP systems, Illinois, USA) was used for flushing and sealing the bags. The products were stored at 4°C until further analysis.

3.7 Reference product

Currently, on a commercial basis, there are limited choice of texture modified products for people with dysphagia. In Norway, for example, products from NUTRICIA, NESTLE, Fresenius Kabi and Sooftmeals® are used (Puaschitz & Reigstad, 2010). Sooftmeals® is one of the few manufacturers, producing texture modified food based on natural raw materials like fish and meat. They are sold frozen and are described to have a soft and pureed consistency

(level 1-geleringskost), in accordance with the Kosthåndboken. (Helsedirektoratet, 2012). Considering that the goal of this thesis work was to develop a product of same consistency level 1, Sooftmeals® fish products were chosen as reference product.

Sooftmeals® products based on salmon and Alaskan pollock (EPD: 2070779, Vitalernæring AS, Oslo, Norway) were used as the reference product in texture analysis and sensory evaluation (Figure 3.6). The individually frozen portions weighed 50 g. The fatty fish and the lean fish variants were made of salmon and Alaskan pollock respectively. They are referred to as sooftmeal salmon (SM-S) and sooftmeal pollock (SM-P). The frozen products had a shelf-life of 12 months and were enriched with whipping cream, cream cheese and protein powder. The nutrition labels of the products are provided in Appendix D. The frozen reference sample were thawed overnight at 4°C, before using for respective analyses. They were analyzed only once and not on different storage days. This was because no change was expected in their characteristics during storage period as they were frozen products.

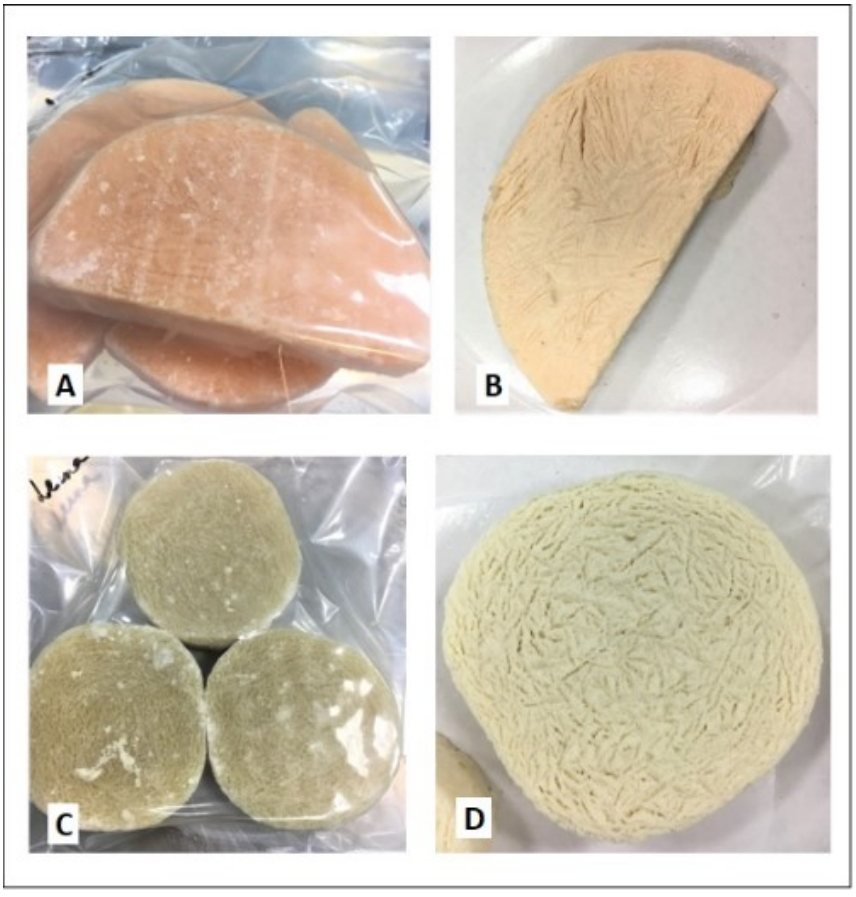


Figure 3.6 Reference product Sooftmeal™-salmon (SM-S): **(A)** frozen and **(B)** thawed at 4°C. Sooftmeal™-Alaskan pollock (SM-P): **(C)** frozen and **(D)** thawed at 4°C.

3.8 Texture analysis

The texture modified foods for dysphagia people with IDDSI consistency level 4 must be soft and without lumps. It should not require any chewing and should be easily disintegrated with the use of tongue. To see if the salmon and haddock products had a soft consistency of level 4, they were analyzed instrumentally to measure their firmness or hardness.

The TA. XT Plus Texture Analyzer (Stable Micro Systems Ltd., Godalming, UK) equipped with 5 kg load cell was used to determine the textural parameter of firmness. The Firmness (N) was measured using the penetration method. A Delrin cylinder probe 0.5 R (Stable Micro Systems, Godalming, UK) was selected. The test method was adapted from the sample project (PATE; PAT1_P10.PRJ) provided by the Exponent 32 software (V6.1.13.0) of texture analyzer. This project measured the firmness of meat pate. After several measurement trials, suitable adjustments were made and a test project for texture modified fish (TMF2018.prj) was created with the specific texture analyzer test (T.A) settings (Figure 3.7). The measurements were performed at 60±2°C on day 1, 8, 15, 22, 29, 36 and 43 after production. The samples were evaluated in triplicate with four different measuring points on each sample (n= 3x4). Six samples of each of the reference product (sooftmeal-salmon and sooftmeal-pollock) were measured with two different measuring points on each sample (n= 6x2). Since sooftmeal® are frozen products, much change in the texture was not expected during storage. Therefore, they were measured only once. The value obtained was compared with the different products measured throughout the storage period.

T.A. settings

Caption	Value	Units
Test Mode	Compression	
Pre-Test Speed	1,50	mm/sec
Test Speed	1,50	mm/sec
Post-Test Speed	10,00	mm/sec
Target Mode	Distance	
Distance	12,500	mm
Trigger Type	Auto (Force)	
Trigger Force	5,0	g
Break Mode	Off	
Stop Plot At	Start Position	
Tare Mode	Auto	
Advanced Options	On	

Figure 3.7 T.A settings used in the texture analysis of texture modified salmon and haddock products. Image from TA.XT plus Texture Analyser. Property of Stable Microsystems.

3.8.1 Sample preparation and measurement

The product packages for analysis were removed from the 4°C chilled room. Residual gas for both master bags and trays were measured on storage days 1, 8, 15, 22, 29, 36 and 43 using a CheckMate 3, O_2/CO_2 gas analyzer (Dansensor, Ringsted, Denmark). The master bag was measured first followed by the HDPE tray in the bag (Figure 3.8a, b).

After the measurements, the trays were warmed in the convection oven, preheated at 100°C with 100% steam. The products were warmed to a core temperature of 60±2°C. The temperature was measured by inserting a temperature probe in the center of the product (Figure 3.8c). After warming, they were transferred into the stainless-steel trays with lock, to prevent the heat loss (Figure 3.8d). The steel trays were then placed into a food warming trolley (Metos, Thermia 950H, Finland), set at a temperature of 60°C. The inside of the chamber was monitored by a digital thermometer probe (Exxent, Sweden).

A 0.5 R penetration probe was screwed to the loading arm with 5 kg load cell. The instrument was initiated, and the test project was loaded. The force was calibrated for 2 kg. The heating block (AccuBlock™, Labnet International, USA), was set at 60°C to keep the samples warm during measurement. To prevent heat loss, its side walls were insulated with rectangular cut-outs of expanded polystyrene (EPS), concealed with an aluminium foil. The probe height was

calibrated by placing the insulated heating block on the platform of the instrument and zeroing the height against the base of the block. The height was calibrated for 60 mm.

During analysis, the test product was carefully transferred upside-down from the tray onto an aluminium foil strip. The foil was carefully lifted and placed into the heating block. Three different samples per product type were analyzed. Four different penetration points were measured on each sample. To avoid the penetration within the 'fracture zone' of another test site, each point was measured with 10±2 mm between them. The distance between the test points and the outer edge of the product was also approximately 10 mm.

A trigger force of 5 g was applied. Once the probe triggered on the surface, it proceeded to penetrate to a depth 12,50 mm within the sample (Figure 3.8e). This penetration distance was half of the total height of the product (25±2 mm). The data was collected at an acquisition rate of 500 points per second. The temperature of the test samples was controlled to 60 ±2°C during the texture analysis. It was recorded for each penetration point using a digital thermometer probe (Figure 3.8f).

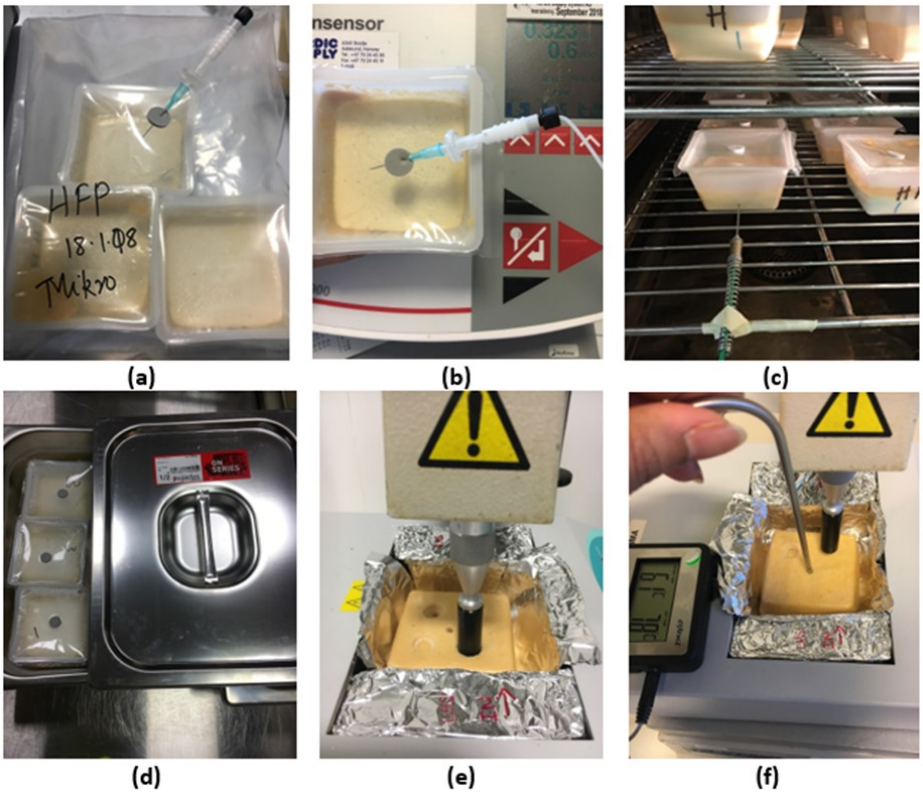


Figure 3.8 An overview of steps involved in texture analysis of salmon and haddock products. (a, b) Gas measurement of master bag and dyno tray prior to warming, (c) warming of samples at 60±2°C, (d) storing the samples in a tray to prevent heat loss, (e) penetration method and (d) temperature control at 60±2°C.

Figure 3.9 shows the typical curve obtained from analyzing the texture modified salmon and haddock products, using a penetration test. F_{max} (N) is the maximum measured force indicating firmness of the products.

The Exponent Software (Version 6.1.13.0.) (Stable Microsystems, Godalming, UK) was used to extract data for the measurement of firmness. The *Macro* was created to collect the data from the graph. The data values were imported to Microsoft ® Excel® 2016 spreadsheet for further statistical analysis by One-way analysis of variance (ANOVA) and General linear model (GLM).

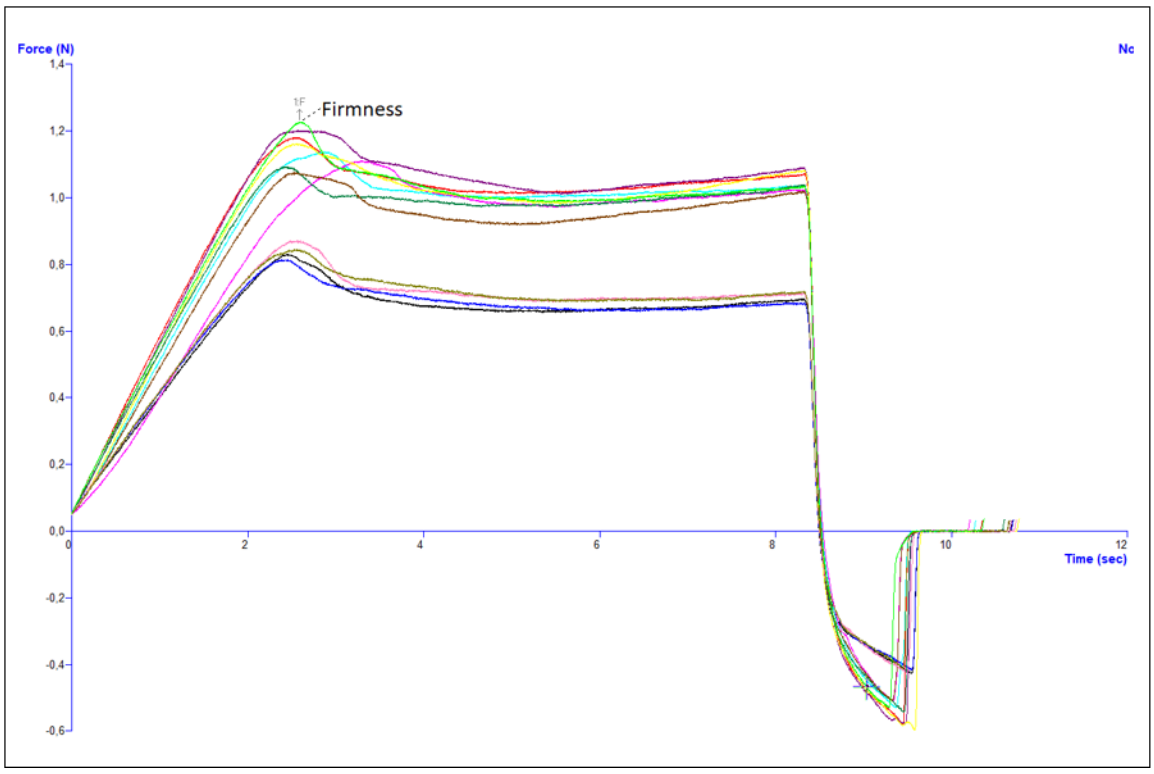


Figure 3.9 Typical test curve from penetration test. The maximum force (F_{max}) is the firmness of texture modified products in Newton (N).

3.9 Fork test

Measuring the textural attributes of modified foods can be a challenge in institutions, commercial kitchens or even at home due to lack of texture instruments. Difficulty in differentiating between consistency levels can also limit the production of products with some consistency levels. To overcome this, the IDDSI has developed simple and convenient tests using basic tools, that helps to categorize texture modified food to a particular consistency level. One such test is fork test that can be used to assess mechanical properties associated with

hardness of food in levels 4-7 (IDDSI, 2016b). Assuming that the consistency of the developed products is of IDDSI consistency level 4, fork pressure test was chosen.

The test was performed on the same samples that were used for texture measurement, except for reference sample (SM-S). New reference sample was used for fork test. The S, SFP, H and HFP samples were tested in triplicate on day 1, 8, 22, 29, 36 and 43. The reference sample was tested only on day 1. The samples were warmed to a core temperature of 60±2°C for measuring the texture instrumentally (Chapter 3.8.1). Once the measurement was completed, the samples were transferred to a porcelain plate in an upside-down manner to expose the smooth surface. A stainless-steel fork with a width of 1.5 cm (entire prong width) was used to apply pressure. The thumb was placed onto the bowl of the fork (just below the prongs) and then pressed onto the samples until blanching was observed (Figure 3.10)

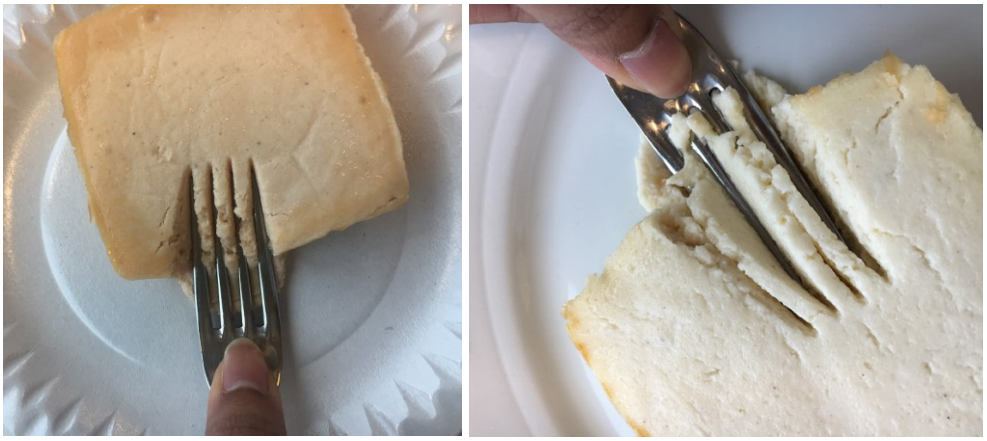


Figure 3.10 **(Left)** An example of fork test performed on texture modified salmon and **(right)** haddock product (right).

3.10 Sensory analysis

The elderly people have diminished sensory abilities that can have a negative impact on their consumption and thereby on their health. Along with the texture modification of food, increasing sensory appeal of food for elderly is also required. For example, simple boost in aroma or flavor of a product may increase their sensory experience (Cichero, 2016). It is thus desirable to have the sensory qualities intact throughout the shelf-life of a product. In this thesis, quantitative descriptive analysis (QDA) was performed to study how the characteristics of the products changed or developed during storage period. In addition, TCATA was performed on salmon products to see how these sensations evolved over stipulated time.

The sensory analysis was performed on stored samples from week 1, 3 and 4. As mentioned in Chapter 3.6, the haddock samples were produced in one day and analyzed on day 8, 22 and 29. The salmon products were produced on three different production days such that the samples were 5, 19 and 26 days old on the analysis day.

3.10.1 Quantitative Descriptive Analysis (QDA)

The salmon (S and SFP) and haddock products (H and HFP) were evaluated performing Quantitative Descriptive Analysis (ISO 13299:2016[E]) at sensory laboratory of Nofima at Ås and Stavanger respectively. Both the laboratories were built according to ISO standard (ISO-8589:2007[E]). The analysis was conducted by nine assessors at Ås and five assessors at Stavanger. The respective panels were trained according to ISO 8586:2012[E].

Training and vocabulary development

A brainstorming by the Ås panel was conducted to develop vocabulary describing the sensory properties of the products (ISO 5492:2008[E]). A tag cloud was generated based on the descriptive words suggested by them. This was followed by an open round table discussion conducted between panel leader and assessor panel. 27 attributes within smell, appearance, taste and texture were shortlisted based on consensus of the panel. Based on the attributes developed for salmon, the haddock attributes were set up, especially within texture. An independent training session was conducted with Stavanger panel with respect to haddock attributes. 17 attributes for haddock products within smell, appearance, taste and texture were shortlisted based on consensus of the panel. The attributes were evaluated with an intensity scale of 1 to 9 (ISO 4121: 2003[E]) where 1= No intensity and 9 = clear intensity. The panel were asked to note down the comments, if any with respect to product evaluation. The list of the attributes is provided in Table 3.5. Refer to Appendix E for more detailed explanation of the attributes. A computerized system EyeQuestion Software version 4.10.4 (Logic8 BV, Wageningen, the Netherlands) was used for code generation and data recording, both at Ås and Stavanger.

Preparation of salmon samples

The salmon products were transported by airplane to Ås under chilled conditions. Prior to the transportation, the modified atmosphere from the master bag was removed to reduce the volume. The bags were re-sealed using 40% vacuum and packed with sufficient cooling elements. The approximate transportation time was around 4.5 h. The samples were stored for

additional 20±2 h at 4°C until further analysis. All salmon samples from storage days 5, 19, and 26 and the reference sample (SM-S) were analyzed on the same day. Two replicates of each variant per storage day were analyzed.

The preparation took place shortly before the evaluation. The sensory attributes were evaluated in warm samples. Two hours prior assessment, porcelain bowls and locks were placed into a warming cabinet at 60±2°C (Figure 3.11 D). A convection oven (Electrolux air-o-steam, 260462, North Italy) was preheated at 100°C (moist heat mode). The salmon samples were warmed at 60±2°C in the sealed HDPE trays. After warming the product was removed in an upside-down manner and cut into 6 equal portions (Figure 3.11 A). Each portion weighing an average of 20±1g was placed into porcelain bowl labeled with three-digit codes and covered with the lock (Figure 3.11 B, C).

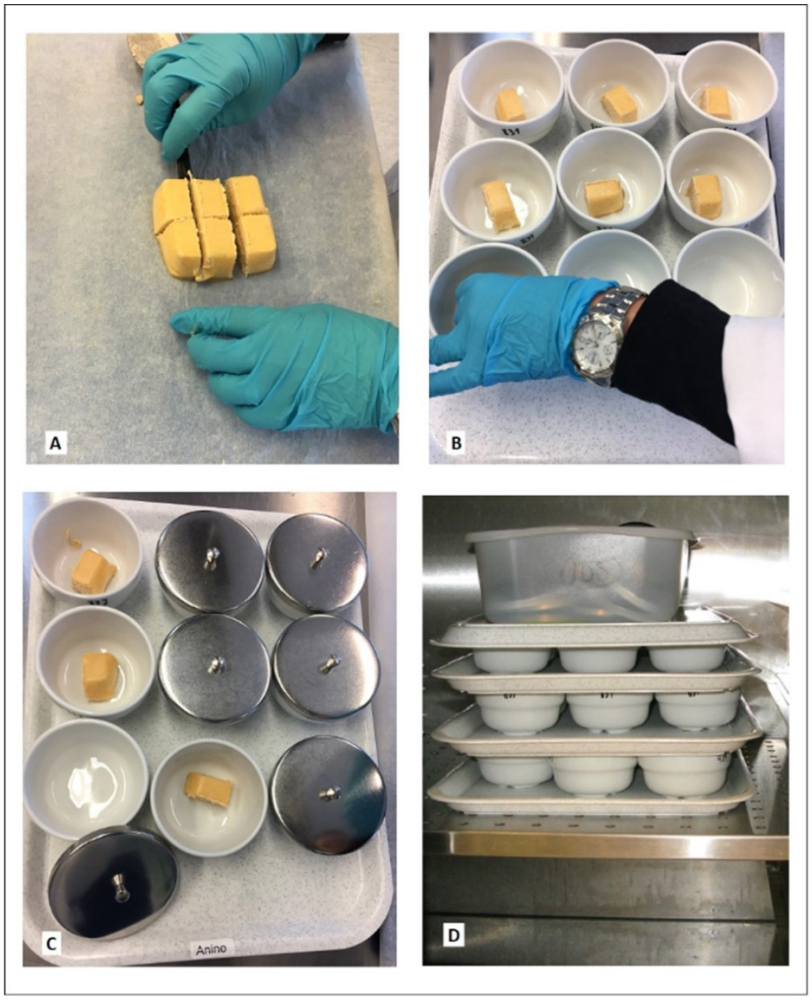


Figure 3.11 Preparation of salmon samples for QDA : **(A)** Dividing the sample after warming at 60±2°C, **(B, C)** serving in porcelain bowls with locks and **(D)** warming the porcelain bowls at 60±2°C prior serving.

Preparation of haddock samples

In Stavanger, the haddock samples were measured for residual oxygen as explained in Chapter 3.8.1. A convection oven (MSCC 201, Metos, Germany) was preheated at 100°C (moist heat mode and air speed 3). The porcelain bowls were pre-warmed at 60±2°C. Prior warming, the test samples were cut using a cookie cutter (diameter 5,5cm). The circular product was then divided into six portions. (Figure 3.12 A). The portions were transferred to a baking tray and covered individually with a plastic bowl. The entire baking tray was then covered with a plastic cling wrap and warmed to a core temperature of 60±2°C (Figure 3.12 B). The portions were placed in preheated porcelain bowl covered with plastic lids (Figure 3.12 C, D) and maintained warm at 60±2°C until serving. The haddock samples were coded with random three-digit binding codes and analyzed in triplicate on day 8, 22 and 29 along with the reference sample (SM-P).

Figure 3.12 Preparation of haddock samples for QDA : **(A)** Dividing the sample and **(B)** warming at 60±2°C. **(C)** Serving of the samples and **(D)** covering the porcelain bowls.

3.10.2 Temporal Check-All-That-Apply (TCATA)

When developing products for older people, it may be logical to have an elderly panel. As cognitive abilities gradually decrease due to ageing, profiling methods like QDA can be difficult to perceive. Also, such methods require repeated tests and a trained sensory panel. Temporal Check-All-That-Apply (TCATA), on the other hand is a rapid, time efficient and does not require intensive training sessions. It is a novel method that tracks and describes the multidimensional sensations in the product as they evolve over time (Castura et al., 2016). It can be interesting to know how older people experience this change in sensations over time.

The sensory properties of salmon products were also analyzed by TCATA by the Ås panel. Ten attributes within taste and texture were selected based on its applicability to each sample at each time slice rather than its dominance (Table 3.5). TCATA was performed on the samples from storage day 5 and day 26. The samples were analyzed in triplicate. The analytical tool, EyeOpenR in EyeQuestion Software version 4.10.4 (Logic8 BV, Wageningen, the Netherlands) was used for statistical analysis of data.

Preparation and evaluation of samples

Based on training and open discussions led by the panel leader, the assessors agreed on 10 attributes that best described the sensory profile of the samples (Table 3.5). The method of preparation of samples and serving method were same as for QDA of salmon products. (Chapter 3.10.1). The ten attributes were visible on the computer screen. The assessors were asked to click the start button immediately after putting the sample into the mouth and commence the evaluation. They were free to check and uncheck one or multiple attributes that were most relevant in that moment. Assessors were also permitted to leave them without checking whenever not applicable. The end of evaluation time was defined as the time when the sample was ready to swallow.

Table 3.5 List of attributes for quantitative descriptive analysis of texture modified salmon and haddock products.

Attributes	Salmon	Haddock
Odour	Sour odour	Milk odour
	Sweet odour	Fish odour
	Metallic odour	Stale (unfresh) odour
	Milk odour	
	Spice odour	
	Fish odour	
	Cloying odour	
Appearance	Uniformity	Uniformity
	Dotted	Discoloration
	Glossy	
Taste	Sourness*	Saltiness
	Sweetness	Bitterness
	Saltiness*	Milky taste
	Bitterness*	Spiciness
	Umami	Fish taste
	Metallic	Stale (unfresh) taste
	Dairy taste*	
	Spiciness*	
	Fish taste*	
	Cloying taste*	
Texture	Softness	Hardness
	Fattiness	Fattiness
	Granularity*	Fibrous
	Cohesiveness	Juiciness
	Adhesiveness*	Cohesiveness
	Astringency	Adhesiveness
	After-taste	

*Attributes used in TCATA method

3.11 Shelf life study

One of the goals of the process was to develop a cold storage product (4°C) with a shelf life of more than 4 weeks. To evaluate this, a 43 days microbiological shelf life study was conducted on salmon and haddock products stored at 4°C. Two variants of each salmon (S and SFP) and haddock (H and HFP) were analyzed.

3.11.1 Preparation of samples

The four fish variants were analyzed in triplicate for a six-week period on day 1, 8, 15, 22, 29, 36 and 43 after production. On the day of analysis, the product packages were removed from 4°C and measured for residual O_2 level as described in chapter 3.8.1. A 25±2 g of sample was

removed aseptically from the center of the product and transferred into a sterile lab blender bag (Separator 400, Grade packaging Ltd, UK). The test sample was diluted to 1:10 proportion with 0,85% peptone salt diluent according to (NMKL 91, 2010). The diluted sample was homogenized for 120 secs in a SMASHER® homogenizer (AES blueline, bioMérieux, France) on normal setting (560 strokes/min). 10 ml homogenate of each sample was collected in three different sterile tubes (PP, 15ml, 17x118 mm, VWR, Norway). Each of these tubes were used for aerobic plate count, spore-forming bacterial count and pH measurement.

The pH of the homogenate (1:10), was also measured with bench top pH meter (FiveEasy Plus™ FEP20, Metler Toledo, USA) using a LE438 electrode (Metler Toledo, USA). One reading per sample was measured.

3.11.2 Method of analysis

Aerobic plate count

The number of viable aerobic microorganisms in fish products was determined using the NMKL 189 (2017) for aerobic microorganisms. The method was modified in terms of plating and instead of pour plate, a spread technique was used. A 100 µl of aliquot from each dilution was plated on Plate Count Agar (ISO 4833 GranuCult™, Merck KGaA, Germany). The inoculum was spread evenly using a sterile L-shaped rod. The plates were incubated upside down at 37°C for 72 hours before enumeration of colonies.

Bacterial spore count

The aerobic and anaerobic bacterial spores were enumerated on Blood agar plates (PB0115A, Oxoid) according to the NMKL Nr. 86 (2013).

The 10^{-1} homogenate was heat treated in a tube (PP, 15ml, 17x118 mm, VWR, Norway) at 80±1°C, for 10±1 min in water bath (Lauda Ecoline E300 star edition). The heat-treated sample was cooled immediately in crushed ice. 100 µl of aliquot was spread evenly on two sets of blood agar plates. All plates were incubated in an upside-down manner. The aerobic count plates were incubated at 37°C for 48 hours and the anaerobic count plates were paced in an anaerobic chamber and incubated at 30°C for 72 h.

3.11.3 Colony counting

After the incubation period, the colony forming unit (cfu) on all media were noted. Colonies from both aerobic and anaerobic blood agar plates were observed for hemolysis as described in

NMKL 67 (2010) for Presumptive Bacillus cereus. For presumptive tests, Baird parker agar plates (PO5014A, Oxoid, UK) were used.

3.12 Statistics analysis

Statistical analysis of the results referring to sensory analysis and texture analysis measurement was performed using Minitab®18 (Minitab, Coventry, UK). One-way analysis of variance (ANOVA) and General linear model (GLM) were performed using Tukey's Pairwise Comparisons at a probability level of $p<0.05$. All results are given as mean ± SD unless stated otherwise.

4 Results and discussion

4.1 Development of process and technique for texture modified food

To understand the technique and the process of developing texture modified foods, three products were produced based on the KOMAT project (Chapter 3.1). Product I consisted of minced salmon and starch as texture modifier (Figure 4.1a). Product II consisted of minced salmon, but also hydrocolloid mix of agar-agar (40%), gellan gum (40%) and lecithin (20%) (Figure 4.1b, d). Product III consisted of ground salmon and a whole egg for binding (Figure 4.1c). Products; I and III were subjected to heat-treatment at 90°C for 15mins. Product II was subjected to two heat treatments at 90°C. First, the raw fish and ingredients were blended and then cooked at 90°C. The cooked mixture exuded liquid (oil and water) during the first heat treatment (Figure 4.1e) and had a grainy texture (Figure 4.1f). After cooking the mixture was blended again and re-cooked at 90°C. A simple analysis of firmness was performed using the back of a plastic spoon. Product I had a compact and elastic texture, resembling fish pudding. Product II was found to be softer than I and III. One reason can be protein denaturation, that may have broken linkage responsible for the elasticity of fish. The low-acyl gellan gum used here is known to give non-elastic, brittle gels. But hydrocolloids such as gellan gum are expensive and can be impractical to use in institution kitchens and hospitals. Product III had a harder texture, large particle size compared to both product I and product II and exuded oil after cooking. The large particle size was a result of grinding the fish through the meat grinder. Apart from fish, whipping cream and whole egg, no other source of protein enrichment was used in the products. The nutrient content of these products was not calculated. The protein-enrichment and the nutrient calculation is an important aspect of the dysphagia diet and was therefore included in the further experiments.

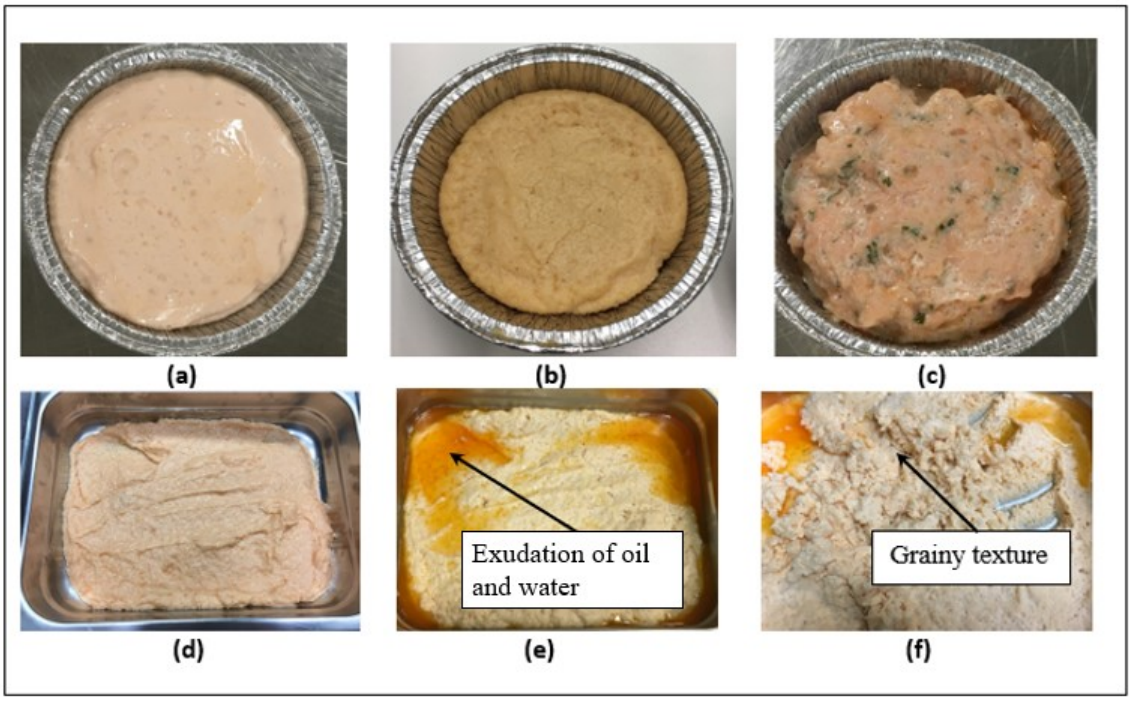


Figure 4.1 **(a)** Product I with minced salmon and starch, **(b)** product II with minced salmon and hydrocolloid mix of gellan gum, agar-agar and lecithin. **(c)** Product III with ground salmon and whole egg. **(d)** Appearance of product II mixture before heat treatment at 90°C. **(e)** Exudation of liquid (oil+ water) and **(f)** grainy texture of product II after the first heat-treatment at 90°C.

The following conclusions were drawn from these trials : 1) a process needs to be developed to break down the elasticity of product to achieve a soft, non-elastic product, 2) use of starch, stabilizers and functional hydrocolloids should be considered to provide a basic matrix of structure and thus prevent exuding of oil and water, 3) cooking temperature for heat treatment should be evaluated as the aim is to develop a product with minimum shelf life of 4 weeks at 4°C, 4) commercial and readily available protein powders such as milk proteins should be added to increase the protein and energy content, and 5) nutrient calculation should be performed to assess the nutrient content of the final product.

These conclusions from the development of process and techniques of texture modified foods were taken into consideration and applied in preliminary experiments.

4.2 Preliminary experiments

In the preliminary experiments, a total of ten recipes with salmon and five recipes with haddock were developed. The haddock recipes were based on the knowledge obtained from processing salmon recipes. The recipes that gave optimum results in terms of texture and protein content were selected for use in the pilot production. Only those ingredients that are discussed in this chapter are presented in Table 4.1. The detailed recipe information is presented in the

(Appendix B). The steps involved in this product optimization process such as raw or precooked fillet (salmon and haddock), texture modification, product fortification, nutrient calculation, heat treatment and texture analysis) are presented in Figure 3.3.

1. *Raw and precooked fillet (salmon and haddock)*: In the KOMAT trial (Chapter 4.1), the product I (minced salmon and starch) and III (ground salmon+ whole egg) were heat-treated only once at 90°C. The product II consisted of minced salmon, hydrocolloid mix of agar-agar (40%), gellan gum (40%) and lecithin (20%) and was heat-treated twice at 90°C. It was found that cooking the mixture of fish and ingredients before exposing to the second heat-treatment lead to a softer product.

This knowledge was used to develop salmon recipes in the preliminary process. The experiments were conducted on salmon fillet and the gained knowledge was then applied in developing the haddock products. The recipes 3a and 3b had the exact same ingredient composition with only difference in the raw material (Appendix B). In recipe 3a, raw fish was used. It was blended with the ingredients and then cooked at 90°C. But in recipe 3b, the fish fillet was first pre-cooked and then blended with the rest of the ingredients. The final mixture was cooked at 90°C. A rough sensory evaluation round revealed that the product with precooked fish was homogenous and smooth in appearance and without exudation of liquid (oil+ water) (Figure 4.3a). It had a soft paté like consistency (Figure 4.3b). On the other hand, the product with raw fish had a porous appearance (Figure 4.2a) and those heat processed at 70°C and 80°C exuded oil when reheated at 60±2°C (Figure 4.2b). It had a crumbly and grainy texture and required some effort in mastication by tongue (Figure 4.2c). In context to this thesis, food that does not require chewing and can be masticated easily by tongue was preferable. The exudation of liquid (oil+ water) may also lead to the loss of some nutrients such as fat soluble and water-soluble vitamins.

A possible assumption for why precooked fish had a soft consistency and exuded no oil as compared to its counterpart raw fish can be that when the fish is cooked, it denatures its native protein structure. This unfolded state exposes the hydrophobic core of denatured protein. It also reduces the elasticity responsible for a firm product. When the precooked fish is blended with the texture modifiers (modified starch and locust bean gum) and heat-treated again, an interaction occurs between the denatured fish protein and the texture modifiers. The texture modifiers interact with denatured fish protein and induces crosslinking. This gives a better gel that holds moisture and prevents oil separation (Chapter 2.10). The work done by Karmas and

Turk (1976) on water binding abilities of cooked fish with various proteins supports this assumption. In their work, they found that the denatured protein matrix led to more water retention due to synergistic interaction between the cooked fish protein and binder proteins such as sodium caseinate. Since the precooked fish variants gave a better product than the raw fish variants in terms of texture and cohesiveness, it was chosen for further experiments. Another advantage of choosing this method is increased food safety due to double pasteurization steps, one in cooking the fish and then the final cooking of the minced product.

2. *Texture modification with protein enrichment*: To provide a basic matrix of structure, modified corn starch and locust bean gum (LBG) were used (Table 4.1). All recipes of salmon and haddock had the same quantity of cornstarch and locust bean gum in grams (Appendix B). The LBG was chosen as a less-expensive alternative to gellan and agar-agar. It has been described by Van Nieuwenhuyzen et al. (2006) that the addition of starch and locust bean gum shows a synergistic effect by enhancing the structure, retaining moisture and holding the shape of the product even after reheating. It is the property of starch that enables the thermal stability during reheating at serving temperatures (Kasapis, 2009; Ramírez et al., 2011). The gums and starches is also known to promote the formation of a continuous matrix by interacting with water and protein in fish and providing mechanical structure (Ramírez et al., 2011). The ratio of gums and starch is very important to establish a cohesive, non-elastic product without syneresis. The stabilizing property of LBG is found to prevent the syneresis and oil-water separation in the product. (Van Nieuwenhuyzen et al., 2006).

Egg white powder was used in some of the initial salmon recipes (recipe 1, 2, 3a, 3b, 4, 5a) and haddock recipes 1 and 2 (Table 4.1). It was added mainly for its protein content and to make the product less compact. It also gave a souffle effect to the products. This means that the product was fluffy and less dense. The elderly people generally eat meals in smaller portions (Chapter 2.3). These portions should therefore be nutrient dense in order fulfill the necessary nutrient requirement. But if the products are light and airy in addition to small portion size, it will not give a satiated feeling. There was neither any remarkable change with respect to density and compactness of the products when egg white powder was not used. So, it was decided not to use egg white powder in further recipes of salmon (5a, 6, 7a and 7b) and haddock recipes (3, 4a, 4b) (Table 4.1).

The recipes were enriched with either sodium caseinate, whey protein concentrate 80 (WPC80), fish protein hydrolysate (FPH) or a combination of these. The amount and type of protein powder influenced the texture (firmness) as seen in the texture measurements of preliminary products Figure 4.4 and Figure 4.5. When only caseinate was used (recipe 3b), the consistency of the mixture before cooking was very compact and difficult to mix with spatula. It also made the product very adhesive and stuck to the palate. The adhesiveness can be due to high water-binding capacity of sodium caseinate. According to Karmas and Turk (1976), sodium caseinate has high water-binding capacity than WPC80 due to its high protein content. To reduce the adhesiveness of the product without compromising the final protein content, WPC80 was used in addition to caseinate. In recipe 4, both WPC80 and sodium caseinate were used. This made the product less adhesive and gave a rounded taste to the product 4. There was also reduced fish taste in the product with only WPC80. This was probably because a milky taste imparted by WPC80 masked the fish taste. Higher proportion of WPC80 made it dry and crumbly. Recipe 5a (2.4% caseinate, 4.8% WPC80, 175ml whipping cream) and recipe 5b (2.2% caseinate, 4.4% WPC80, 250ml whipping cream) contained equal proportion of sodium caseinate and WPC80 but different amount of whipping cream Table 4.1. The amount of liquid also changed the parameters of firmness as more liquid led to a softer product.

In recent years, there has been focus on the bio-economical aspect of utilizing fish rest raw material for protein production directed towards human consumption. These include fish protein powder, fish protein isolate, fish protein hydrolysate etc. The fish protein hydrolysate, for example have high nutritional value and exhibit various functional properties such as water-holding capacity, emulsification, antioxidant properties etc. (Kristinsson & Rasco, 2000; Nordic Innovation Centre, 2009). Owing to these properties, the fish protein hydrolysate was added to salmon recipes (6 and 7a) and haddock recipes (3 and 4a) to study their influence on physical and sensory properties of products. Also, as the product was based on fish, it was natural to use fish protein hydrolysate powder for enrichment purpose. The other purpose was to test the quantity one could use without giving the end product an unacceptable taste such as bitterness. The addition of fish protein hydrolysate (FPH) made the products softer compared to those without FPH (Chapter 4.2, point 5). The best results with an optimum proportion of the texture-modifiers and protein powders were chosen for further work.

Table 4.1 Variations in ingredients, nutrition and texture measurement of the preliminary salmon and haddock recipes.

SALMON	Starch%	[1]LBG%	[2]EWP(%)	[3]SC%	[4]WPC80%	[5]FPH%	Protein%	Fat%	Firmness(N)
Recipe 1*	0.5	0.3	0.4	–	–	–	10.5	24.4	–
Recipe 2*	0.5	0.3	0.4	–	10.5	–	19.5	27.3	–
Recipe 3a*	0.5	0.3	0.4	7.9	–	–	18.4	27.6	–
Recipe 3b	0.5	0.3	0.4	7.9	–	–	18.2	27.7	–
Recipe 4	0.5	0.3	0.4	4.0	4.0	–	18.4	27.6	1.49
Recipe 5a	0.6	0.4	0.5	2.4	4.8	–	18.6	27.2	2.40
Recipe 5b	0.5	0.3	–	2.2	4.4	–	17.0	28.2	1.39
Recipe 6	0.6	0.3	–	1.7	4.0	1.7	18.4	27.4	1.13
Recipe 7a	0.6	0.3	–	2.3	4.6	–	17.8	27.6	1.03
Recipe 7b	0.6	0.3	–	1.7	3.5	1.7	18.1	27.5	0.60

HADDOCK	Starch%	[1]LBG%	[2]EWP%	[3]SC%	[4]WPC80%	[5]FPH%	Protein%	Fat%	Firmness(N)
Recipe 1	0.6	0.4	0.5	2.4	4.8	–	16.5	17.8	2.72
Recipe 2	0.6	0.3	0.5	2.3	4.6	–	16.1	18.3	1.44
Recipe 3	0.6	0.3	–	2.3	4.6	1.7	17.2	18.1	1.23
Recipe 4a	0.6	0.3	–	2.3	4.6	–	15.9	18.4	1.50
Recipe 4b	0.6	0.3	–	1.7	3.5	1.7	16.1	18.4	0.82

[1] locust bean gum, [2] egg white protein, [3] sodium caseinate, [4] whey protein concentrate 80, [5] fish protein hydrolysate.
* All recipes contain precooked fish except for recipe 1, 2 and 3a for salmon which contained raw fish.

3. *Nutrient calculation*: The nutrient calculation gave the total protein and energy content of the product. It helped to understand how the dilution with liquid affected the nutrient level. Accordingly, the quantity of protein powders was adjusted to increase the protein level without compromising the consistency. The calculation was used to compare the protein content of raw fish (Table 3.1) and the end product, and whether a protein level equivalent to the raw fish could be achieved or not. The recipes for the pilot production were mainly decided on the basis of these nutrient calculations as well as texture measurements.

4. Heat-treatment process : Since these products are intended for people with dysphagia, who are more vulnerable to food-borne diseases and illnesses (Kendall, Val Hillers, & Medeiros, 2006), food safety and heat processing of the products are important parameters. Besides, the starch and gums require specific temperatures to activate and gelatinize (Saha & Bhattacharya, 2010). To study the effect of different temperatures on proteins-texture modifiers interactions and texture of the products, three temperatures of 70°C, 80°C and 90°C were chosen for heat-processing of products using recipe 3a (raw fish) and recipe 3b (pre-cooked fish). No difference was observed in the appearance between the products from recipe 3a (raw fish), processed at three different temperatures (Figure 4.2a). No liquid (oil + water) was exuded from the products either. But when these products from recipe 3a were reheated to

60°C, a clear difference was observed. Except for the products processed at 90°C, the product from 70°C and 80°C had exuded liquid (oil + water) (Figure 4.2b). There was no difference in the appearance of the product from recipe 3b (precooked fish), processed at three different temperatures (Figure 4.3a). No change was observed in products 3b processed at 70°C, 80°C and 90°C, even after reheating at 60°C. The product 3b with precooked fish had a smooth texture in contrast to the product 3a with raw fish that had a grainy texture (Figure 4.2c,4.3b).

Multiple cooking steps or overcooking can pose a problem in keeping the structure and shape of the product intact. When it comes to dysphagia diet, a product that can hold its shape during processes such as pasteurization, thawing of frozen products, reheating at eating temperature is highly desirable. In the above preliminary experiments, precooked products 3b processed at all three temperatures held the shape together without exuding any oil on reheating at 60°C. But, in the product 3a (raw fish) only the highest processing temperature 90°C did not exude any oil. This indicated a need of using a temperature above 90°C for pasteurization of the pilot products with precooked fish.

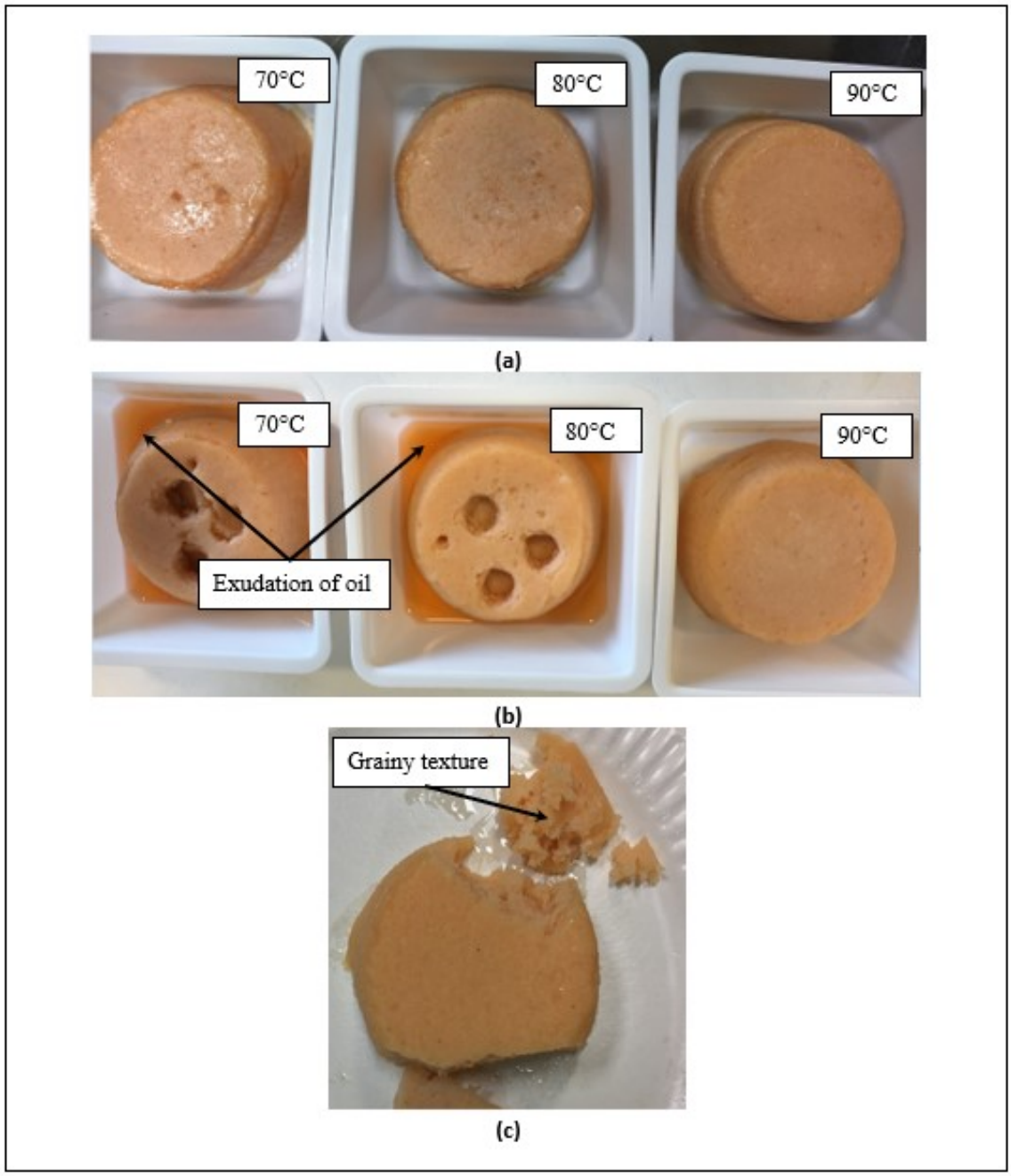


Figure 4.2 Preliminary products from raw salmon (recipe 3a) heat processed at 70°C, 80°C and 90°C. **(a)** Products before reheating at 60±2°C. **(b)** exudation of liquid (oil+ water) from products processed at 70°C and 80°C after reheating at 60±2°C, and **(c)** grainy texture of product 3a.

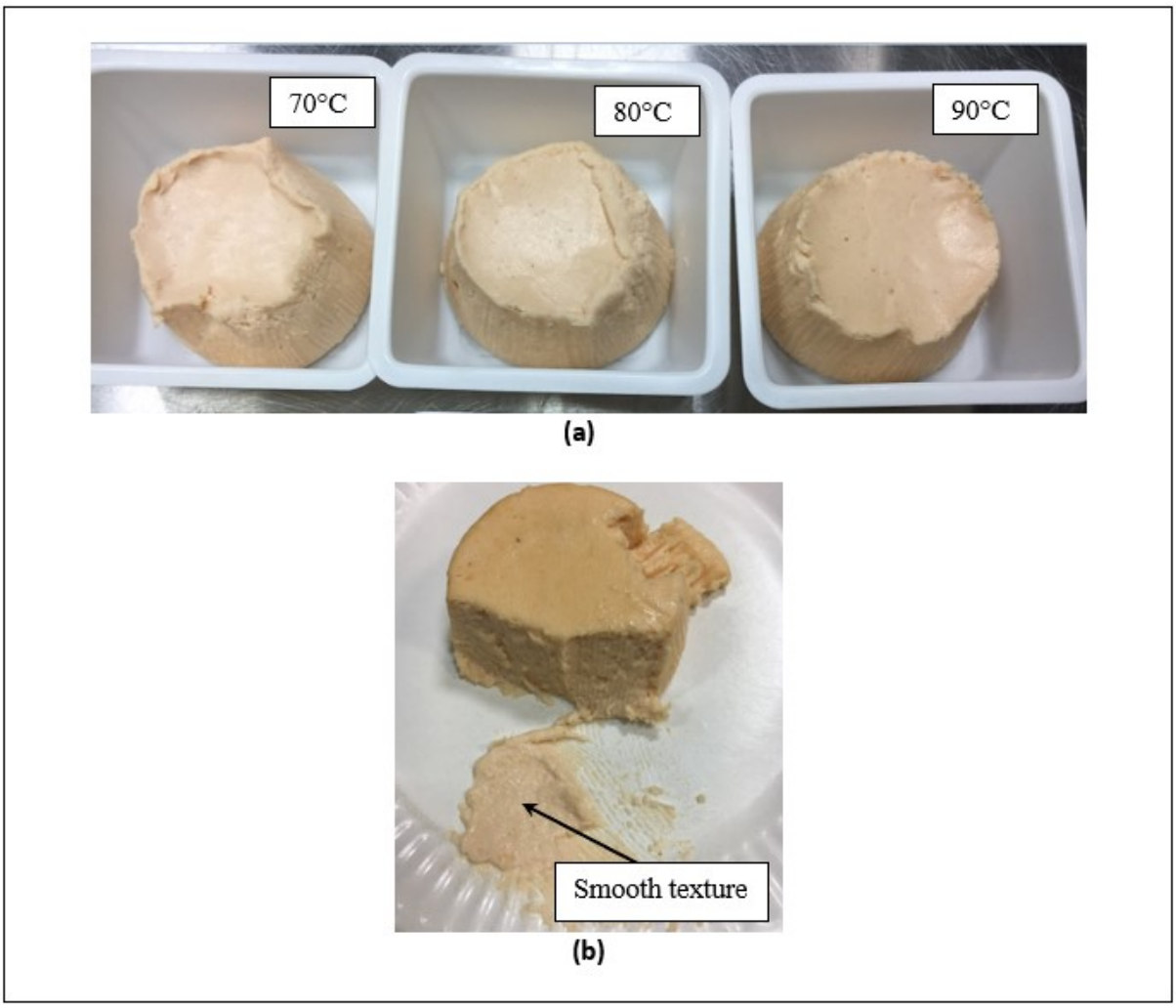


Figure 4.3 **(a)** Preliminary products from precooked salmon (recipe 3b) heat processed at 70°C, 80°C and 90°C. **(b)** smooth texture of product 3b.

5. *Texture measurement*: The food texture choices changes for healthy elderly people due to ageing and also for people with dysphagia. Foods that are sticky, hard, fibrous or dry may be problematic for people with dysphagia. Ideally, a moist, cohesive and slippery bolus is considered as "swallow-safe" (Cichero, 2016). It was important to study how these compositions influence the texture of the products and recipes that give the appropriate texture along with the nutrient dense product. This was done by analyzing the texture instrumentally using penetration method. The preliminary products from some selective recipes of salmon and haddock (Table 4.1) were analyzed for firmness (N) at a temperature of 60±2°C.

The firmness of salmon product 5b with 2.2% sodium caseinate, 4.4% whey protein concentrate 80 (WPC80), 27.5% whipping cream was measured as 1.39 N. The product 5a with 2.4% sodium caseinate, 4.8% whey protein concentrate 80 (WPC80), 20.9% whipping cream had a

firmness of 2.40 N. The measurements show that the product 5b was softer than product 5a. The only difference in these two recipes was the amount of liquid (whipping cream). The liquid makes the product soft but also dilutes the nutrient content. The product 7b with 1.7% caseinate, 3.5% WPC80, 1.7% FPH gave a softer product than product 7a with only 2.3% caseinate, 4.6% WPC80. The firmness of 7a and 7b was 1.03 N and 0.60 N respectively. Between the salmon products 4, 5a, 5b and 7a containing only sodium caseinate and WPC80 protein powders, recipe 7a gave the least firm product with 1.03 N. The firmness (N) of product 7a and 7b was lower than the firmness of the reference product of sooftmeal-salmon.

The firmness of haddock product 1 with 2.4% sodium caseinate, 4.8% WPC80, 20.9% whipping cream was measured to be 2.72 N. The product 2 with 2.3% sodium caseinate, 4.6% WPC80, 23.1% whipping cream was measured to be 1.44 N. The softness of product 2 is likely because of more amount of whipping cream. The recipe 3 had the same amount of sodium caseinate, WPC80 and whipping cream as recipe 2. In addition, it had 1.7% of fish protein hydrolysate. The firmness of product 3 was measured to be 1.23 N. The firmness of haddock products with recipe 4a (2.3% caseinate, 4.6% WPC80) and recipe 4b (1.7% caseinate, 3.5% WPC80, 1.7% FPH) was measured to be 1.50 N and 0.82 N respectively. From all the haddock recipes, the product 4b containing WPC 80 and equal amount of sodium caseinate and fish protein hydrolysate gave the least firm product with 0.82 N.

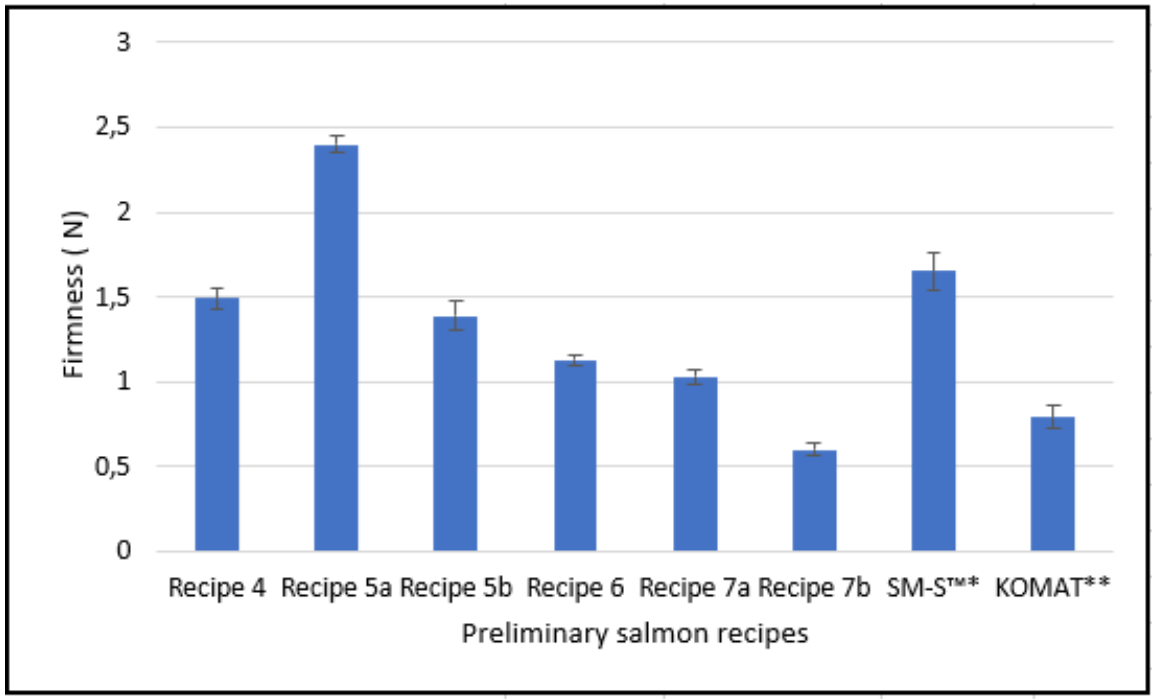


Figure 4.4 Texture measurements of preliminary salmon products by penetration method. Firmness(N) of salmon products made from recipe 4, 5a,5b, 6, 7a and 7b compared with *sooftmeal-salmon(SM-S) and KOMAT** modified salmon product**.** The values for SM-S and KOMAT product were obtained from the KOMAT project.

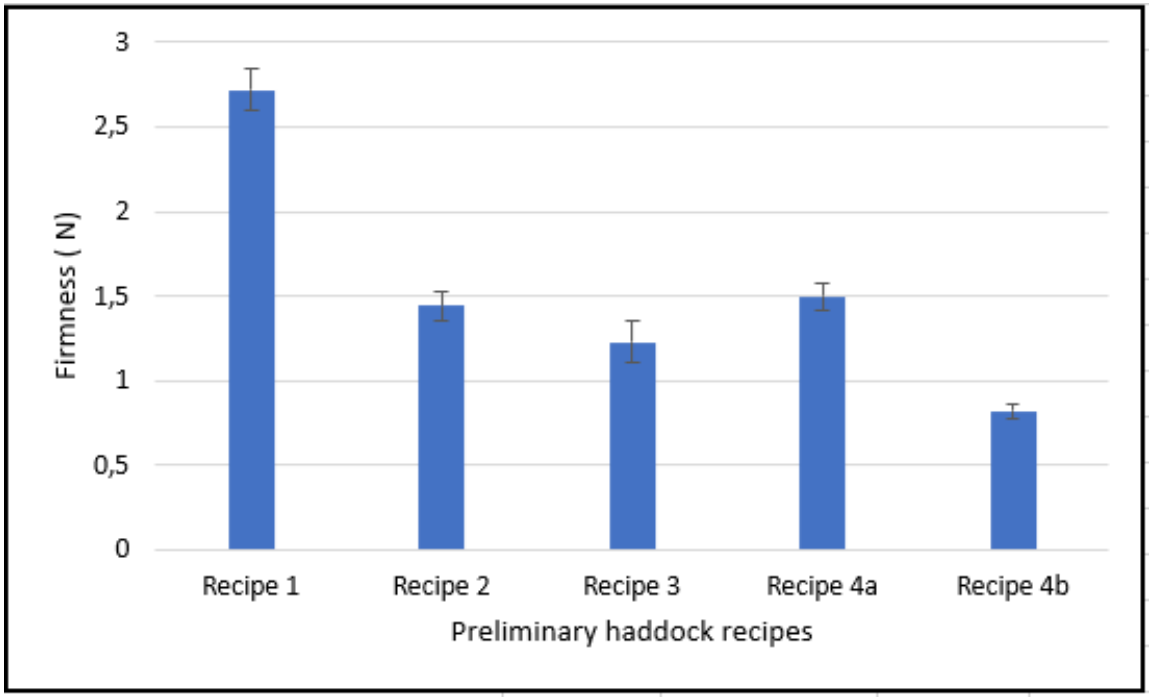


Figure 4.5 Texture measurements of preliminary haddock products by penetration method. Firmness(N) of haddock products made from recipe 1, recipe 2, recipe 3, recipe 4a and recipe 4b.

On the basis of all the results from preliminary experiments with respect to type of raw material, protein powders, texture modifier, nutrient calculation, process temperature and texture, the following variables were used in the pilot production:

(1) Precooked salmon was used because it gave a homogenous product without exuding oil even at higher temperature. (2) The preliminary recipes 7a and 7b were used to design the two recipes A and B for pilot production as they gave best results in terms of texture and protein content. The two recipes A and B used in the pilot production of salmon and haddock products were based on preliminary recipes 7a and 7b respectively. (3) Sodium caseinate, WPC80 and FPH were used as protein enrichment source as their interaction gave a soft textured product (4) Pasteurization temperature of 95°C (core temperature) for 15 mins was used. This high temperature provided increased food safety without disrupting the structure of the product. (5) As it was necessary to know if the products withheld their texture after reheating at the serving temperature, the texture measurement and sensory analysis was performed at 60±2°C. (6) The penetration method was found to be suitable method for texture measurement.

4.3 Pilot Production

The pilot production was a result of application of the knowledge obtained from the KOMAT project in Chapter 4.1 and the preliminary production in Chapter 4.2. A total four products, two each of salmon and haddock were produced. These products were evaluated for texture (Chapter 4.3.1), sensory characteristics (Chapter 4.3.3) and microbiological (Chapter 4.3.6) parameters perceived weekly for 43 days. Fork test (Chapter 4.3.2) in compliance with IDDSI standards was also performed on the products and compared with the instrumental measurements.

4.3.1 Texture measurements

The textural attribute; firmness was measured in all four products at a temperature of 60±2°C. This temperature was chosen because it corresponds to the serving temperature used at institutions (hospitals / nursing homes) and is therefore used as the eating temperature for the consumers. Also, it can determine whether the product holds its shape and maintains the desired consistency level and shape under consumption. Each sample was analyzed in triplicate, where four different points per sample were measured (n=3x4). The reference products of sooftmeal-salmon (SM-S) and sooftmeal-haddock (SM-P) were measured only one time on day 1 as much change was not expected in them due to storage because they were frozen products.

The texture data was analyzed individually for salmon and haddock products, performing GLM (Table 4.2). The GLM showed significant difference ($p<0.001$) between the products (including reference product) and as an effect of the storage period.

Table 4.2 Firmness of (a) salmon and (b) haddock variants in 43 days of storage. Mean texture scores (n=12) obtained by applying ANOVA (GLM) and expressed as mean± S.D.

(a) **Firmness of salmon products (N)**

Storage period (days) at 4°C

Salmon[1)]	D1	D8	D15	D22	D29	D36	D43
S	1.25±0.08	1.34±0.06	1.11±0.08	1.00±0.05	1.03±0.13	0.91±0.04	1.00±0.04
SFP	1.12±0.08	1.05±0.16	0.79±0.15b	0.81±0.14	0.66±0.04	0.72±0.14	0.86±0.13
SM-S[2)]				1.67±0.20			
p-value				***p<0.001[3)]***			

(b) **Firmness of haddock products (N)**

Storage period (days) at 4°C

Haddock[1)]	D1	D8	D15	D22	D29	D36	D43
H	0.82±0.08	0.74±0.07	0.65±0.07	0.75±0.07	0.85±0.10	0.58±0.07	0.66±0.10
HFP	0.39±0.05	0.40±0.08	0.47±0.09	0.35±0.02	0.42±0.08	0.45±0.04	0.37±0.03
SM-P[2)]				1.84±0.19			
p-value				***p<0.001[3)]***			

1) S= salmon without fish protein hydrolysate. SFP= salmon with fish protein hydrolysate & SM-S- reference product sooftmeal salmon. H= haddock without fish protein hydrolysate, HFP= haddock with fish protein hydrolysate & SM-P- reference product sooftmeal pollock.
2) Only one value of SM-S and SM-P are used respectively for comparison as they were measured only once.
3) The significant difference of $p<0.001$ is applicable to both products and storage period.

Both salmon without fish protein hydrolysate (S) and with fish protein hydrolysate (SFP) had a softer texture compared to the reference product (SM-S) (Table 4.2 and Figure 4.6a). The whey protein concentrate 80 has good gelling properties (Morr & Ha, 1993) and caseinates are known for their water binding abilities (Southward, 2003). Caseinates have also shown to increase the water binding capacity of cooked fish (Karmas & Turk, 1976). The use of these ingredients could have helped in retaining the moisture in the product and making them soft. The salmon products with the fish protein hydrolysate (SFP) were softer than products without hydrolysate (S) throughout the entire storage (Table 4.2). In practice, the ratio of WPC80 and caseinate was less in SFP recipe compared to S. So, SFP was expected to be firmer than S because these milk proteins contribute for water-binding abilities. However, this was compensated by the addition of fish protein hydrolysate that was added for its functional properties and for protein enrichment. Fish protein hydrolysate are known to have good water

holding properties (Kristinsson & Rasco, 2000) and can show a positive effect in retaining the moisture and making the product softer as seen in S and SFP. Lastly, the amount of liquid was kept constant in both S and SFP recipes. The higher ratio of liquid to the decreased quantity of milk protein powders may have contributed in making SFP, a moist and softer product. It was observed that its firmness decreased throughout the rest of the storage period (day 15 to day 43). The plot also showed decrease in the firmness of SFP, from day 1 to day 43, with fluctuation in the firmness values from day 22.

The haddock variant with fish protein hydrolysate (HFP) was softer than the variant without fish protein hydrolysate (H). The difference in the firmness of H and HFP could be argued for the same reasons as mentioned above for the salmon products such as the gelling and water binding properties of the caseinate and whey protein concentrate 80. Both variants were also significantly softer than the reference product (SM-P). When compared to the salmon products (S and SFP), the haddock variants (H and HFP) were measured to be less firm (Table 4.2a, b). Except for the fish raw material, the composition of haddock variant H and HFP was the same as that of S and SFP variant. The fat content of salmon is high as compared to the haddock. The fat makes the product firmer. In addition, haddock also has better water binding capacity than salmon. This ability in conjunction with the functional properties of WPC80 and sodium caseinate can be the reason why it gave a softer product than salmon.

The Figure 4.6a also shows a negative correlation for each S and SFP variant with the regression coefficients of 0.725 and 0.516 respectively. Although it shows a trend of decreasing firmness over storage, there were variations in the firmness values from day 1 to day 43. As seen in Figure 4.6b, fluctuations in the firmness during storage was also seen in the H and HFP samples. The H showed regression coefficient of 0.228, thereby showing a weak negative correlation. The HFP showed no correlation with a regression coefficient value of 0.000. These fluctuations were probably because of variations in the temperatures during measurement. Each of the four points per sample were measured for temperature. When using the heating block to keep the reheated product warm at 60°C, it was difficult to control the temperature at exact 60°C. During measuring of the samples, the temperature varied by ±2 °C. Also, in the time span required to measure the four points, a soft crust was formed in some samples. This crust could have exerted counter force on probe while penetrating leading to a high firmness value.

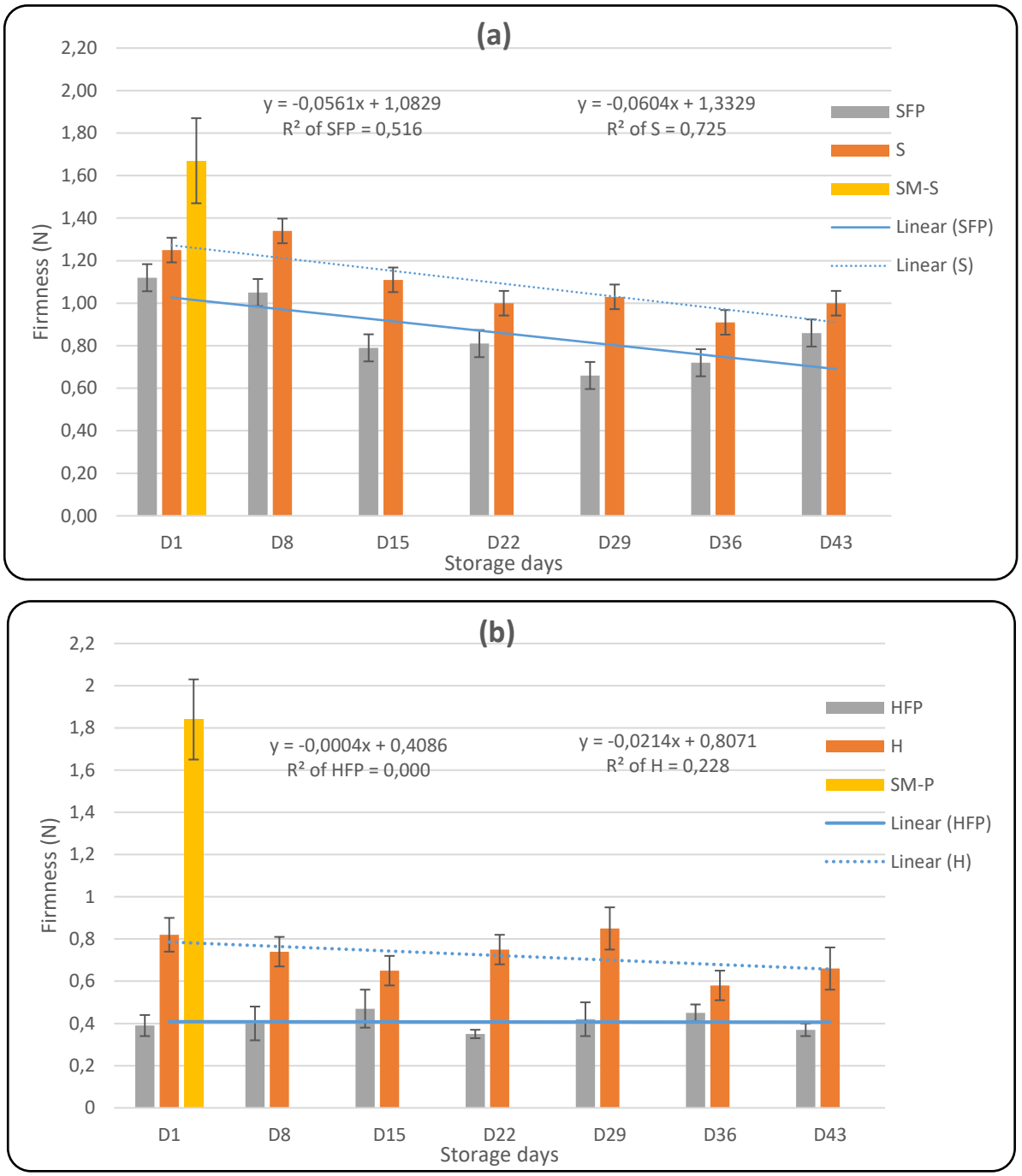


Figure 4.6 Firmness (N) of (a) salmon products and (b) haddock products in 43 days storage period. The standard deviations are represented by error bars. The linear trendline is shown by solid line (SFP and HFP) and dotted line (S and SFP). Their R^2 value are displayed on the graph. The SM-S and SM-P value is displayed only on day 1 as they were measured only one time. This was done because they were frozen products and so no change was expected during their storage.

4.3.2 IDDSI standardization (Fork test)

The IDDSI committee have developed some practical tests to measure the consistency of the texture modified product. These tests are performed using basic tool such as syringe, spoon, chopsticks, fork and even fingers. The purpose of such tests is to provide a platform for institutions kitchens, hospitals, catering personnel etc. who may not have access to the texture measuring instruments. The fork test is applied to categorize the food in IDDSI levels 5-7 by applying the pressure on the sample (Chapter 2.6.1)

The fork test conducted on salmon without fish protein hydrolysate (S) and salmon with fish protein hydrolysate (SFP) during 43 days of storage did not show any pronounced difference. This also applied to haddock without fish protein hydrolysate (H) and haddock with fish protein hydrolysate (HFP). Therefore, only measurement from day 1 and day 43 for salmon and haddock products are displayed in Figure 4.7 and Figure 4.8 respectively. The observation showed that it needed higher pressure to make thumb nail white in samples S than the samples SFP. Also, in both cases (S and SFP), blanching of thumbnail was more visible on samples from day 1 compared to day 43. The sooftmeal-salmon (SM-S) showed more prominent blanching as compared to both S and SFP samples. This showed that S and SFP were softer than SM-S. The observations from fork test complies with results from instrumental measurement of texture (Table 4.2), where S and SFP were slightly firmer on day 1 than on day 43. The firmness value of SM-S was higher than both S and SFP samples, which is also indicated by the fork test.

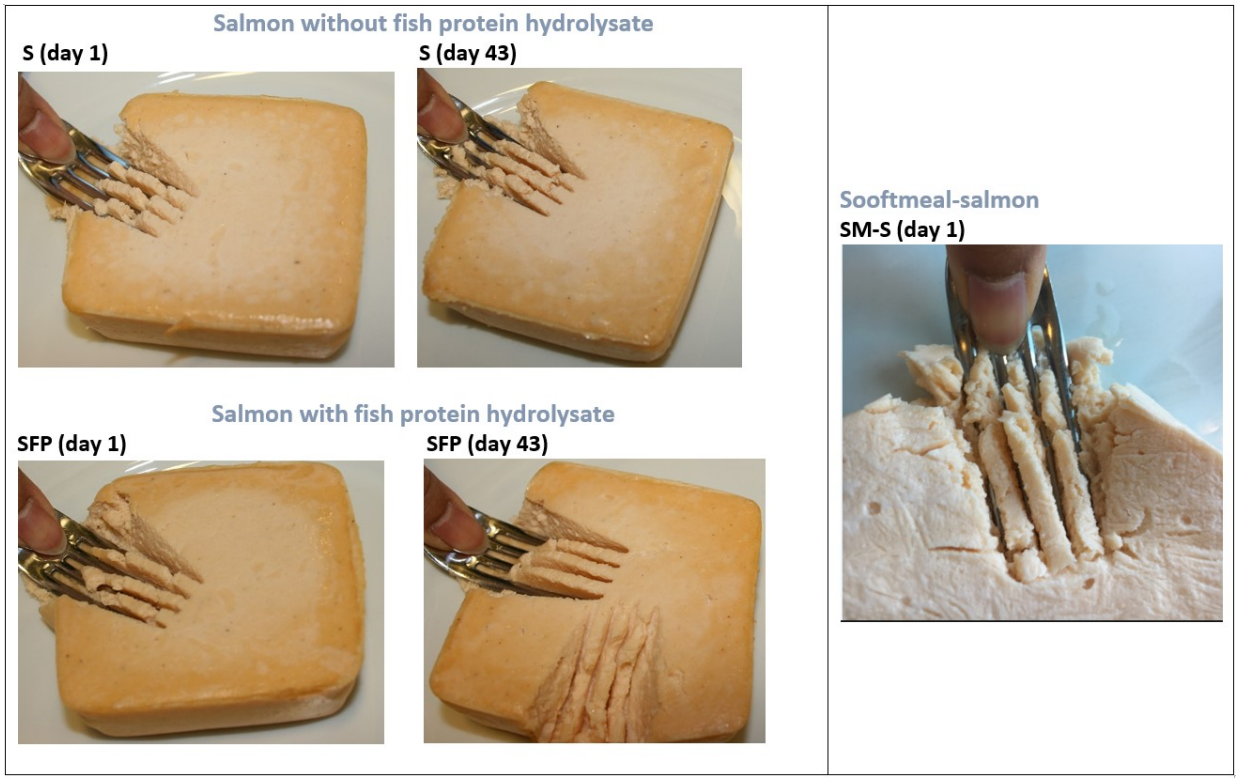


Figure 4.7 IDDSI Fork test performed on salmon without protein hydrolysate(S) and with hydrolysate(SFP) on day 1 and day 43. Fork test on reference sample sooftmeal-salmon (SM-S) on day 1.

The fork test on haddock (H) showed more blanching on day 1 in comparison to day 43. This suggests that the samples on day 43 were slightly softer than on day 1. The texture analysis result confirms this observation (Table 4.2). When compared with the blanching norms as per the IDDSI standard (Figure 2.6), the blanching of nail on HFP (day 1 and day 43) was not prominent and did not show any difference. The instrumental texture values for the same also showed non-significant difference.

More blanching of nail was seen on sample H as compared to HFP. This indicates that more pressure was required to press the fork through H samples. The Figure 4.6 of texture analysis also corresponds that sample HFP were softer than H samples. The whitening of the nail appears to be similar in sample H (day 1) and sample SM-P (day 1). This contradicts the values obtained from texture analysis, where H (0.82 N) is found to be softer than SM-S (1.84 N). This difference of approximately 1 Newton was difficult to observe visually by the fork test as it is not as sensitive as the instrument measurement. Another reason for this must be the difference in temperature while performing fork test. As mentioned in Chapter 3.9, the fork test was performed on the samples used for the texture analysis. The samples were controlled at 60±2°C during texture analysis but not during fork test. Their temperature was measured only once before commencing the fork test. The average range of the temperature for all salmon and

haddock products was 55±2°C which was lower than the temperature used for measuring texture. This was because one sample was measured at a time, which caused delay and decreased the temperature of the product. Decrease in the temperature made the sample firmer.

The literature search showed that, no literature has validated fork-test method with instrumental texture analysis yet. Hence, it is difficult to correlate the instrumental values with the degree of nail blanching with certainty. The IDDSI test was not developed to give an exact value but to provide a general information about the texture of the product such as hardness or softness (Cichero et al., 2016). The thumb nail blanching is quantified approximately to 17 kPa which corresponds to the tongue pressure used during swallowing (Cichero et al., 2016; IDDSI, 2016b). This test therefore explains how much pressure needs to be applied to the sample to masticate it without chewing. No blanching indicates a pressure less than 17 kPa. Ideally, the dysphagia diet should be masticated by the application of very little pressure as the people suffering from dysphagia can have inadequate oral skills.

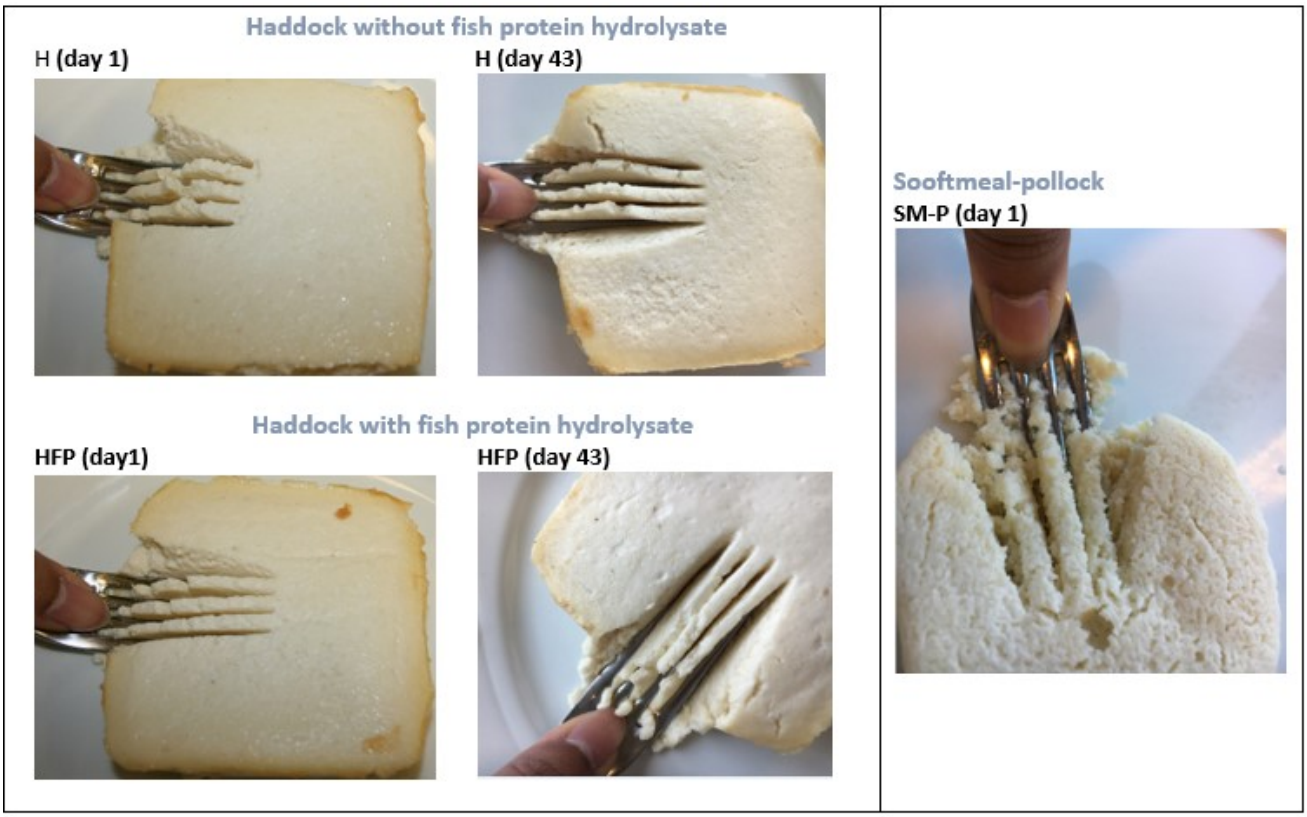


Figure 4.8 IDDSI Fork test performed on haddock without protein hydrolysate(H) and with hydrolysate(HFP) on day 1 and day 43. Fork test on reference sample sooftmeal-pollock (SM-P) on day 1.

4.3.3 Sensory analysis

The sensory analysis was performed to study the change or development in the characteristics of the products over storage period. The evaluation of both salmon (QDA and TCATA) and haddock (QDA) were carried out on stored samples from week 1, 3 and 4. The salmon products were produced at different dates and stored at chill temperature (4°C). They were analyzed on the same day (Chapter 3.10). Total 27 attributes of salmon products (S, SFP) and 17 attributes of haddock products (H, HFP) were determined (Table 3.5).

4.3.4 Quantitative Descriptive Analysis (QDA)

The significant difference in attributes for products during storage period was calculated performing ANOVA (one-way) using Tukey's Pairwise Comparison on sensory scores. The mean scores with standard deviations for each attribute of salmon products and haddock products are presented in Table 4.3 and Table 4.4 respectively.

The salmon products, S and SFP samples were significantly different from the reference product of sooftmeal-salmon in terms of odour (*spice and fish*), appearance (*uniformity, dotted, glossy*), taste (*bitterness, spiciness and fish taste*) and texture (*softness, fattiness, granularity, cohesiveness and adhesiveness*) (Table 4.3 and Figure 4.9a, b). There was significant difference between the S, SFP and SM-S samples with respect to the spice odour and fish odour, where S and SFP had more spice odour than the SM-S. A main cause can be the use of aromatic spice powders such as dry ginger, fennel, mustard powder, white pepper and dry ginger powder (Table 3.2). They also had less fish odour as compared to SM-S. The use of milk-based ingredients (whipping cream, WPC80 and caseinate) and dry spices could have dominated the fish taste.

The appearance of S and SFP was more uniform and glossier than SM-S. This was because the S and SFP were homogenous and refrigerated products, contrary to SM-S which was a frozen product. The freezing damage on SM-S was visible after thawing and warming (Figure 4.10a, b). The use of spices, especially pepper powder gave S and SFP products a dotted appearance. Evaluation of the taste attributes showed significant difference in the bitterness, where S and SFP were more bitter than the SM-S samples. The fish protein hydrolysate (FPH) has a characteristic bitter taste (Kristinsson & Rasco, 2000) and its addition to SFP might have contributed to this bitter taste. However, no significant difference was found in the bitterness scores of salmon variant without FPH (S) and the salmon with FPH (SFP). It can be either

assumed that the amount of FPH used in the recipe did not give any bitter taste to the product or milk ingredients such as the whipping cream, sodium caseinate and whey protein concentrate 80 helped in masking its bitter taste. The S and SFP samples were significantly spicier than the SM-S samples. The reason for this is the added spices such as dry ginger, white pepper and mustard. The fish taste of S and SFP was significantly lower than that of the SM-S. The two interpretations for this reduced fish taste could be the use of milk-based ingredients (whipping cream, WPC80 and caseinate) which minimized the fish taste or the addition of dry spices that dominated the fish taste. The latter is also seen in Figure 4.9a where the fish taste decreases as the spiciness increases.

Both S and SFP were more soft, fatty, granular, cohesive and adhesive in texture as compared to the SM-S. The salmon products (S and SFP) were softer than the reference product (SM-S). In addition to the moisture from whipping cream and oil, gelling properties of whey protein concentrate 80 (Morr & Ha, 1993) and water binding abilities of the sodium caseinates (Southward, 2003) could have made these two products softer than SM-S by helping in retaining the moisture.

The two salmon variants S and SFP were fattier in taste than the SM-S variants. All variants contained fatty fish, salmon, as raw material. But the addition of the oil and milk-based ingredients in the recipe could be the reason for the increased fattiness. The S and SFP variants were more cohesive and adhesive than the SM-S. These two attributes may interrelate as seen from the Figure 4.9a. The more adhesive a product was, the more cohesive it was. This was a result of moisture from the added liquid in the products and sodium caseinate. As reviewed by (Southward, 2003), the soluble form of caseins such as sodium caseinate has a tendency to make certain foods sticky or ‘doughy’ by binding too much water. This can result in making the food more adhesive and cohesive in texture. The S and SFP samples were also less granular than the SM-P samples. The precooking of the fish before mixing with the ingredients denatured the fish proteins, making the fish tender. The vigorous mincing and homogenization before second pasteurization turned the product less granular in texture.

Other quality diminishing parameters such as oxidation that leads to rancidity of product is important for the shelf life and should also be taken into consideration. Salmon being a fatty fish is prone to lipid oxidation which is responsible for development of rancid off-odors and taste. This has a negative effect on the shelf life of a product. Before sealing, the oxygen in the

packaging was replaced by modified atmosphere with 100% N_2 to delay oxidative rancidity and to inhibit the growth of aerobic spoilage micro-organisms (Farber, 1991; Sivertsvik, Jeksrud, & Rosnes, 2002). The rancidity attribute was not included in the assessment, but this could have been interesting to study during the shelf life period. Analyzing the product for the sensory parameter of rancidity would have provided with this information.

Table 4.3 Average sensory scores from QDA (n=18, mean± S.D) of salmon products (with and without fish protein hydrolysate [FPH]) on storage day 5, 19 and 26. Reference product is sooftmeal-salmon. The *p*-values in red colour represent the attributes that differed significantly for the products. Means with different lowercase superscripts in a row indicates significant difference.

Attributes	Salmon without FPH			Salmon with FPH			Sooftmeal®	*p-value*
	D5	D19	D26	D5	D19	D26	D0*	
Sour odour	4.68±1.00	4.57±0.82	4.56±1.05	4.36±0.70	4.61±0.78	4.04±1.09	4.86±1.66	*0.369*
Sweet odour	4.06±0.80	3.98±0.91	4.12±0.82	4.16±0.90	4.07±0.94	3.91±0.72	3.30±0.88	*0.055*
Metallic odour	3.96±1.16	3.54±1.15	3.92±1.30	3.67±1.15	3.87±1.12	3.69±1.18	4.10±1.17	*0.811*
Milk odour	4.13±0.98	4.05±1.05	4.06±1.03	4.02±1.16	4.36±1.12	4.04±1.23	3.77±1.64	*0.884*
Spice odour	$4.56±1.22^{a}$	$4.09±1.01^{ab}$	$4.43±0.81^{a}$	$4.51±0.76^{a}$	$4.52±0.81^{a}$	$4.33±0.81^{a}$	$3.39±0.70^{b}$	*0.001*
Fish odour	$3.72±0.86^{b}$	$4.02±1.10^{ab}$	$3.91±1.04^{b}$	$3.56±0.89^{b}$	$3.78±1.05^{b}$	$4.03±1.27^{ab}$	$5.03±1.31^{a}$	*0.003*
Cloying odour	1.88±1.34	1.61±0.89	2.06±1.25	2.06±1.38	2.07±1.32	2.75±1.46	1.57±1.02	*0.109*
Uniformity	$6.33±1.15^{ab}$	$6.24±0.86^{ab}$	$5.65±1.04^{ab}$	$6.42±1.03^{a}$	$6.01±1.21^{ab}$	$6.40±0.84^{a}$	$5.37±0.93^{b}$	*0.011*
Dotted	$3.13±0.74^{a}$	$3.99±1.06^{a}$	$4.01±1.09^{a}$	$3.51±1.03^{a}$	$3.68±1.14^{a}$	$3.84±1.21^{a}$	$1.04±0.19^{b}$	*<0.001*
Glossy	$5.06±0.70^{a}$	$4.65±0.67^{a}$	$5.26±0.94^{a}$	$5.10±0.93^{a}$	$5.36±0.88^{a}$	$4.95±0.73^{a}$	$2.17±0.95^{b}$	*<0.001*
Sourness	4.04±1.01	4.28±0.97	4.43±0.91	3.88±0.82	4.46±0.89	3.94±0.87	4.80±1.16	0.051
Sweetness	3.99±0.81	3.96±0.75	4.10±0.73	4.19±0.91	3.99±0.83	3.79±0.95	3.51±0.70	*0.234*
Saltiness	4.98±0.80	4.79±0.77	5.20±1.13	5.19±1.18	5.31±1.35	5.17±1.08	4.57±0.92	*0.345*
Bitterness	5.29±0.95	$4.80±0.84^{ab}$	5.21±1.12	5.34±0.97	5.32±1.08	5.24±0.90	$4.44±0.80^{b}$	*0.041***
Umami	4.44±1.26	4.35±1.17	4.49±1.34	4.59±1.34	4.71±1.59	4.67±1.29	3.67±0.86	*0.233*
Metallic	4.05±1.42	3.91±1.33	4.04±1.38	4.04±1.37	4.14±1.28	4.13±1.38	3.86±1.31	*0.995*
Dairy taste	3.93±0.89	3.96±1.12	3.87±1.11	3.84±0.98	4.19±1.09	3.76±1.25	3.37±1.26	*0.495*
Spiciness	$4.93±0.86^{a}$	$4.74±0.99^{a}$	$4.99±0.57^{a}$	$5.14±0.50^{a}$	$5.03±0.88^{a}$	$4.80±0.88^{a}$	$3.49±0.67^{b}$	<0.001
Fish taste	$4.10±0.94^{bc}$	$4.31±0.75^{bc}$	$4.23±0.62^{bc}$	$3.77±0.74^{c}$	$4.62±0.79^{b}$	$4.73±0.86^{ab}$	$5.46±1.04^{a}$	*<0.001*
Cloying taste	2.53±1.40	2.23±1.16	2.57±1.56	2.81±1.55	2.23±1.20	2.64±1.47	1.58±0.82	*0.132*
Softness	$6.56±0.98^{a}$	$6.72±0.87^{a}$	$6.74±0.88^{a}$	$7.44±0.93^{a}$	$6.97±0.75^{a}$	$7.38±0.89^{a}$	$5.65±0.88^{b}$	*<0.001*
Fattiness	$4.43±0.79^{a}$	$4.52±0.70^{a}$	$4.53±0.87^{a}$	$4.68±0.72^{a}$	$4.66±0.88^{a}$	$4.81±0.89^{a}$	$3.05±0.58^{b}$	*<0.001*
Granularity	$5.83±1.26^{b}$	$5.99±1.14^{b}$	$6.12±1.06^{b}$	$5.68±1.53^{b}$	$5.59±1.37^{b}$	$5.67±1.55^{b}$	$7.42±0.88^{a}$	*<0.001*
Cohesiveness	$6.93±1.46^{a}$	$6.88±1.26^{a}$	$7.02±1.64^{a}$	$6.72±1.52^{a}$	$6.63±1.48^{a}$	$7.12±1.33^{a}$	$3.64±0.99^{b}$	*<0.001*
Adhesiveness	$7.07±1.09^{a}$	$6.30±1.05^{a}$	$7.27±1.18^{a}$	$6.88±1.69^{a}$	$6.70±1.61^{a}$	$7.04±1.32^{a}$	$3.89±1.38^{b}$	*<0.001*
Astringency	4.36±1.52	3.82±1.33	4.46±1.50	4.14±1.74	3.96±1.52	4.08±1.72	4.25±1.85	*0.912*
After-taste	5.54±1.06	5.18±1.13	5.67±1.06	5.69±0.94	5.46±0.87	5.64±1.08	4.75±0.90	*0.060*

* Reference sample (SM-S) was analyzed only once.
** Grouping based on Fisher method.

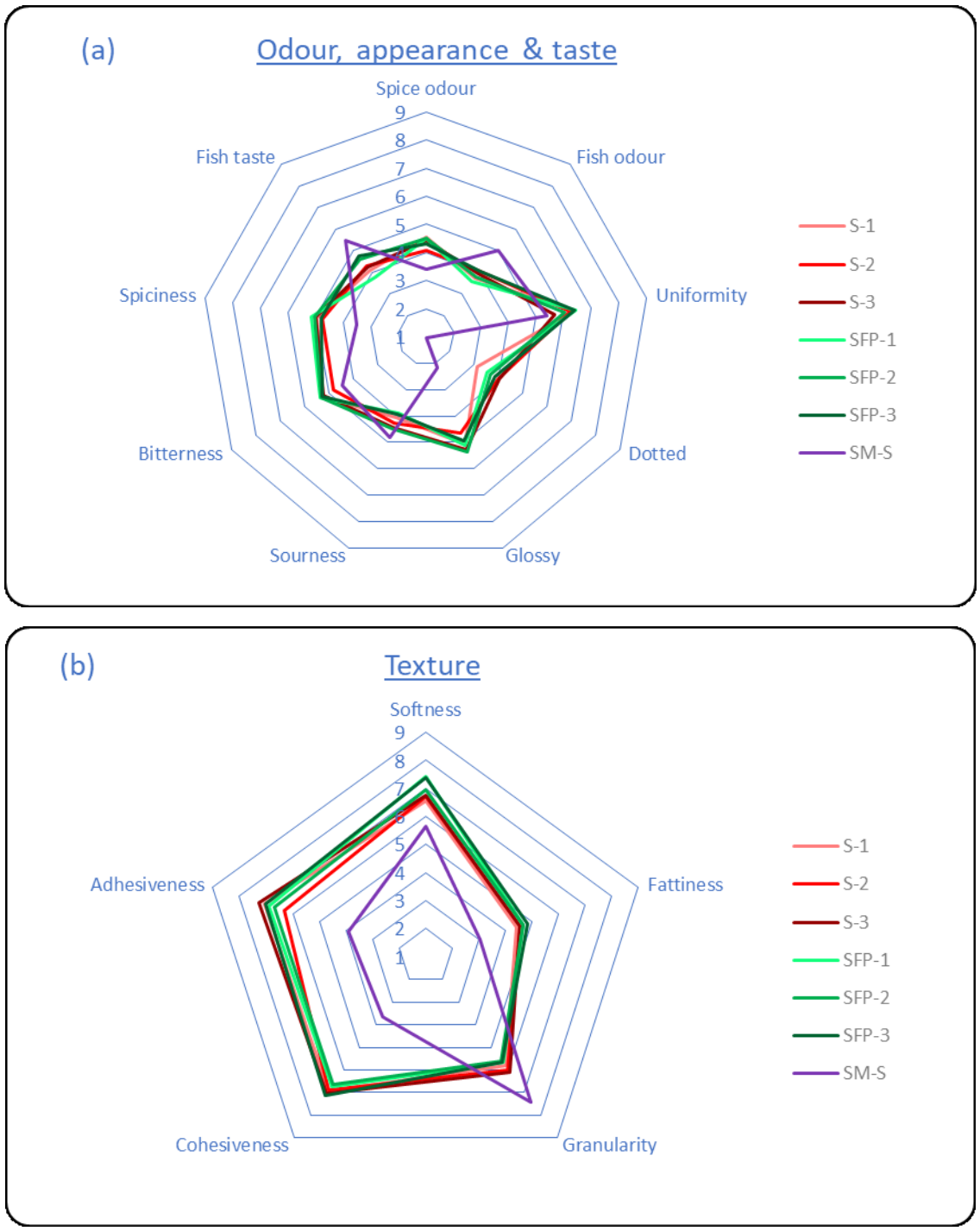


Figure 4.9 The radar plot of significantly different attributes within (a) odour, appearance, taste and (b) texture of salmon without fish protein hydrolysate (S), salmon with fish protein hydrolysate (SFP) and sooftmeal-salmon samples (SM-S). The plot is based on the average sensory scores (n=18). The axis is from 1-9 corresponding to sensory score range.

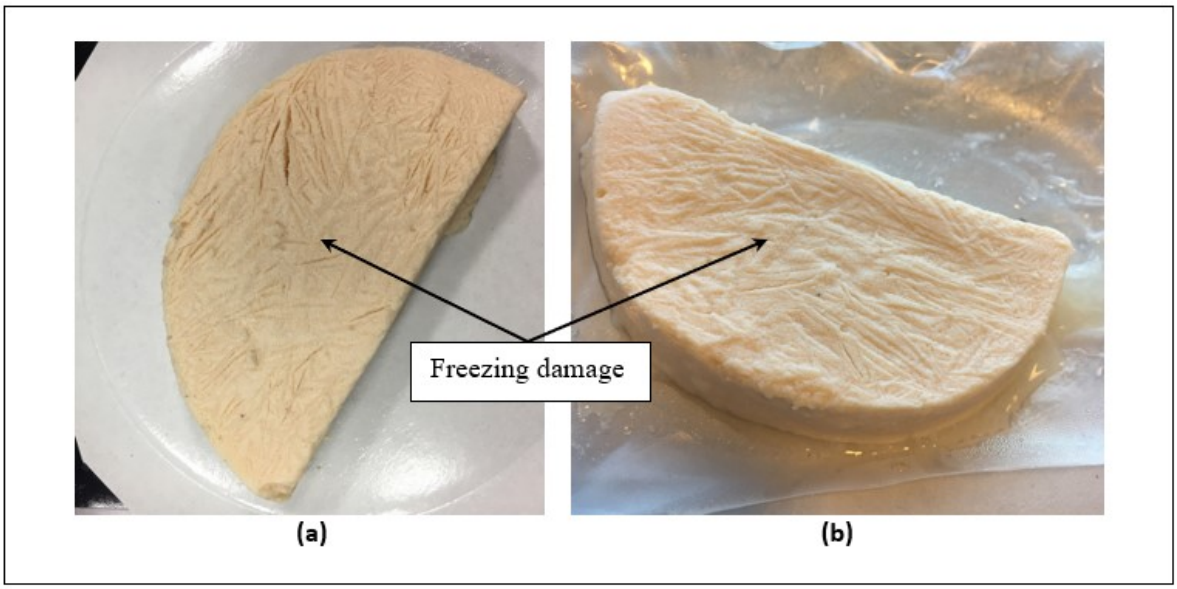


Figure 4.10 (a) Freezing damage on reference product; sooftmeal salmon after thawing overnight at 4°C and (b) after warming at 60±2°C.

The haddock products (H and HFP) were significantly different from the SM-P samples with respect to odour (*milk and fish*), taste (*saltiness, milky taste, spiciness, fish taste*) and all texture attributes (*hardness, fattiness, fibrous, juiciness, cohesiveness, adhesiveness*) (Table 4.4 and Figure 4.11a, b). The milk odour was significantly higher in H and HFP on day 29 as compared to day 8. The fish odour showed a non-significant decrease in the H and SM-S samples from day 8 to day 29. This can be an effect of increasing milk odour during storage that masked the fish odour. The higher spiciness level of haddock products was due to the use of dry spice powders could have elevated the spicy taste in the haddock products.

Table 4.4 Average sensory scores from QDA (n=15, mean± S.D) of haddock products (with and without fish protein hydrolysate [FPH]) on storage day 8,22 and 29.Reference sample is sooftmeal-pollock. The p-values in red colour represent the attributes that differed significantly for the products. Means with different lowercase superscripts in a row indicates significant difference.

Attributes	Haddock without FPH			Haddock with FPH			Sooftmeal®			p-value
	D8	D22	D29*	D8	D22	D29*	D8	D22	D29*	
Milk odour	3.80±0.68^{b}	4.73±0.59^{ab}	5.00±0.59^{a}	3.67±0.82^{b}	4.67±0.49^{ab}	5.00±0.59^{a}	4.27±1.10^{ab}	4.47±1.64^{ab}	5.00±1.53^{a}	*<0.001*
Fish odour	4.53±0.92^{a}	4.33±0.72^{a}	3.67±0.59^{ab}	4.13±0.99^{a}	4.20±0.41^{a}	3.72±0.46^{ab}	4.20±1.15^{a}	3.66±1.11^{ab}	3.00±1.61^{b}	*<0.001*
Stale (unfresh) odour	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	*NS***
Uniformity	9.00±0.00	8.87±0.35	9.00±0.00	9.00±0.00	9.00±0.00	9.00±0.00	9.00±0.00	8.93±0.26	8.89±0.32	*0.181*
Discoloration	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.07±0.26	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	*0.381*
Saltiness	4.00±0.54^{abc}	3.80±0.86^{bc}	4.39±0.92^{ab}	4.27±0.46^{ab}	3.67±0.72^{bcd}	4.67±0.77^{a}	2.80±0.78^{d}	3.20±0.94^{cd}	3.83±0.79^{bc}	*<0.001*
Bitterness	1.00±0.00	1.27±0.46	1.17±0.38	1.00±0.00	1.13±0.35	1.33±0.49	1.33±0.72	1.27±0.46	1.33±0.49	*0.150*
Milky taste	4.13±0.52	3.80±0.41	4.56±0.51^{a}	4.33±0.62	4.07±0.46	4.50±0.62^{a}	4.07±1.28	3.67±1.05	3.89±1.32^{c}	*0.029****
Spiciness	3.47±0.52^{a}	2.40±0.63^{c}	3.17±0.38^{ab}	3.53±0.52^{a}	2.53±0.52^{bc}	3.11±0.47^{ab}	2.20±1.08^{c}	1.87±0.52^{c}	2.11±0.83^{c}	*<0.001*
Fish taste	3.13±0.35^{ab}	3.00±0.66^{ab}	2.33±0.49^{bc}	3.33±0.62^{a}	3.13±0.83^{ab}	2.33±0.49^{bc}	2.47±1.41^{abc}	2.40±0.99^{abc}	2.06±1.11^{c}	*<0.001*
Stale (unfresh) taste	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	*NS***
Hardness	1.13±0.35^{b}	1.47±0.74^{b}	1.06±0.24^{b}	1.07±0.26^{b}	1.07±0.26^{b}	1.00±0.00^{b}	3.13±0.92^{a}	2.60±0.83^{a}	2.61±1.09^{a}	*<0.001*
Fattiness	3.20±0.56^{a}	3.13±0.35^{a}	2.89±0.32^{a}	3.27±0.70^{a}	3.00±0.38^{a}	3.11±0.32^{a}	2.07±0.26^{b}	2.27±0.70^{b}	1.72±0.67^{b}	*<0.001*
Fibrous	2.00±0.76^{b}	1.27±0.59^{bc}	1.00±0.00^{c}	1.60±0.74^{bc}	1.27±0.59^{bc}	1.17±0.38^{bc}	3.40±1.68^{a}	1.80±1.15^{bc}	1.00±0.00^{c}	*<0.001*
Juiciness	4.13±0.64^{ab}	3.67±0.90^{bc}	3.89±0.32^{abc}	4.87±1.06^{a}	4.07±0.80^{ab}	4.11±0.58^{ab}	2.40±0.91^{d}	2.86±1.30^{cd}	3.33±1.68^{bcd}	*<0.001*
Cohesiveness	4.93±0.26^{ab}	4.53±0.64^{b}	5.56±0.62^{a}	5.00±0.38^{ab}	4.13±0.64^{bc}	5.44±0.86^{a}	3.27±1.58^{c}	3.27±0.59^{c}	2.39±0.78^{d}	*<0.001*
Adhesiveness	4.80±0.68^{ab}	4.73±0.59^{ab}	4.44±1.04^{abc}	5.07±0.59^{a}	4.33±0.82^{abc}	4.89±0.58^{ab}	3.40±1.50^{cd}	3.73±1.28^{bcd}	2.94±1.80^{d}	*<0.001*

* On day 29, n= 18.

**Non-significant values as all scored consistently with minimum value 1.

***Grouping based on Fisher method.

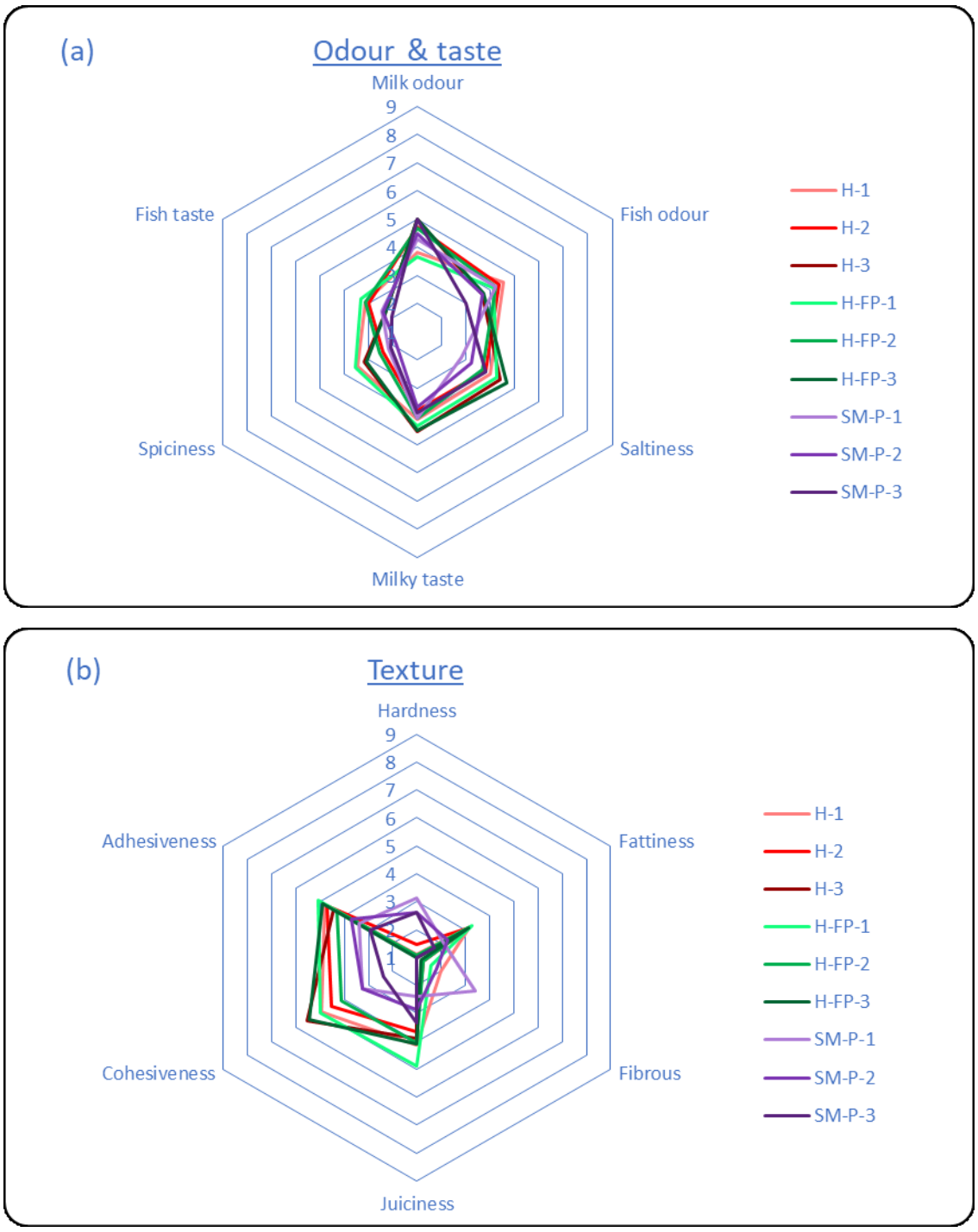


Figure 4.11 The radar plot of significantly different attributes within (a) odour, appearance, taste and (b) texture of haddock without fish protein hydrolysate (H), haddock with fish protein hydrolysate(HFP) and sooftmeal-pollock samples (SM-P).The plot is based on the average sensory scores (n=15). The axis is from 1-9 corresponding to the sensory score range.

The milky taste had higher sensory scores than the fish taste. The H and HFP were spicier than the SM-P samples owing to the use of pungent spices such as pepper, ginger etc. There was no significant difference in the fish taste of H and HFP. Although all three products showed a gradual non-significant decrease in the fish taste. The key difference between the H and HFP products was presence of fish protein hydrolysate. Based on the score values, it could be assumed that FPH did not impart any additional fish taste to the product. The saltiness of the products showed variations during the storage. The two haddock products were salty in taste compared to SM-P. As per the nutrient content calculation using 'Kostholdsplanleggeren', the H and HFP products consisted of 1.0 % salt (Appendix F). As per the nutrition labelling of SMP, it contained 1.2 %, which is more than haddock products. But the use of spices and fish stock powder probably enhanced the salty taste of haddock products.

The stale (unfresh) odour and taste were consistently scored with minimum value of 1 during the storage period of 29 days and are denoted as non-significant (NS) in Table 4.4. This suggests that the products were not perceived as stale despite of three weeks storage. This is promising as product freshness is a desired quality of refrigerated foods. The H and HFP were softer, cohesive and adhesive than SM-P and the parameters did not change much during storage period. Comparison within haddock samples indicates that HFP were softer than H samples. The haddock samples were also assessed to be prominently softer than the S and SFP products. The texture measurements (Figure 4.6a, b) also confirm the same.

4.3.5 Temporal Check-All-That-Apply (TCATA)

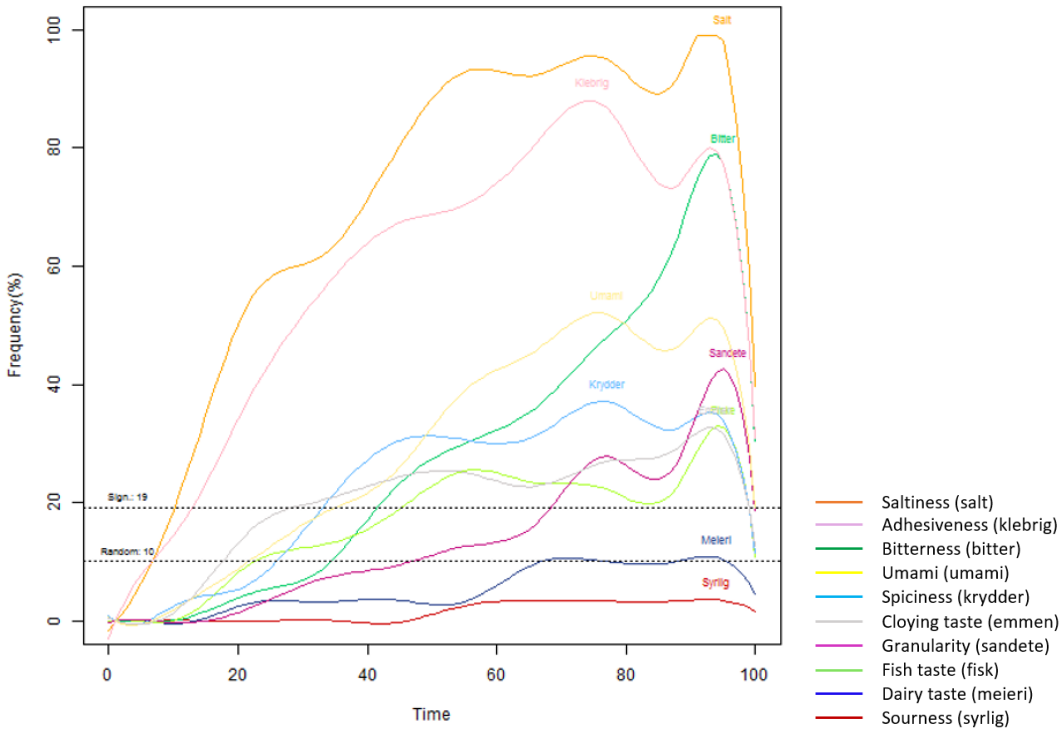
The purpose of TCATA analysis was to understand how defined sensory characteristics were perceived as dominant or not during the given evaluation time. TCATA was performed on five different salmon samples. Samples with fish protein hydrolysate (SFP) and without (S) had been stored for 5 and 26 days prior testing. In addition, a reference sample of sooftmeal-salmon was used. The analytical tool, EyeOpenR in EyeQuestion software version 4.10.4 (Logic8 BV, Wageningen, the Netherlands) was used for data analysis and to generate curves, see Figure 4.12- Figure 4.14.

The attributes exceeding the top horizontal significance line during evaluation were significantly dominant attributes (5% level). The frequency for each attribute at a given time

was based on the proportion of judgements (assessors x replicates) for which the given attribute was selected as dominant (Ares et al., 2015).

Salmon samples stored for 5 days, SFP5 and S5 (Figure 4.12 a, b) were characterized by significantly dominant attributes of saltiness and adhesiveness shortly after the samples were put in the mouth. These two attributes had high frequency of dominance throughout the evaluation. This was followed by cloying taste, spiciness, umami, bitterness and fish taste. The granularity attribute in both samples became dominant towards the end when they were ready to spit out. The fish taste in S5 had higher frequency of dominance than the SFP5 probably been due to saltiness and umami taste that had masked the fish taste.

(a) SFP- Day 5



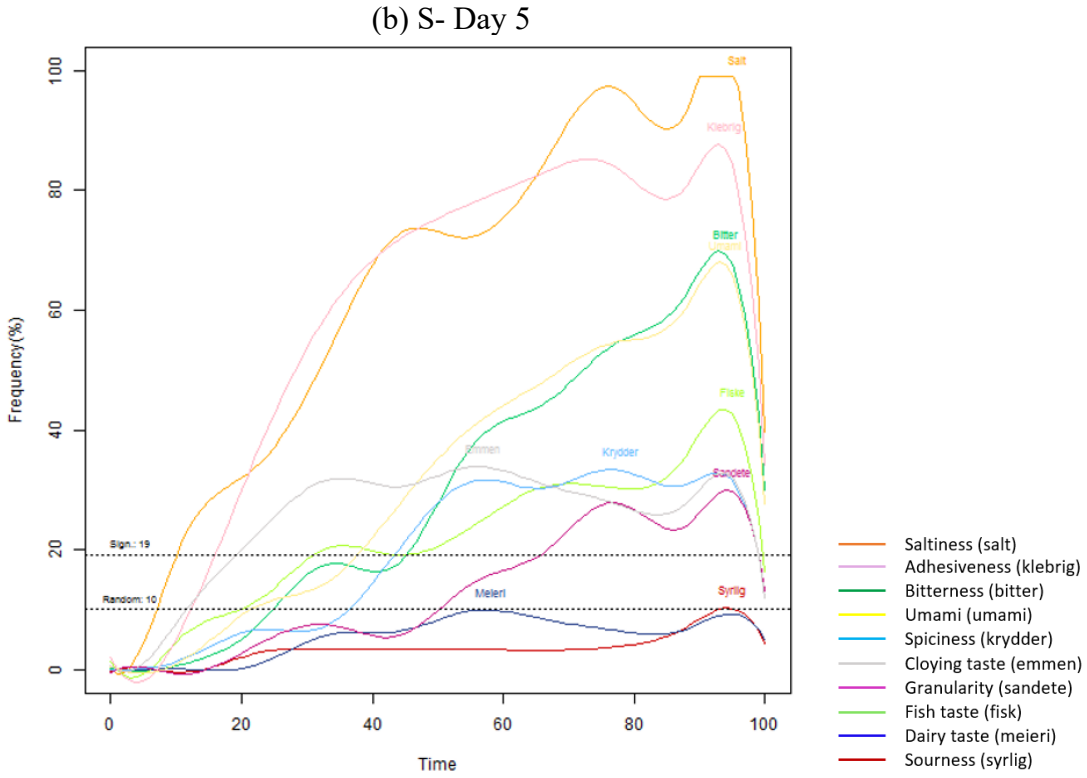


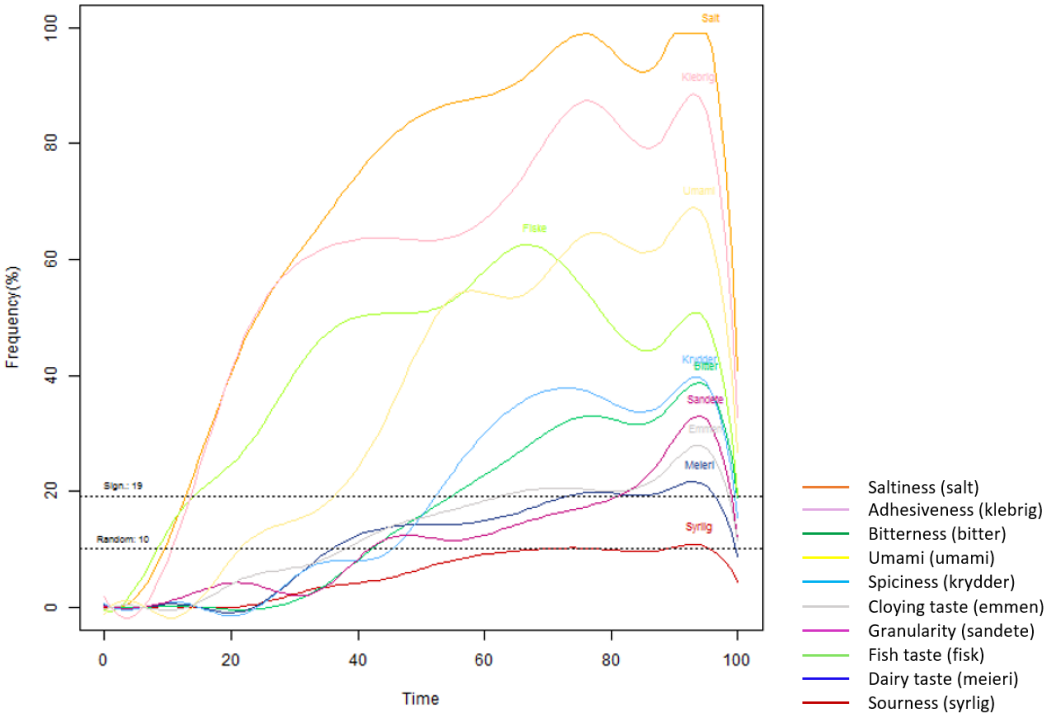
Figure 4.12 TCATA curves obtained from EyeOpenR for 5 days old sample of (a) salmon with fish protein hydrolysate (SFP5) and (b) salmon without fish protein hydrolysate (S5). The top horizontal line in the curves correspond to 5% significance level.

Sample SFP26, which was stored for 26 days (Figure 4.13c) was characterized by high frequency of dominance for saltiness and adhesiveness throughout the evaluation, followed by umami and fish taste. The attributes of spiciness, bitterness and cloying taste became significantly dominant in the middle of the evaluation but with a lower frequency. Towards the end of the evaluation when the sample was ready to spit out, granularity and dairy taste became dominant. Similarly, the attributes of saltiness and adhesiveness were frequency dominant in S26 (Figure 4.13d) from the beginning of the evaluation. Their dominance was followed by fish taste and umami. The next dominant attribute after fish taste and umami was spiciness but with a lower frequency. In the middle of the evaluation, granularity and bitterness became dominant.

The fish taste of SFP26 showed higher frequency dominance as compared to the sample S26. Attribute granularity had higher frequency of dominance in S26 contrary to the sample SFP26, where it became significantly dominant towards the end of the evaluation when they were ready to spit out. The cloying taste and dairy taste in S26 did not reach the significant

dominance at any point during evaluation but were found to be significantly dominant in SFP26 during the end duration of evaluation.

(c) SFP- Day 26



(d) S- Day 26

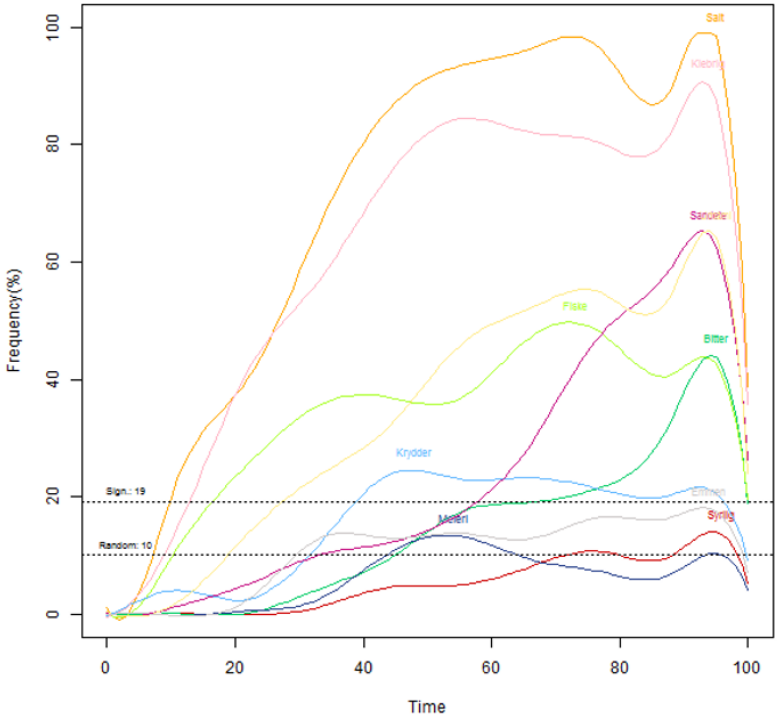


Figure 4.13 TCATA curves obtained from EyeOpenR for 26 days old sample of (c) salmon with fish protein hydrolysate (SFP26) and (d) salmon without fish protein hydrolysate (S26). The top horizontal line in the curves correspond to 5% significance level.

The sample S5 had higher frequency dominance for bitterness than the sample S26. This indicates that the intensity of this attribute decreased during the storage period. On the other hand, the frequency dominance of fish taste and granularity was higher in the sample S26 than S5. The decrease in the bitterness may have enhanced the fish taste in the sample. The cloying taste which was dominant in S5 sample, never reached the significant dominance in S26 at any point during the evaluation.

The frequency dominance of the attribute bitterness decreased in salmon sample with fish protein hydrolysate from day 5 to day 26 of storage. The attribute fish taste in SFP26 reached significant dominance early in the evaluation. This could be a result of the decrease in the bitterness that may have brought forward the fish taste. The dairy taste was not a dominant attribute in SFP5 but developed slightly during storage and became dominant in SFP26 during the end of the evaluation.

The attributes exhibiting higher frequency of dominance in reference sample SM-S (Fig. 4.13 e) were saltiness and fish taste. During the middle of the evaluation, attributes of granularity and sourness reached the significant dominance level.

(e) SM-S

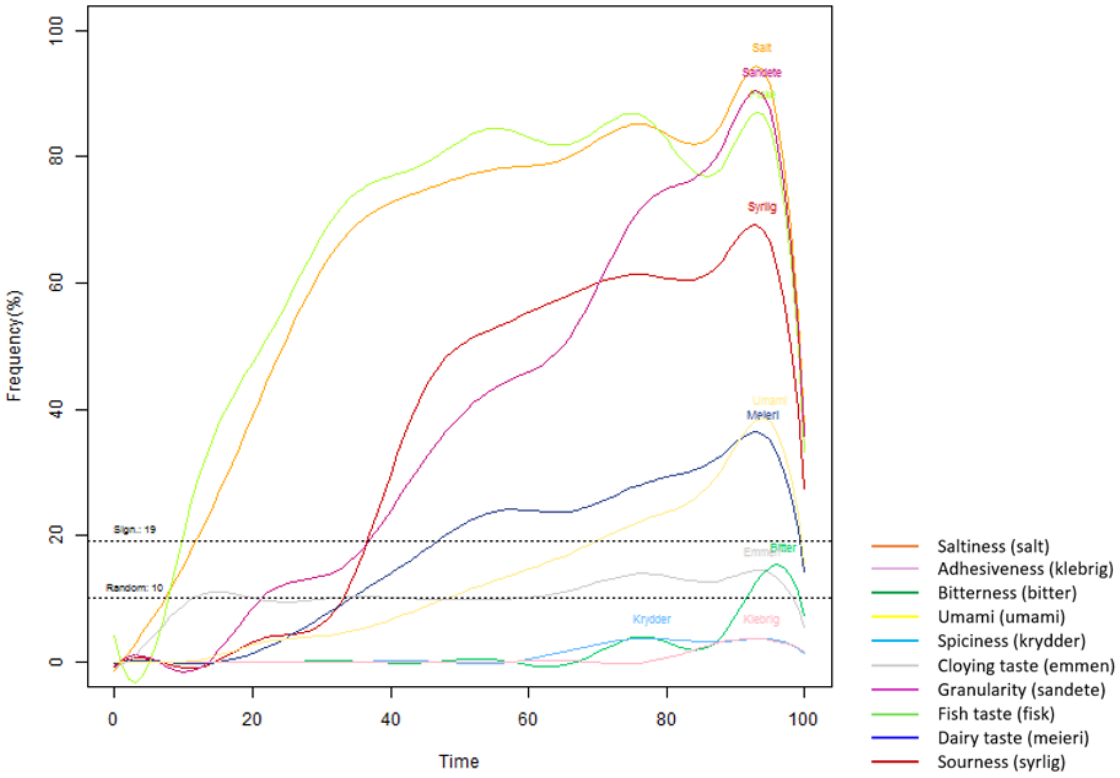


Figure 4.14 TCATA curves obtained from EyeOpenR for reference sample, (e) sooftmeal- salmon. The top horizontal line in the curves correspond to 5% significance level.

In contrast to the four test samples (S5, SFP5, S26, SFP26) the attributes of SM-S with respect to adhesiveness, bitterness, spiciness, cloying taste were not significant during any time of the evaluation. The salmon samples with and without fish hydrolysate were also less granular than the SM-P samples. This may be a result of precooking of the fish before mixing with the ingredients. This denatured the fish proteins, thus making the fish tender. The vigorous mincing and homogenization before second pasteurization turned the product less granular in texture. Unlike SM-S, all four salmon test samples were also characterized by significantly dominant attribute of adhesiveness. This can be a result of sodium caseinate (Southward, 2003) and the moisture from the added liquid that tends to make food more adhesive in nature.

The above results show that saltiness and adhesiveness were dominant for all salmon samples with and without fish protein hydrolysate. More work needs to be done with the product to enhance other attributes. Especially, fish taste because it is a fish product. TCATA has the potential to deliver detailed description of the how sensory characteristics of the product evolve over time (Ares et al., 2015). Hence, this method should be studied further to draw more conclusions. It would also be interesting to understand how the sensory properties of a texture modified food are perceived over time by dysphagia patients during consumption.

4.3.6 Shelf life study

During the 43 days shelf-life test, the salmon and haddock products were analyzed on day 8, 15, 22, 26, 36 and 43 for aerobic plate count on PCA and aerobic and anaerobic spore-forming bacteria on blood agar plates. Three parallel samples for each product were analyzed. The growth observed on PCA and blood agar plates for salmon samples with and without fish protein hydrolysate (S and SFP) was below the detection level (<10 cfu/g) except for day 36 and day 43. On day 26, one of the three-parallel samples of S showed a total aerobic count of $2.5x10^3$ cfu/g on PCA. Similarly, one parallel sample analyzed on day 43, showed a total growth of $2.1x10^3$ cfu/g on aerobically incubated blood agar plate. Out of this, $6x10^2$ cfu/g showed a clear beta hemolysis zone. A total aerobic count of $1.0x10^2$ cfu/g on PCA was found in one parallel sample of SFP on day 43.

The growth on haddock samples with and without fish protein hydrolysate (H and HFP) was below the detection level (<10 cfu/g), except for one parallel sample of H on storage day 43. This sample showed a total aerobic count of $1.0x10^2$ cfu/g on PCA.

Presumptive tests were performed on well isolated colonies by performing microscopy and using Baird parker agar as selective growth media. The colonies from PCA (day 36) and blood agar (day 43; aerobic incubation) were observed under microscope using a 1000x magnification. Cocci in clusters, typical of Staphylococcus morphology were observed for both plates. The Baird Parker agar showed black colonies with opaque haloes after incubation at 37°C for 24 hrs. This positive identification of Staphylococcus confirmed its presence.

Table 4.5 Bacterial growth (cfu/g) observed on PCA agar (aerobic plate count) and blood agar plates (spore-forming aerobic and anaerobic bacteria) for salmon products (S, SFP) and haddock products (H, HFP).

	AEROBIC PLATE COUNT (cfu/g)						
	Day 1	Day 8	Day 15	Day 22	Day 29	Day 36	Day 43
S1	<10	<10	<10	<10	<10	<10	<10
S2	<10	<10	<10	<10	<10	<10	<10
S3	<10	<10	<10	<10	<10	**$2.5x10^3$**	<10
SFP1	<10	<10	<10	<10	<10	<10	<10
SFP2	<10	<10	<10	<10	<10	<10	**$1.0X10^2$**
SFP3	<10	<10	<10	<10	<10	<10	<10
H1	<10	<10	<10	<10	<10	<10	<10
H2	<10	<10	<10	<10	<10	<10	**$1.0X10^2$**
H3	<10	<10	<10	<10	<10	<10	<10
HFP1	<10	<10	<10	<10	<10	<10	<10
HFP2	<10	<10	<10	<10	<10	<10	<10
HFP3	<10	<10	<10	<10	<10	<10	<10

	AEROBIC / ANAEROBIC SPORE-FORMING BACTERIA (cfu/g)						
	Day 1	Day 8	Day 15	Day 22	Day 29	Day 36	Day 43
S1	<10	<10	<10	<10	<10	<10	**$2.1x10^3$/<10**
S2	<10	<10	<10	<10	<10	<10	<10
S3	<10	<10	<10	<10	<10	<10	<10
SFP1	<10	<10	<10	<10	<10	<10	<10
SFP2	<10	<10	<10	<10	<10	<10	<10
SFP3	<10	<10	<10	<10	<10	<10	<10
H1	<10	<10	<10	<10	<10	<10	<10
H2	<10	<10	<10	<10	<10	<10	<10
H3	<10	<10	<10	<10	<10	<10	<10
HFP1	<10	<10	<10	<10	<10	<10	<10
HFP2	<10	<10	<10	<10	<10	<10	<10
HFP3	<10	<10	<10	<10	<10	<10	<10
The cfu/g is expressed only once, when they are <10 cfu/g for both aerobic and anaerobic growth.							

The finding of Staphylococcus could probably be caused by cross contamination, post-cooking, as the growth was found in a random sample from day 36 and day 43. For Staphylococcus aureus, a D_{70} = 0.1 min (ECFF, 2006) is often used where a 6 log reduction is obtained after 0.6 min at 70°C. In this case the products were subjected to a pasteurization at 95°C for 15 mins in the core (Chapter 3.6.3). At this temperature vegetative cells are killed, and only spore-forming bacteria survive. The absence of the spore-forming bacteria leads to a conclusion that the coccoid Staphylococcus originated from a recontamination. The finding of cocci after the pasteurization can be explained by the leakage in the package because of improper sealing, during autoclaving or subsequent chilling. During chilling of the packages, the volume of the gas phase will decrease, creating a vacuum effect. This will cause the ice water to seep in and may contaminate the samples. As the products were sealed, they were handled without gloves. Staphylococcus constitutes a part of normal flora of our body and the manual handling of product while cooling, sorting and analysis may have led to contamination.

The packages of salmon and haddock products were similar, and they were subjected to the same heat-treatment process of 95°C for 15 mins. Hence, only the temperature curve and pasteurization (P_0) values from the heat-treatment of the salmon product is presented in Figure 4.15. The measured P_0 values are calculated based on D and z values from

psychrotrophic non-proteolytic Clostridium botulinum type E. The accumulated P_0 values from three probes of three different packages are shown on the right-hand side y-axis in the figure. The values ranged from 126 mins to 157 mins, which is much higher than the heat load normally used for safety for non-proteolytic Clostridium botulinum type E. This explains the low microbial survival in the samples.

The high pasteurization value of more than 90°C for 10 mins is sufficient to inactivate non-proteolytic Clostridium botulinum E/B with a large margin. The D_{90} = 1.6 min (ECFF, 2006) and 6 log reduction is obtained after 9.6 min at 90ºC. Since this is a chilled fish product, only the psychotropic Clostridium type E can grow (minimum growth at 3.3°C). The spore forming bacillus is not regularly associated with the fish, but is often isolated from the starch, spices etc. present in the ingredients. B. cereus has higher heat tolerance, D_{100} = 8 min, and 48 min at 100°C is needed to obtain a 6-log reduction. Spores from Bacillus may therefore survive the heat treatment even though they were not detected in this shelf life study. As their minimal growth temperature is 4°C, it is not likely that they can reach infective doses at about 105 cfu/g (ECFF, 2006) in 4-5 weeks.

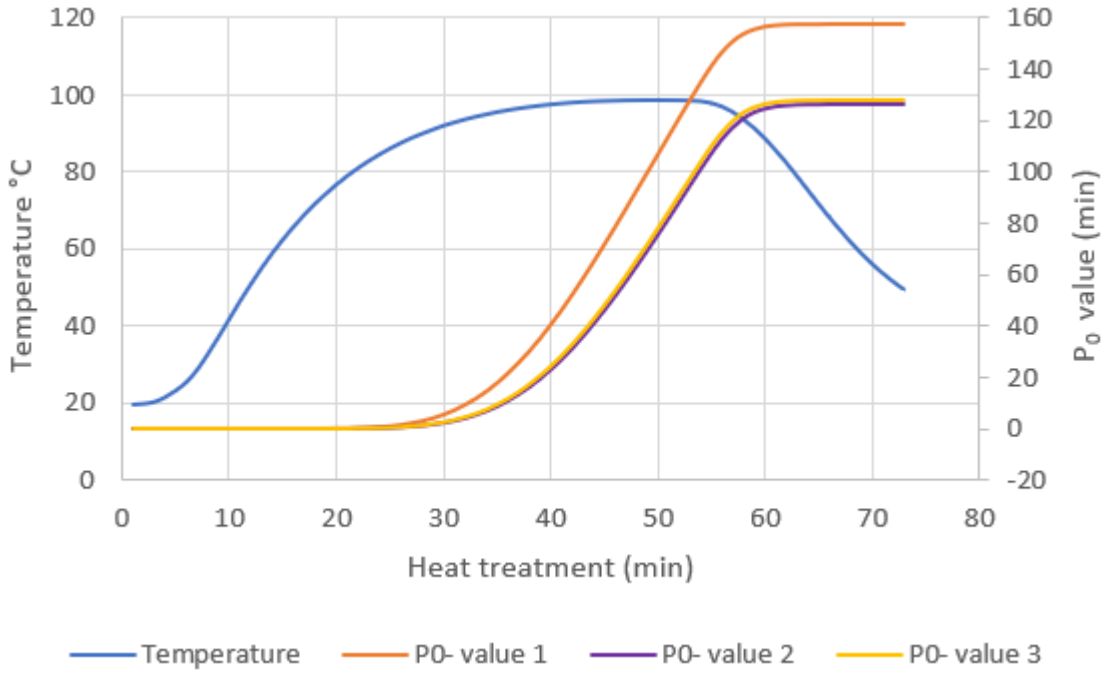


Figure 4.15 Temperature curve and P_0 values from three different probes in the center of the salmon product.

As mentioned in Chapter 3.8.1 and Chapter 3.10.1, it would be normal to reheat the food to 60±2°C before consumption. However, to evaluate the worst-case scenario, the samples were not warmed to 60±2°C before microbiological analysis. This additional heating step could have eliminated the detection of microbial growth during chilled storage.

Additionally, the residual oxygen measured in the HDPE trays and the master bags of the salmon and haddock products during 43 days of storage was measured below 1% (Figure 4.16). This is lower than the typical residual oxygen levels of 2% to 5%, detected in the gas-flushed packages (DeWitt & Oliveira, 2016). The reduction in the oxygen also delays the oxidative rancidity, a sensory spoilage parameter and inhibits the aerobic spoilage microorganisms that may limit shelf-life (DeWitt & Oliveira, 2016; Sivertsvik et al., 2002). The type of packaging material plays an important role in maintaining low residual oxygen level. The findings suggest that the packaging material used in this process was effective in extending product shelf life and promoting the product quality.

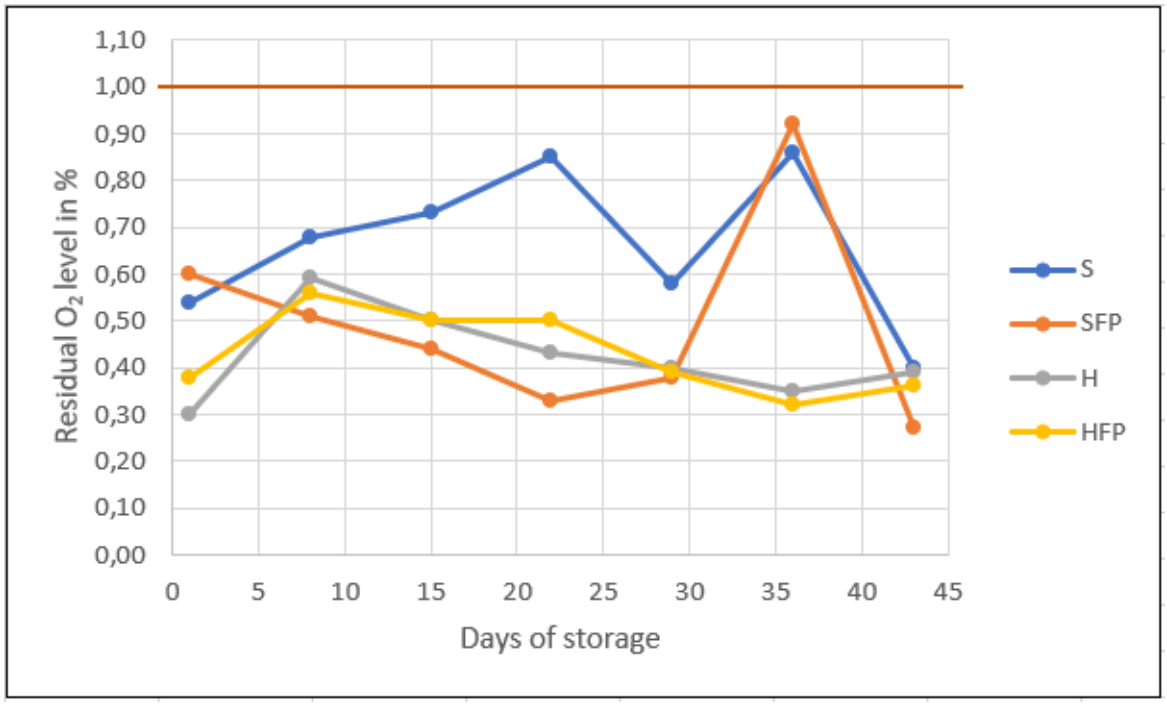


Figure 4.16 Percentage of residual oxygen levels in salmon (S,SFP) and haddock (H, HFP) products during 43 days of storage.

The older people are more susceptible to food-borne illnesses due to their compromised immune system and loss of the physical barriers. They have higher incidences of infection from foodborne pathogens such as *Listeria, Salmonella and Staphylococcus* (Kendall et al.,

2006). It is therefore critical to subject the modified food designed for elderly to a proper heat treatment and to store them at chilled conditions to prevent health risks. Here, the bacterial count in 43 days shelf life study at 4°C, did not indicate any sign of high microbial growth and subsequent spoilage. This confirm that the processes from this study may be used in the future for a chilled distributed product with a shelf life of at least 4-5 weeks.

5 Conclusions

Two fish products from salmon and haddock with modified texture and specific softness level, customized for people with dysphagia were developed. The products were texture modified and enriched with caseinate, whey protein concentrate 80 and fish protein hydrolysate. The texture analysis, sensory analysis and the shelf life study provided a valuable insight on the texture (firmness) and the quality of the product during 43 days storage period at 4°C. The modification of fish raw material with texture modifiers, milk proteins and fish protein hydrolysate gave a softer product with higher protein content compared to the commercially available dysphagia product.

The texture analysis showed that the product with fish protein hydrolysate, measured at 60±2°C was significantly softer ($p<0.05$) than the product without fish protein hydrolysate. The products from day 43 were softer than on day 1. However, the firmness of the products fluctuated during the storage days. The IDDSI fork test conducted on salmon and haddock products revealed that the products without fish protein hydrolysate required higher pressure to make thumb nail blanch compared to products with fish protein hydrolysate.

Although the observations from IDDSI fork test were found to be in accordance with the instrumental texture values, it is difficult to correlate the degree of blanching with the texture values with certainty. This is because the IDDSI test is not as precise as the instrumental analysis and hence not capable of identifying a firmness difference of 1 Newton visually.

The QDA showed that salmon and haddock products were significantly different from their commercial counterpart, mostly with respect to the attributes within texture. The presence or absence of fish protein hydrolysate used in this thesis did not lead to significant difference in the bitterness of salmon and haddock products. The TCATA method showed that the attributes of saltiness and adhesiveness had a high frequency of dominance throughout the evaluation in the salmon (S, SFP) and haddock (H, HFP) products from day 5 and day 26. This indicates that more work is required to enhance other attributes, especially the fish taste.

Modified fish products were packaged in modified atmosphere (100% N_2), sealed and heat treated with a high pasteurization value ($D_{95}>120$ min), in order to make safe products for vulnerable user groups. The low microbial load (<10 cfu/g) in 43 days shelf life study at 4°C

suggests that the processes from this study can be used in the production of a chilled distributed dysphagia product.

6 Future work

The results from the experiments have given some answers but have also revealed areas that need to be developed and optimized in future projects. Some suggestions are stated below.

- The texture was measured at serving temperature (60±2°C). However, it would be beneficial to study the changes in the texture with varying temperatures. For e.g. textural changes from ambient temperature to the serving temperature. This can help us to distinguish the influence of different temperatures on the texture modification.

- During this study, only the firmness of the products was measured using texture analyzer. Other relevant attributes for texture modified food such as adhesiveness and cohesiveness should be evaluated in further experiments.

- One should bear in mind that the texture modified products are intended for the consumption by elderly with swallowing disability. This group may have variable preferences due to diminished sensory abilities. In the future, an elderly sensory panel should be trained to run the test. This will give a more precised description of the acceptance of the modified product.

- Qualitative descriptive analysis can be cumbersome to perform on elderly panel due to diminished sensory perception of the older people. Such methods are time consuming and need training. Rapid methods such as TCATA are easy to perform and less time consuming. This method should therefore be explored more in the future, keeping in mind that the diminished sensory perceptions of some elderly people.

- High pasteurization value was used in this study. Lower pasteurization values can be used to optimize the product and see if the better quality of product is obtained.

- The nutrient content of the developed products was calculated using the Norwegian Food reference calculator/table. This calculation does not consider the nutrient loss as result of heat processing and storage. The products should be analyzed using laboratory standard methods especially for the exact protein content.

- The products in this thesis have been enriched with proteins such as whey, casein and fish hydrolysates. No studies were conducted in laboratory to check the digestibility and the

assimilation of these proteins-enriched products. *In-vitro* human gastrointestinal simulation model could be used to generate an idea of protein metabolism.

- Various types and proportions of hydrolysates could be tested for protein enrichment in the future. In recent years, there has been a huge focus on utilization of the protein-rich residual raw materials from marine industries to generate higher valued products for human consumption. This increased utilization will also give an impetus to the growth in the bioeconomy. Various types and proportions of hydrolysates should be tested in the future for their health benefits, protein enrichment and sensory characteristics.

- The primary focus of this study was to obtain a texture modified and protein-enriched product with IDDSI consistency level 4. Appearance and taste were secondary focus area. More emphasis should also be given on enhancing the taste, palatability and the appearance of the products. For example, taste could be enhanced to increase the food acceptability and intake.

- Lipid oxidation and development of rancidity is a quality problem associated with the storage of fatty fish products. According to earlier findings, the fish protein hydrolysate is known to have antioxidant properties. But no analysis was conducted to measure the oxidation level in the products. In future work, the products should be analyzed for lipid oxidation using for e.g. thiobarbituric acid reactive substances (TBARS) assay which can give an insight on the effect of antioxidative properties of fish protein hydrolysate on the oxidation process.

- The effect of the starch and proteins (WPC80, caseinate, hydrolysates) in the modification of product was not studied on a structural level. A possible study of the structure changes induced by the ingredients, processing, temperature and storage should be conducted. Microtome, microscopy and image analysis can be used for this purpose. This can provide the knowledge of the structural effect of starch and hydrocolloids on the texture modification, when used individually or in combination. The quantity of the ingredients can then be adjusted accordingly to acquire specific targeted structure.

- The packaging material used gave a good oxygen barrier but is not ideal for the retail market. In future, practical, appealing and easy to handle packaging material should be used and tested at normal distribution conditions.

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Appendix A

Recipe I, II and III based on the KOMAT project

Recipe I		
Sequence of addition	Ingredients	Weight in grams
1	Frozen salmon fillet	500
2	Salt	10
3	Whole milk 3.5% fat	250
4	Whipping cream 3.8% fat	250
5	Whole Egg	45
6	Potato starch	10
7	White pepper powder	0.5
	Ground ginger powder	0.5
	Mustard powder	0.5
	Ground fennel powder	0.5

Method

1. 500 g frozen salmon fillet was thawed overnight.
2. All the ingredients were blended in thermomixer as per the sequence.
3. A 90±5 g of this mixture was divided into round aluminium foil trays and covered with plastic cling wrap. The mixture was pasteurized to a core temperature of 90°C.

Recipe II		
Sequence of addition	Ingredients	Weight in grams
1	Frozen salmon fillet	500
2	Salt	3
3	Whole Egg	45
4	Whipping cream 3.8% fat	120
5	Sunflower oil	90
6	Potato starch	10
7	40% agar-agar+ 40% gellan+ 20% lecithin	4.5
8	White pepper powder	0.5
	Ground ginger powder	0.5
	Mustard powder	0.5
	Ground fennel powder	0.5

Method

1. 500 g frozen salmon fillet was thawed overnight.
2. All the ingredients were blended in thermomixer as per the sequence.
3. The blended mixture was layered on a stainless-steel tray and cooked to a core temperature of 90°C.
4. After cooking, the oil and water separated from the mixture.
5. The mixture was mixed with spatula and blended again in thermomixer until a smooth consistency was achieved.
6. A 90±5 g of this mixture was divided into round aluminium foil trays and covered with plastic cling wrap. The mixture was pasteurized to a core temperature of 90°C.

Recipe III

Method

1. 500 g of frozen salmon fillet was thawed overnight.
2. 1g salt was added to the fish and was grounded using a grinding machine (Kenwood cooking-chef kitchen machine).
3. 100g mixture of Recipe II was blended with the ground fish mixture.
4. 2 tablespoon of whole egg mixture was added for binding.
5. 0.5 g of each white pepper powder, ground ginger powder, mustard powder and ground fennel was added.
6. A 90±5 g of this mixture was divided into round aluminium foil trays and covered with plastic cling wrap. The mixture was pasteurized to a core temperature of 90°C.

Appendix B

Preliminary recipes of salmon products and nutrient contents

Sequence of addition	Ingredients	Recipe 1*	Recipe 2*	Recipe 3a*	Recipe 3b	Recipe 4	Recipe 5a	Recipe 5b	Recipe 6	Recipe 7a	Recipe 7b
1	Precooked salmon fillet	500	500	500	500	500	500	500	500	500	500
2	Table salt	10	10	10	10	10	10	10	10	3	3
3	Cream, whipping, 38 % fat	250	250	272	280	250	175	250	200	200	200
4	Milk, whole milk, 3,5 % fat	250	-	-	-	-	-	-	-	-	-
5	Oil, sunflower	90	80	80	80	80	80	80	80	80	80
6	Egg white Powder, MyProtein	4	4	4	4	4	4	-	-	-	-
7	Corn starch	5	5	5	5	5	5	5	5	5	5
8	Whey Protein concentrate (WPC80,Tine	-	100	-	-	37,5	40	40	35	40	30
9	Sodium Caseinate (Kapa JPR 1002)	-	-	75	75	37,5	20	20	15	20	15
10	Salmon protein Hydrolysate (Hofseth)	-	-	-	-	-	-	-	15	-	15
11	White pepper powder	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
12	Mustard powder	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
13	Ground ginger powder	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
14	Ground fennel powder	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
15	Fish stock powder, Maggi	-	-	-	-	-	-	-	-	10	10
16	Locust bean gum, Natur Drogeriet A/S	3	3	3	3	3	3	3	3	3	3
	Nutrients /100g										
	Protein	**10,6**	**19,5**	**18,4**	**18,2**	**18,4**	**18,6**	**17,0**	**18,4**	**17,8**	**18,1**
	Fat	**24,4**	**27,3**	**27,6**	**27,7**	**27,6**	**27,2**	**28,2**	**27,4**	**27,6**	**27,5**
	Kilojoules (kJ)	**1119**	**1373**	**1358**	**1360**	**1361**	**1346**	**1358**	**1324**	**1358**	**1330**
	Kilocalories (kcal)	**271**	**331**	**328**	**328**	**328**	**325**	**328**	**320**	**328**	**321**
	Carbohydrates	**2,2**	**2,2**	**1,5**	**1,5**	**1,7**	**1,7**	**1,8**	**1,6**	**2,2**	**2,1**
	Salt	**1,0**	**1,2**	**1,4**	**1,4**	**1,3**	**1,4**	**1,2**	**1,3**	**0,9**	**0,9**
	***All recipes contain precooked fish except for recipe 1, 2 and 3a which contained raw fish**										

Preliminary recipes of haddock products and nutrient contents

Sequence of addition	Ingredients	Recipe 1	Recipe 2	Recipe 3	Recipe 4a	Recipe 4b
1	Precooked haddock fillet	500	500	500	500	500
2	Table salt	10	10	10	3	3
3	Cream, whipping, 38 % fat	175	200	200	200	200
4	Milk, whole milk, 3,5 % fat	-	-	-	-	-
5	Oil, sunflower	80	80	80	80	80
6	Egg white Powder, MyProtein	4	4	-	-	-
7	Corn starch	5	5	5	5	5
8	Whey Protein concentrate (WPC80,Tine)	40	40	40	40	30
9	Sodium Caseinate (Kapa JPR 1002)	20	20	20	20	15
10	Salmon protein Hydrolysate (Hofseth)	-	-	15	-	15
11	White pepper powder	0,5	0,5	0,5	0,5	0,5
12	Mustard powder	0,5	0,5	0,5	0,5	0,5
13	Ground ginger powder	0,5	0,5	0,5	0,5	0,5
14	Ground fennel powder	0,5	0,5	0,5	0,5	0,5
15	Fish stock powder, Maggi	-	-	-	10	10
16	Locust bean gum, Natur Drogeriet A/S	3	3	3	3	3
	Nutrients /100g					
	Protein	**16,5**	**16,1**	**17,2**	**15,9**	**16,1**
	Fat	**17,8**	**18,3**	**18,1**	**18,4**	**18,4**
	Kilojoules (kJ)	**964**	**979**	**960**	**986**	**958**
	Kilocalories (kcal)	**232**	**236**	**231**	**237**	**231**
	Carbohydrates	**1,7**	**1,7**	**1,7**	**2,2**	**2,1**
	Salt	**1,4**	**1,4**	**1,4**	**1,0**	**1,0**

Appendix C

Product datasheet for 562 Dynopack HDPE trays

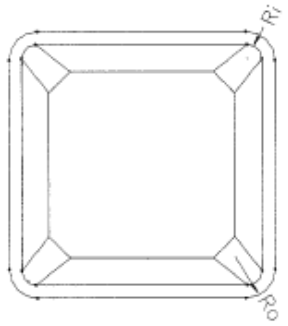
BEBO
FOOD PACKAGING

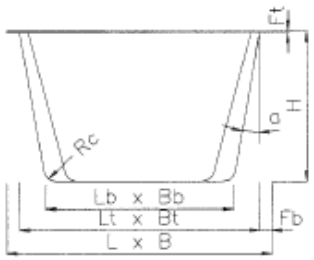
Disclaimer: All information in this specification are given in good faith and without warranty. Material: HDPE. Approved for food contact to Code of Federal Regulations, issued by Food Drug Administration,(FDA), paragraph 21,CFR 177,1520(olefins polymers)

Group 01

Revised Date: 10-jan-18

tore





The dots indicates where we measure the Lenghts and Widths. At other places on the tray the measures may be different.

EXT. DIMENSIONS	Symbol	562 XX 00	Unit
Lenght	L	93± 1,0	mm
Width	B	93± 1,0	mm
Depth	H	53	mm
Lenght u/ flange	Lt	83± 0,5	mm
Width u/ flange	Bt	83± 0,5	mm
Lenght, bottom	Lb	65	mm
Width, bottom	Bb	65	mm
FLANGE			
Width, Long side	Fb1	4,50± 1,50	mm
Width, Short side	Fb	4,50± 1,50	mm
Thickness, nom	Ft	0,9	mm
Curvature, corner	Ro	10,0	mm
Curvature, inside	Ri	4,0	mm
WALL			
Thickness, min	s	0,2	mm
Angle	a	10	°
Curvature, bottom	Rc	4	mm
VOLUME	V	280	cm³
WEIGHT, nom	W	9,2	g
WEIGHT, min	w	8,5	g
EXPOSED AREA			
Tray	As	213	cm²
Membrane	Af	69	cm²
GAS PERMEAB. OF TRAY			
Oxygen O2	QO2	3,3	cm³/d.atm
Nitrogen N²	QN2	1,0	cm³/d.atm
Carbondioxide CO²	QCO2	14,0	cm³/d.atm
Water Vapour H²O	QH2O	<0,01	g/d

Dynoseal ST 1575 is especially well suited for high processing temperatures, such as sterilisation. Withstands processing temperatures up to 121 °C. Consists of 15 micron biaxially oriented polyamide laminated to 75 micron special polyethylene.

Technical specifications/Tekniske spesifikasjoner/Technische Beschreibung/Renseigments techniques 1):

	GPO 1570	ST 1575	GPP 1250	Units/Enheter Einheiten/Unités
Nominal weight/Nominell vekt/Vorhandenes Gewicht Poids normal	84,1	87,1	69,0	g/m^2
Thickness/Tykkelse/Dichtigkeit/Epaisseur	86,5	90,0	62,0	mc
Water vapour transmission/Vanndamp gjennomgang Wasserdampfdurchlässigkeit/Perméabilité à la vapeur d'eau	< 3,1	< 1,5	< 1,6	g/m^2
0_2 transmission/O_2 gjennomgang/O_2 Durchlässigkeit Perméabilité à O_2	< 35	< 35	< 50	cm^3/m^2
CO_2 transmission/CO_2 gjennomgang/CO_2 Durchlässigkeit Perméabilité à CO_2	< 140	< 130	< 200	cm^3/m^2
N_2 transmission/N_2 gjennomgang/N_2 Durchlässigkeit Perméabilité à N_2	< 8	< 5	< 15	cm^3/m^2
Sealing temperatur range/Forseglingstemperatur Versiegelungstemperatur/Température de scellage	160-180	160-180	160-180	°C
Max processing temperature/Max prosess temperatur/Max. Verfahrenstemperatur/Temp. maxi de traitement thermique	+ 110	+ 121	+ 85	°C

Figure C. 1 Technical specification of Dynoseal film ST 1575, Promens

Appendix D

Source: http://vitalernaering.no/sooft-meals-blandingseske-med-fisk/ (Access date: 03.11.18)

PRODUKTARK

Sooft Meals, Blandingseske med Fisk, 5x1 kg
EPD: 2070779

Gjennom grossist tilbys Sooft Meals også som løsvekt i blandingsesker. Denne blandingsesken består av 5 x 1 kg poser med fisk (3 x 1 kg pose med hvit fisk og 2 x 1 kg pose med laks). I hver pose er det 20 enkelfryste stykker á 50 gram. På denne måten kan man enkelt ta ut etter behov og kombinere med annen moset mat.

Laks

Ingredienser:
Kokt og moset laks (48%), fløte 30 % (fløte av 15 fett og 1% storfegelatin), kremost 17 %, salt, stabilisator: johannesbrødkj.mel og guarkj.mel, eggehvite, tapiokastivelse, storfegelatin, gjærekstrakt, løk, maltodekstrin, krydder.

Næringsinnhold pr.100 gram ferdig vare:

Energi: Kcal/kJ	Fett (g)/hvorav mettet fett (g)	Karbohydrater (g)/hvorav sukkerarter (g)	Protein (g)	Salt (g)
206/864	16,6/7,2	3,2/0	14,7	1,2

Hvit fisk

Ingredienser:

Kokt og moset hvit fisk (48%), fløte 31 % (fløte av 15 fett og 1% storfegelatin), kremost 17 %, salt, stabilisator: johannesbrødkj.mel og guarkj.mel, eggehvite, tapiokastivelse, storfegelatin, gjærekstrakt, løk, maltodekstrin, krydder.

Næringsinnhold pr.100 gram ferdig vare:

Energi: Kcal/kJ	Fett (g)/hvorav mettet fett (g)	Karbohydrater (g)/hvorav sukkerarter (g)	Protein (g)	Salt (g)
147/616	10/5,9	3,2/0	13,7	1,2

Appendix E

BEDØMMELSE AV FISKEPRODUKT

Egenskapsforklaring

(Salmon, Ås)

LUKT

Syrliglukt	Relateres til en frisk, balansert lukt som skyldes organiske syrer Ingen intensitet = ingen syrlig lukt Tydelig intensitet = tydelig syrlig lukt
Søtlukt	Relateres til grunnsmaken søt (sukrose) Ingen intensitet = ingen søtsmak Tydelig intensitet = tydelig søtsmak
Metallukt	Lukt av metall (ferrosulfat) Ingen intensitet = ingen metallukt Tydelig intensitet = tydelig metallukt
Meierilukt	Lukt av meieriprodukter som flyt og romme Ingen intensitet = ingen melk-/fløtelukt Tydelig intensitet = tydelig melk-/fløtelukt
Krydderlukt	Lukt av krydder, f. eks karri, pepper, muskat Ingen intensitet = ingen krydderlukt Tydelig intensitet = tydelig krydderlukt
Fiskelukt	Lukt av fisk (laks) Ingen intensitet = ingen fiskelukt Tydelig intensitet = tydelig fiskelukt
Emmen lukt	En ufrisk / kvalmende lukt Ingen intensitet = ingen emmen lukt Tydelig intensitet = tydelig emmen lukt
Forlukt	Relateres til lukter av dyrefor Ingen intensitet = ingen forlukt Tydelig intensitet = tydelig forlukt

UTSEENDE

Jevnhet	Relateres til jevnhet i prøven, prøven er homogen Ingen intensitet = ingen jevnhet (uhomogen) Tydelig intensitet = tydelig jevnhet (homogen)
Prikkete	Prikker i prøven Ingen intensitet = ingen prikker Tydelig intensitet = tydelig prikker
Glans	Helhetsinntrykket Ingen intensitet = ingen glans, matt Tydelig intensitet = tydelig glans, glinsende

SMAK

Syrligsmak	Relateres til en frisk, balansert smak som skyldes organiske syrer Ingen intensitet = ingen syrlig smak Tydelig intensitet = tydelig syrlig smak
Søtsmak	Relateres til grunnsmaken søt (sukrose) Ingen intensitet = ingen søtsmak Tydelig intensitet = tydelig søtsmak
Saltsmak	Relateres til grunnsmaken salt (NaCl) Ingen intensitet = ingen saltsmak Tydelig intensitet = tydelig saltsmak
Bittersmak	Relateres til grunnsmaken bitter (kinin, koffein) Ingen intensitet = ingen bittersmak Tydelig intensitet = tydelig bittersmak

Umami-smak	Relateres til grunnsmaken umami Ingen intensitet = ingen umami smak Tydelig intensitet = tydelig umami smak
Metallsmak	Smak av metall (ferrosulfat) Ingen intensitet = ingen metallsmak Tydelig intensitet = tydelig metallsmak
Meierismak	Smak av meieriprodukter som fløte og rømme Ingen intensitet = ingen meierismak Tydelig intensitet = tydelig meierismak
Kryddersmak	Smak av krydder, f. eks karri, pepper, muskat Ingen intensitet = ingen kryddersmak Tydelig intensitet = tydelig kryddersmak
Fiskesmak	Smak av fisk (laks) Ingen intensitet = ingen fiskesmak Tydelig intensitet = tydelig fiskesmak
Emmen smak	En ufrisk / kvalmende smak Ingen intensitet = ingen emmen smak Tydelig intensitet = tydelig emmen smak
Forsmak	Relateres til smaker av dyrefor Ingen intensitet = ingen forsmak Tydelig intensitet = tydelig forsmak

TEKSTUR

Hardhet	Mekanisk teksturegenskap relatert til kraft som må til for å bite gjennom prøven. Bedømmes ved 1.bitt Ingen intensitet = ingen hardhet Tydelig intensitet = tydelig hardhet
Fethet	Overflateteksturell egenskap relatert til oppfatningen av mengde fett i et produkt. Ingen intensitet = ingen fethet Tydelig intensitet = tydelig fethet
Sandet	Geometrisk teksturegenskap knyttet til partikkelstørrelse og partikkelform i et produkt. Ingen intensitet = ingen sandethet (glatt) Tydelig intensitet = tydelig sandethet
Sammenheng-barhet	Mekanisk strukturell egenskap relatert til den tid eller antall tygg som kreves for å tygge produktet til en tilstand klar for svelging. Ingen intensitet = ingen sammenhengbarhet (kort, smuldrete) Tydelig intensitet = tydelig sammenhengbarhet
Klebrighet	Mekanisk teksturegenskap relatert til kraften som skal til for å fjerne et stoff som kleber seg fast i munnen. Bedømmes etter at prøven er spyttet ut. Ingen intensitet = ingen klebrighet (lite av prøven sitter igjen i munnen) Tydelig intensitet = tydelig klebrighet (mye av prøven sitter igjen i munnen / vanskelig å fjerne prøven)
Astringent	Beskriver en kompleks følelse, fulgt av sammentrekninger, tørrfølelse, snurping av huden eller slimhinner i munnen, produsert av stoffer som tanniner (garvestoffer) fra slåpetornbær Ingen intensitet - ingen astringens Tydelig intensitet = tydelig astringens

BEDØMMELSE AV FISKEPRODUKT

Egenskapsforklaring

(Haddock, Stavanger)

LUKT

Melke lukt	Lukt av meieriprodukter som fløt og rømme Ingen intensitet = ingen melk-/fløtelukt
Fiskelukt	Lukt av fisk (hvitfisk) Ingen intensitet = ingen fiskelukt Tydelig intensitet = tydelig fiskelukt
Emmen lukt	En ufrisk / kvalmende lukt Ingen intensitet = ingen emmen lukt Tydelig intensitet = tydelig emmen lukt

UTSEENDE

Jevnhet	Relateres til jevnhet i prøven, prøven er homogen Ingen intensitet = ingen jevnhet (uhomogen) Tydelig intensitet = tydelig jevnhet (homogen)
Misfargning	Flekker/ujevnheter i farge som ikke er naturlig for produktet Ingen intensitet = ingen misfarging Tydelig intensitet = tydelig misfarging

SMAK

Saltsmak	Relateres til grunnsmaken salt (NaCl) Ingen intensitet = ingen saltsmak Tydelig intensitet = tydelig saltsmak
Bittersmak	Relateres til grunnsmaken bitter (kinin, koffein) Ingen intensitet - ingen bittersmak Tydelig intensitet = tydelig bittersmak
Melke smak	Smak av meieriprodukter som fløte og rømme Ingen intensitet = ingen meierismak Tydelig intensitet = tydelig meierismak
Kryddersmak	Smak av krydder, f. eks karri, pepper, muskat Ingen intensitet = ingen kryddersmak Tydelig intensitet = tydelig kryddersmak
Fiskesmak	Smak av fisk (hvitfisk) Ingen intensitet = ingen fiskesmak Tydelig intensitet = tydelig fiskesmak
Emmen smak	En ufrisk / kvalmende smak Ingen intensitet = ingen emmen smak Tydelig intensitet = tydelig emmen smak

TEKSTUR

Hardhet	Mekanisk teksturegenskap relatert til kraft som må til for å bite gjennom prøven. Bedømmes ved 1.bitt Ingen intensitet = ingen hardhet Tydelig intensitet = tydelig hardhet
Fethet	Overflateteksturell egenskap relatert til oppfatningen av mengde fett i et produkt. Ingen intensitet = ingen fethet Tydelig intensitet = tydelig fethet
Fibret	Geometrisk teksturegenskap knyttet til partikkelstørrelse og partikkelform i et produkt. Ingen intensitet = ingen fibrethet (glatt) Tydelig intensitet = tydelig fibrethet
Saftighet	Væske som skilles ut i prøven, munnfølelse etter flere tygg Ingen intensitet = tørr prøve Tydelig intensitet = høy grad av væskeutskillelse ved tygging
Sammenheng-barhet	Mekanisk strukturell egenskap relatert til den tid eller antall tygg som kreves for å tygge produktet til en tilstand klar for svelging. Ingen intensitet = ingen sammenhengbarhet (kort, smuldrete) Tydelig intensitet = tydelig sammenhengbarhet (seig)
Klebrighet	Mekanisk teksturegenskap relatert til kraften som skal til for å fjerne et stoff som kleber seg fast i munnen. Bedømmes etter at prøven er spyttet ut. Ingen intensitet = ingen klebrighet (lite av prøven sitter igjen i munnen) Tydelig intensitet = tydelig klebrighet (mye av prøven sitter igjen i munnen / vanskelig å fjerne prøven)

Appendix F

Table F. 1 Nutrient content / 100g of salmon (S,SFP) and haddock (H, HFP) products from pilot production.

Nutrient content /100g	S	SFP	H	HFP
Protein	17,8	18,1	15,9	16,1
Fat	27,6	27,5	18,4	18,4
Kilojoules (kJ)	1358	1330	986	958
Kilocalories (kcal)	328	321	237	231
Carbohydrates	2,2	2,1	2,2	2,1
Salt	0,9	0,9	1,0	1,0