



UPPSALA  
UNIVERSITET

*Digital Comprehensive Summaries of Uppsala Dissertations  
from the Faculty of Social Sciences 138*

## Rye bread in Sweden

*Health-related and sensory qualities, consumer  
perceptions and consumption patterns*

PERNILLA SANDVIK



ACTA  
UNIVERSITATIS  
UPSALIENSIS  
UPPSALA  
2017

ISSN 1652-9030  
ISBN 978-91-554-9847-4  
urn:nbn:se:uu:diva-316598

Dissertation presented at Uppsala University to be publicly examined in A1:111a, Biomedical Centre (BMC), Husargatan 3, Uppsala, Friday, 28 April 2017 at 13:15 for the degree of Doctor of Philosophy. The examination will be conducted in English. Faculty examiner: Professor Emerita Hely Tuorila (University of Helsinki).

### **Abstract**

Sandvik, P. 2017. Rye bread in Sweden. Health-related and sensory qualities, consumer perceptions and consumption patterns. *Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Sciences* 138. 97 pp. Uppsala: Acta Universitatis Upsaliensis. ISBN 978-91-554-9847-4.

Rye bread has shown potential as a health-beneficial component in the diet, especially in relation to non-communicable diseases. To have a beneficial effect in reality, however, it also needs to be available, chosen and eaten. Less research has focused on rye bread from a consumer perspective. The main aim was to investigate consumption patterns, health-related and sensory qualities and consumer perceptions of bread, more specifically commercial rye bread. In Study I, secondary analysis was performed on bread consumption data from a national dietary survey (n=1,435, 18-80 years). In Study II, commercial rye breads (n=24) were characterized by sensory descriptive analysis; the in vitro measurement fluidity index (FI) was used to predict glycemic properties, and chemical acidity was measured. Study III was a consumer test (n=398, 18-80 years), where acceptance and perceptions of nine rye breads were investigated. Study IV was a web-based and postal sequential mixed-mode survey (n=1,134, 18-80 years) with open-ended items covering health-related perceptions of bread. Consumers with the lowest intake of whole grain and rye bread were from younger age groups, families with children and groups with lower educational levels. Health-related and sensory properties of commercial rye bread varied widely. The FI indicated more beneficial glycemic properties in half of the samples and this was associated with a chewy, dry texture and sour flavor. The younger consumer group (18-44 years) differed in their liking compared to the older group (45-80 years) and displayed a preference toward bread with less whole grain and rye, although different clusters were identified. Rye bread liking was associated with bread type consumed in childhood, food choice motives and educational level. Most (75%) knew of bread they considered healthy. Coarse, whole grain, fiber, sourdough and rye were perceived to be good for the stomach, bowel and, to have good satiation and glycemic properties. Few health claims have been authorized, making it challenging for consumers to identify bread with these properties. Front-of-package label indicating rye bread was sometimes found on breads with very little rye flour. Sensory attributes, foremost textural and flavor, e.g., sourness, correlated with beneficial FI values and could thereby help guide consumers.

*Keywords:* national dietary survey, sensory analysis, preference mapping, sourdough, whole grain, public health, health promotion

*Pernilla Sandvik, Department of Food, Nutrition and Dietetics, Box 560, Uppsala University, SE-751 22 UPPSALA, Sweden.*

© Pernilla Sandvik 2017

ISSN 1652-9030

ISBN 978-91-554-9847-4

urn:nbn:se:uu:diva-316598 (<http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-316598>)

*Edo, ergo sum*



# List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

- I Sandvik, P., Kihlberg, I., Lindroos, A. K., Marklinder, I., & Nydahl, M. (2014). Bread consumption patterns in a Swedish national dietary survey focusing particularly on whole-grain and rye bread. *Food & Nutrition Research*, 58:24024-  
<http://dx.doi.org/10.3402/fnr.58.24024>
- II Sandvik, P., Marklinder, I., Nydahl, M., Næs, T., & Kihlberg, I. (2016). Characterization of commercial rye bread based on sensory properties, fluidity index and chemical acidity. *Journal of Sensory Studies*, 31, 283-295.
- III Sandvik, P., Nydahl, M., Marklinder, I., Næs, T., & Kihlberg, I. Different liking but similar healthiness perceptions of rye bread among younger and older consumers. (Revised and resubmitted).
- IV Sandvik, P., Nydahl, M., Kihlberg, I., & Marklinder, I. Consumers' health-related perceptions of bread – implications for labeling and dietary counseling. (Submitted).

Reprints were made with permission from the respective publishers.



# Contributions

The contribution of Pernilla Sandvik to the papers included in this thesis was as follows:

Paper I: Designed and planned the analysis in collaboration with co-authors. Withdrew and processed dietary survey data from the database, performed the statistical analyses. Main responsibility for writing and revising the manuscript, in collaboration with co-authors.

Paper II: Designed and planned the study in collaboration with supervisors. Acquired and handled bread samples. Recruited, trained and managed the sensory panel with support from supervisor. Performed statistical analysis with support from co-author. Main responsibility for writing and revising the manuscript, in collaboration with co-authors.

Paper III: Designed and planned the study in collaboration with supervisors. Responsible for data collection, supervising students aiding with sample preparation and data collection. Performed statistical analysis with support from co-author. Main responsibility for writing and revising the manuscript, in collaboration with co-authors.

Paper IV: Designed and planned the study in collaboration with supervisors. Managed data collection and processing, performed statistical analysis. Main responsibility for writing and revising the manuscript, in collaboration with co-authors.



# Contents

Background .....	13
Introduction.....	13
Investigating factors related to the consumption of rye bread with potential health benefits.....	15
Bread in the Swedish diet .....	16
Objective and subjective food quality.....	18
Health-related qualities of bread in general and rye bread in particular .....	20
A nutritional perspective .....	20
Nutrition recommendations, dietary guidelines and labeling.....	23
Consumers' health-related bread quality perceptions .....	25
Sensory qualities of bread in general and rye bread in particular .....	27
Connecting the product to the person.....	27
Sensory characteristics of rye bread.....	29
Consumers' sensory quality perceptions.....	30
Aim.....	33
Materials and methods.....	34
Secondary analysis of food survey data (Paper I).....	35
Characterization of commercial rye breads (Paper II).....	36
Consumer test of commercial rye breads (Paper III).....	39
Questionnaire exploring consumers' health-related perceptions of bread (Paper IV).....	40
Main statistical analyses and clustering.....	42
Ethical considerations.....	44
Findings.....	46
Consumption patterns for whole-grain and rye bread (Paper I).....	46
Sensory profiles, fluidity index and chemical acidity of commercial rye breads (Paper II) .....	47
Liking and perceptions of rye bread among younger and older consumers (Paper III).....	51
Consumers' health-related perceptions of bread (Paper IV).....	52

Discussion .....	55
Principal findings .....	55
A dietetic marketing perspective .....	55
Identification of target consumers .....	57
Availability and sensory characteristics of rye bread with potential health benefits .....	59
Sensory-related challenges and opportunities for consumption .....	60
The product meets the consumer .....	61
Consumer meets the product .....	62
Challenges and opportunities for communication of health-related bread characteristics .....	64
Implications in relation to the 4 Ps .....	66
Methodological considerations .....	69
Future perspectives .....	72
Conclusion .....	74
Svensk sammanfattning .....	76
Acknowledgement .....	82
References .....	84

# Abbreviations

EFSA	European Food Safety Authority
FCQ	Food Choice Questionnaire
FI	fluidity index
GI	glycemic index
GP	glycemic profile
NFA	National Food Agency
NCD	non-communicable diseases
NNR	Nordic Nutrition Recommendations
PCA	Principal Component Analysis
PCR	Principal Component Regression
PLS	Partial Least Squares Regression
WG	whole grain



# Background

## Introduction

“Of all foods bread is in truth the most noble. It is a food that is so necessary that we usually describe a true pauper with the words ‘he has not even a crumb of bread.’ It is served on the tables of both the rich and the poor, is beneficial in all diseases and suitable for all temperaments and it imparts a pleasant taste to food that is of itself tasteless. Therefore, since bread is so widespread and strengthens us and pleases our taste, I beg you distinguished reader, to not feel disturbed by paying attention to a dietetic investigation of bread.”

The above words were written 1757 by Carl von Linné and can be read in the introduction to his dissertation *De Pane Dietetico* (Linné, [1757] 1964, p. 1). Here, he systematically describes different types of bread and characterizes them according to their sensory and health-related qualities. Linné considered wheat bread “the most excellent of all,” especially when eaten as dry rusks, whereas bran bread was the most difficult to digest and contained the least amount of nutrients. He was aware that rye bread was less constipating than breads made from other cereals. He strongly warned against eating newly baked warm bread with butter and underpinned this with observations from Amsterdam, where consumption among citizens had led to stomach complaints, poor digestion, flatulence, hysterical afflictions and 600 other problems (Linné, [1757] 1964; Räsänen, 2007).

Research on the health-related qualities of different types of cereals and bread is still ongoing and highly relevant. Famine and malnutrition were the major nutritional struggles of the 18<sup>th</sup> century. Today, on the other hand, especially westernized society is facing the opposite dilemma. There is an abundance of food. Eating too much and making food choices in relation to our sedentary lifestyles instead constitute the challenge. Non-communicable diseases (NCD), such as cardiovascular diseases, diabetes and some types of cancer, have been on the rise for several decades, and by 2010 were found to account for 86% of deaths and 77% of the disease burden in Europe (WHO, 2016a). Non-communicable diseases are related to our lifestyle, and a high body mass index (BMI) is one major risk factor (Zimmet, Alberti, & Shaw, 2001). Since 1980, obesity has more than

doubled worldwide (WHO, 2016b). In 2015, almost one third (29%) of the women and even more of the men in Sweden (42%) reported being overweight, i.e. BMI 25-30, and 14% of both men and women were classified as obese, i.e. BMI >30 (PHA, 2016). Different dietary patterns have been associated with the risk of developing the metabolic syndrome that is considered a precursor of diabetes type 2 and cardiovascular disease (Hosseini, Whiting, & Vatanparast, 2016). The metabolic syndrome is defined as the prevalence of central obesity together with any two of the following conditions: raised triglycerides, reduced HDL cholesterol, raised blood pressure or raised fasting plasma glucose (Alberti, Zimmet, Shaw, & Group, 2005). A lower risk of developing the metabolic syndrome has been associated with dietary patterns characterized by, e.g., higher dietary fiber intake (Maghsoudi & Azadbakht, 2012). Diets that contribute to a reduction in postprandial glycaemia and insulinemia have also been shown to reduce the risk of these conditions (Augustin et al., 2015).

Historically, bread has been and still is an everyday food in many parts of the world. There has been much debate in the Swedish media since the early 2000s regarding the health benefits of lowered consumption of carbohydrate-rich foods (Mann & Nye, 2009; Holmberg, 2015). Bread is the primary source of carbohydrates in most parts of Europe and is also an important source of whole grain and fiber, especially in the Scandinavian countries (Cust et al., 2009; Kyrø et al., 2012). The composition of bread can however vary widely, and from a health perspective it is therefore relevant to differentiate between different bread types. Worldwide, wheat is the most common basis for bread baking, but other cereals are also used. Breads based on or containing rye are most commonly seen in northern, central and eastern Europe and the US (Cauvain, 2015). Research has revealed many positive health benefits of rye, especially related to NCDs, and thus rye bread is often described as a healthy component of the Nordic diet (Åman, Andersson, Rakha, & Andersson, 2010; Olsen et al., 2011; Adamsson et al., 2012). Although the Nordic countries and eastern Europe are often called the “rye belt,” the consumption of rye in Sweden has steadily been declining. Statistics from the Swedish board of agriculture show that the total consumption of rye flour, for use both in industry and directly by consumers, has decreased from 15 kg per person and year in 1960 to six kg per person and year in 2015 (BOA, 2016).

For rye bread to have a potential beneficial health effect, it needs to not only be available, but also chosen, liked and eaten by consumers. In contrast to the greater number of studies on the nutritional aspects of rye and rye-based products, such as bread, there has been less focus on the consumer perspective. This is a gap that the present thesis attempts to bridge.

## Investigating factors related to the consumption of rye bread with potential health benefits

The present thesis investigates factors related to the potential of rye bread to be a health-beneficial component in the Swedish diet. Thereby it contributes knowledge for development of strategies to support consumption of rye bread from a public health perspective, e.g., through interventions, policy- and product development or dietary counseling. First, the patterns of bread consumption in Sweden are investigated; second, the health-related and sensory characteristics of commercial rye bread in Sweden are described, third, consumers' sensory liking of these breads is studied and, fourth, also their health-related perceptions of bread.

Models that attempt to explain food choices are often multifaceted and complex. The Food Choice Process Model by Sobal, Bisogni, Devine, and Jastran (2006), for example, was inductively constructed based on qualitative interviews with consumers and incorporates multiple perspectives. The model includes components related to the *life course* (e.g., transition, turning-points and historical context), *influences* (ideals, resources, present context, personal and social factors), and *personal food systems* (food choice values people bring to food choice, e.g., taste, cost, health, convenience, relationships). This illustrates the many different factors affecting what we eat, and it motivates the interdisciplinary approach of the present work. Here, *some* challenges and opportunities related to the consumption of rye bread with potential health benefits are identified.

In line with a doctoral thesis in the same field, focusing on consumption and perceptions of fruit and vegetables from a public health perspective (Simunaniemi, 2011), concepts and ways of thinking from social marketing have been incorporated. Social marketing is a framework used in public health programs where commercial marketing techniques are applied to influence the voluntary behavior of a target audience, the aim being to improve their personal welfare and that of society (Kotler & Zaltman, 1971; Andreasen, 1994; Lefebvre, 2011). An initial step is consumer research and market analysis, and this is where the present thesis has its focus (Rimer & Glanz, 2005). Here, internal and external factors that may influence consumer behavior are studied, which in turn will aid in identifying potential solutions to the social issue in focus (Da Silva & Mazzon, 2016). Social marketing intervention strategies are tailored to the wants, needs, resources, and current behaviors of different market segments and, therefore, identifying different consumer groups is an important step (Lee & Kotler, 2016).

Simply telling people to change their diets and eat healthier often does not produce the incentive required (Cawley, 2004). Social marketing emphasizes a voluntary behavior change, thus, that consumers will choose a behavior in exchange for receiving benefits they consider valuable and/or through a reduction in relevant barriers (Pettigrew, 2016). With regard to food, people may for example be reluctant to forsake the hedonic aspect, and thus the sensory perspective is important in promoting healthy eating (Ares & Gambaro, 2007; Tuorila & Monteleone, 2009). Identification of sensory barriers to the acceptance of healthful food has therefore been described as central to targeting product development and nutritional counseling (Tuorila, 2000). Results from the studies in this thesis enable identification of different consumer segments and describe the availability of rye bread in relation to consumers' sensory liking and health-related perceptions as well as the association between different rye bread liking and consumer background variables. Program development in social marketing involves identifying a "marketing mix" of Product, Price, Place, and Promotion (4 Ps) that heightens benefits, reduces barriers, and offers a better choice than the competition, thereby increasing the chance to influence behavior (Grier & Bryant, 2005). In the thesis, these 4 Ps are used to discuss the potential implications of the results from the studies included.

## Bread in the Swedish diet

Let us continue with a short overview of bread in the Swedish diet, both from a historic and a present-day perspective. Traditionally, cereal types other than wheat have been most frequently used in Sweden, and at the end of the 19<sup>th</sup> century, the typical Swede still used mainly rye, barley or oat to make his daily bread (Campbell, 1950). Peasants, especially in the northern part of Sweden, often baked storage bread types twice a year. Based on the bread consumption around 1880, Campbell (1950) classified Sweden into four bread regions. Unfermented soft barley bread (e.g., rieska) was common in the northernmost part of Sweden, and moving a bit farther south it was hard barley bread (e.g., thin bread). In the coastal part of northern Sweden, Svealand and the northern part of Götaland, fermented hard rye bread was most common, while soft rye bread was common in the southernmost part of Sweden. Cities, however, have always had a wider variety of bread types. During the shift to a modern urban and industrialized society, bread types changed when large industrial bakeries introduced new soft breads with more refined wheat flour, which from the early 1920s was often sweetened. It has been noted that there was a flour deficiency during

World War I. But given good availability of beet sugar, bakeries were urged to instead add more sugar, which would increase the energy value in times of rationing (Notaker, 2009). From that point on, bread was often bought from stores and bakeries, rather than baked at home, and thus the regional variation decreased. Other cultures have also influence the range of bread in Sweden both through immigration as well as tourism and some examples are, breads eaten with falafel, kebabs and hamburgers (Carlsson-Kanyama & Lindén, 2001).

The Swedish Board of Agriculture calculates per capita statistics for food consumption through *direct consumption* in households and among caterers as well as *total consumption*, which includes the delivery of raw material, such as flour, to industry (BOA, 2016). Breads in Sweden are often broadly categorized into soft and dry crisp bread. Per capita statistics show that direct consumption of dry crisp bread has declined, from 7 kg per person and year in 1960 to 4 kg in 2015 (BOA, 2016). Conversely the consumption of soft bread has increased from 31 kg per person and year in 1960 to 53 kg in 2015. The direct consumption of prefabricated bread has steadily been increasing, from 38 kg per person and year in 1960 to 56 kg in 2015, while household consumption of flour has decreased from 19 kg per person and year in 1960 to 9 kg in 2015 (BOA, 2016). This indicates that most of the bread is baked outside the home and that industry plays an important role in what type of bread is consumed. The number of bakeries in Sweden has also been decreasing, from around 4700 in 1960 to around 1000 in 2012, but around this time, a rise in the number of smaller bakeries became observable (Fagerlind, 2012). Today, older bread types still exist alongside new ones and new varieties of different breads are constantly being launched. Rye bread is a traditional bread type in Sweden, but as stated in the introduction, the total consumption of rye flour has steadily been decreasing and today a mix of wheat and rye flour is most commonly seen in commercial bread. This is also one reason why studying the intake of rye bread in Sweden is a challenge. There is a wide selection of bread types, which are sold both prepackaged and unpackaged, straight from bakeries or through bake-off systems in supermarkets and at gas stations. Common ingredients often highlighted on bread packages today are e.g., seeds, sea salt, sourdough, berries and root vegetables. Emotionally appealing, fantasy commercial bread names such as “Happiness” (Glädje) and “Longing” (Längtan) are common.

The National Food Agency (NFA) studies food consumption through national dietary surveys. In Riksmaten 2010-11, 98% of respondents reported having eaten bread, and the total reported consumption of bread was 75 g/day (SD 41) for women and 102 g/day (SD 55) for men,

approximately 2-4 slices a day (Amcoff, 2012a). Overall, bread contributed to on average 11% of the total energy intake, 28% of the total fiber intake and 51% of the total whole grain intake. Even so, only 12% of participants reached the recommended intake of whole grain, and only one out of three the recommended intake of fiber (Amcoff, 2012a). The NFA has presented overall results on bread consumption from the dietary survey. Studies on consumers of different types of bread and the context of bread consumption have however not previously been conducted in a national representative setting in Sweden. An in-depth analysis of this, already available, bread consumption data would provide a more detailed description of both consumption and consumer patterns related to this specific food group.

## Objective and subjective food quality

Quality has been described as a core concept in building consumer value and satisfaction and is, thereby, a relevant concept for investigation of consumer perceptions, choice and consumption of rye bread (Oude Ophuis & Van Trijp, 1995). It is a complex concept that includes many different aspects; the combination of nutritional and sensory qualities has been described as biological quality and as representing the essential core of food quality (Peri, 2006). Food quality can be divided into objective and subjective/perceived food quality. Objective quality refers to the physical characteristics built into the product and is typically dealt with by engineers and food technologists. Subjective quality, on the other hand, is the quality perceived by consumers (Brunso, Fjord, & Grunert, 2002). From a subjective perspective, food quality is often classified into four dimensions of importance to consumers: hedonic, health-related, convenience-related and process-related dimensions (Grunert, Bech-Larsen, & Bredahl, 2000). Hedonic quality, often casually referred to as “taste,” is related to sensory pleasure and is therefore mainly linked to the appearance, odor, texture and flavor of the food. Health-related quality is concerned with the ways in which consumption will affect consumer health. Convenience-related quality concerns the time and effort that must be expended when buying, storing, preparing and consuming the product. Process-related quality refers to characteristics of the production process consumers are interested in, such as organic production or animal welfare. More specifically, hedonic and health-related qualities have been shown to be the two most important dimensions in consumers’ quality perception of bread (Dewettinck et al., 2008), and these two quality aspects are the main focus of the present thesis.

Hedonic quality is described as an experience quality dimension, because it is experienced and evaluated by the consumer when eating the product. Health-related quality, on the other hand is described as a credence quality dimension, because it most often cannot be directly experienced by the consumer. Thereby, perceptions related to credence quality attributes are mainly based on communication (Oude Ophuis & Van Trijp, 1995; Grunert et al., 2000). However, because food most often cannot be tasted before it is purchased, consumers need to create quality expectations about the product, especially when the evaluated product is new and the consumer cannot draw on previous experiences. These quality expectations are most often based on inferences from the information available, and in the process of evaluating the quality of a product, consumers use different cues and connect these to quality attributes (Steenkamp, 1990). Two types of quality cues are described: intrinsic and extrinsic. Intrinsic quality cues are related to the physical product itself, for example appearance, shape, color and structure, while extrinsic quality cues are aspects such as price, brand, store and labeling (Oude Ophuis & Van Trijp, 1995). The formation of a specific individuals' quality judgments is, in addition to the product, related to for example personal and situational factors (Steenkamp, 1990).

The relationship between objective and subjective quality is of importance. It is only when producers can translate consumer wishes into physical product characteristics, and when consumers can infer desired qualities in the product, that quality will be a competitive parameter (Grunert, 2007). To adjust quality to the wants and needs of consumers, it is important to identify consumer-relevant quality indicators and attributes and their relations with physical product parameters. This is a prerequisite for successful product development in the food sector, but is also important from a health policy perspective (Grunert, 2007). Sensory science offers methods that can bridge the gap between the physical characteristics of the product and consumer perceptions (Martens, 1999), and this is further discussed in the section on sensory qualities.

Most bread consumed today is produced outside the home, by large scale bakeries, and is purchased in supermarkets. Commercial companies thereby affect consumption by deciding which products should be available and how they should be marketed (Marshall, 2001). The primary goal of business is most often not to provide food with potential health benefits, but to make a financial profit. However, companies may also aim to “do good” through, e.g., corporate social responsibility (Carroll, 2016), and partnerships between industry, government and academia have been emphasized as important to increasing the availability of desirable and healthful cereal foods (Ferruzzi et al., 2014). Traditional marketing focuses

on giving consumers short-term benefits but short-term benefits (e.g., hedonic pleasure) have been described as not always being in line with consumers' long-term interests (e.g., lasting health). Kotler (1971) describes how companies may consider not only customer satisfaction and profitability, but also long-term consumer welfare. He classifies products in four categories: i) *desirable products*, which are those that combine immediate satisfaction with long-term benefits; while ii) *pleasing products* give immediate satisfaction, but cause harm in the long-run; iii) *salutary products* give long term benefits but no immediate satisfaction and iii) *deficient products* offer neither. Feurst (1991) provides examples of this in the area of food: fresh fruit is *desirable*, cough drops are *pleasing*, whole-wheat crackers are *salutary*, and broiler with fish taste is *deficient*.

## Health-related qualities of bread in general and rye bread in particular

In the next section, health-related quality characteristics of bread and more particularly rye bread are shortly reviewed. First, objective quality from a nutritional perspective is in focus, and extra attention will be paid to the postprandial glycemic and insulin response to rye bread. This refers to the levels of glucose in the blood after consumption of a food and the amount of the hormone insulin that is secreted to control these raised blood glucose levels. Second, this section focus on how health-related bread quality is communicated through recommendations, dietary guidelines and labeling, and third, on consumers' subjective health-related quality perceptions.

### A nutritional perspective

Important attributes for cereal products promoted as being healthy from a nutritional perspective have been summarized as follows: a high whole grain and dietary fiber content and a low salt, added sugar and saturated fat content (Poutanen, Sozer, & Della Valle, 2014). With regard to physiological functionality, the cereal products should contribute prebiotic potential, increased gastrointestinal transit rate and fecal weight, as well as promote satiation and a slow glycemic response (Poutanen et al., 2014). In the case of bread, these physiological functionalities can be achieved in different ways. High fiber content is related to beneficial gastrointestinal effects and can be achieved either by using fiber-rich cereals or by supplementing with bran or other fiber sources (Anderson, Baird, & Davis, 2009; Poutanen et al., 2014). The structure is important for satiety and is

affected by, for example, the dietary fiber present in the grain (Isaksson et al., 2011). Moreover, sourdough fermentation, whole cereal kernels, and viscous fiber are examples of attributes that may positively affect the glycemic response (Liljeberg, Lönner, & Björck, 1995; Fardet, Leenhardt, Lioger, Scalbert, & Remesy, 2006).

The chemical composition, process-induced changes, bioavailability, and physiological responses associated with rye foods have been extensively studied, especially in the Nordic countries during the past 20 years, and several health benefits have been described for rye (Poutanen & Åman, 2014). Rye is a fiber-rich cereal, containing approximately 20 g fiber per 100 g calculated on dry matter (Frølich, Åman, & Tetens, 2013). In comparison, wheat contains 14 g, oat 10 g and barley 15 g fiber.

Rye has shown potential health benefits related to, for example, the bowel (Gråsten et al., 2000; Hongisto, Paajanen, Saxelin, & Korpela, 2006; Gråsten et al., 2007; Holma, Hongisto, Saxelin, & Korpela, 2010), favorable blood lipid concentration outcomes (Leinonen, Poutanen, & Mykkänen, 2000; Magnúsdóttir et al., 2014) and factors related to reduced risk of breast and prostate cancer (Adlercreutz, 2010; Landberg et al., 2010). As described by Landberg, Kolehmainen, Poutanen, Mykkänen, & Hallmans (2014), bread made from whole-grain or endosperm rye both with and without sourdough, as compared to white wheat bread, has also been shown to promote an improved postprandial glycemic profile, indicating low but prolonged blood-glucose response, lower insulin concentrations in the blood, a decreased appetite rating after breakfast and lowered intake at a subsequent voluntary lunch (Leinonen, Liukkonen, Poutanen, Uusitupa, & Mykkänen, 1999; Juntunen et al., 2002; Juntunen et al., 2003; Kallio et al., 2008; Isaksson, Fredriksson, Andersson, Olsson, & Åman, 2009; Rosén et al., 2009; Bondia-Pons et al., 2011; Rosén, Östman, & Björck, 2011; Johansson, Lee, Risérus, Langton, & Landberg, 2015). The mechanisms underlying these beneficial effects of rye are not yet fully understood, but, have been described to most likely be mediated by the content of viscous dietary fiber and structural properties, but have also been suggested to be due to bioactive compounds present in the rye kernel, and colonic fermentation may explain the second meal effects (Juntunen et al., 2003; Isaksson et al., 2009; Rosén, 2011).

Traditionally, rye bread has often been baked with whole meal flour, and whole grain consumption has been related to health benefits such as reduced risk of coronary heart disease, insulin resistance and type 2 diabetes, undesired weight gain, and colorectal cancer (Aune et al., 2011; Ye, Chacko, Chou, Kugizaki, & Liu, 2012; Aune et al., 2016). Sourdough fermentation has also traditionally played an important role in rye bread

baking (Cauvain, 2015). It has the potential to improve mineral availability and reduce starch digestibility (Poutanen, Flander, & Katina, 2009). The beneficial effect on starch digestibility, and thereby the glycemic response, has been attributed to effects of the organic acids formed, mainly lactic and acetic acids and a subsequently lowered pH, for example, in the range 3.8–5.1 and acidity-induced solubilization of dietary fiber (Liljeberg et al., 1995; Katina et al., 2007; Katina & Poutanen, 2013).

The Glycemic Index (GI) ranks carbohydrates according to their blood-glucose-raising potential in the 2 hours' postprandial period (Jenkins et al., 1981). The low but prolonged blood-glucose response to rye products may, however, result in unfairly high GI values (Rosén et al., 2011). To describe the glycaemia in the later postprandial phase (beyond 2 hours) as well, the glycemic profile (GP) was introduced and defined as the duration of the glucose curve above the fasting concentration divided by the incremental glucose peak (Rosén et al., 2009). The above *in vivo* measurements require multiple blood samplings from several individuals for each tested bread product. The fluidity index (FI) – an *in vitro* measure developed by Östman, Rossi, Larsson, Brighenti, and Björck (2006) – has been suggested as a tool for assuring the quality of the glycemic properties of bread by measuring the physiologically relevant viscosity of the bread sample (Östman et al., 2006; Ekström, Björck, & Östman, 2013). By studying the correlations between FI, GI, GP and insulin response, Ekström et al. (2013) showed that the FI was highly correlated with all three measurements. However, the FI mainly takes into account the effect of viscosity in the bread which may affect the blood sugar and insulin response.

Many commercially available types of bread have been described as having an unfavorable GI (Björck, Liljeberg, & Östman, 2000; Atkinson, Foster-Powell, & Brand-Miller, 2008). The glycemic properties of only a few commercial rye breads in Sweden have previously been investigated (Liljeberg & Björck, 1994; Hlebowicz et al., 2009; Johansson et al., 2015). It should be emphasized that the present study does not explore factors that may affect the glycemic properties of bread. In the present thesis, the FI of commercial rye breads in Sweden is investigated and compared to the FI of experimental rye breads that have previously been shown to display beneficial glycemic properties, as measured by postprandial insulin and glucose responses (Rosén et al., 2009). Thereafter, FI and other factors characterizing healthy cereal products (such as whole grain, fiber, low sugar content) are studied in relation to the sensory characteristics of rye bread on the Swedish market.

## Nutrition recommendations, dietary guidelines and labeling

Authorities communicate information concerning the objective, health-related quality of bread with consumers primarily through recommendations, guidelines and labeling. This information may not only guide consumers in choosing healthier products, but also affect the objective quality of products offered to consumers by encouraging companies to reformulate existing products and develop new ones with healthier compositions (Vyth, Steenhuis, Roodenburg, Brug, & Seidell, 2010). Table 1 shows current recommendations, guidelines and nutrition and health claims relevant to rye bread in Sweden. Although carbohydrate quality is mentioned in the Nordic Nutrition Recommendations (NNR) 2012, recommendations on glucose or insulin regulation, or more specifically GI, are not included, with the motivation being that it is unclear how much additional benefits a low-GI diet may offer after compliance with recommendations to increase intake of dietary fiber, whole grain, legumes, fruits and vegetables (Overby, Sonestedt, Laaksonen, & Birgisdottir, 2013; Nordic Council of Ministers, 2014). In a recent scientific summit on the health effects of carbohydrate quality, however, an expert panel concluded that given the high prevalence of diabetes and prediabetes world-wide and the consistency of the scientific evidence reviewed, there is an urgent need to communicate information on the association between reduced post-prandial glycaemia and health to the general public as well as to health professionals, through channels such as national dietary guidelines, food composition tables and food labels (Augustin et al., 2015).

No application of a health claim in relation to the postprandial glucose or insulin response associated with rye bread has yet been approved by the European Food Safety Authority (EFSA). In one application, the panel considered that rye bread not had been sufficiently characterized (EFSA, 2011a); in another, it was concluded that there was a lack of studies showing a cause-effect relationship for the effect of rye fiber (EFSA, 2011b) and; in a third, glucose used as a reference was not considered to be a relevant comparison to high-fiber sourdough rye bread (EFSA, 2014). There are several definitions of whole grain and because of this, EFSA has not considered the term whole grain to be sufficiently characterized and thereby no health claim in relation to whole grain has been approved (EFSA, 2010). The NFA defines whole grain as the whole-grain kernel (endosperm, germ, and bran); the kernel may be ground, crushed or similar, but the components should be included in their original proportion for the respective grains (Becker, Busk, Mattisson, & Sand, 2012). Grains refer to wheat, spelt, rye, oats, barley, maize, rice, millet sorghum and other

sorghum varieties. Other definitions also include pseudo-cereals such as buckwheat, amaranth and quinoa and the allowance of small losses of components – that is, less than 2% of the grain or 10% of the bran (van der Kamp, Poutanen, Seal, & Richardson, 2014).

*Table 1. Recommendations, guidelines and nutrition claims and authorized healthclaims relevant to rye bread*

Authority	Recommendation, guideline, nutrition or health claim
The Nordic Nutrition Recommendations 2012 (Nordic Council of Ministers, 2014)	Food pattern recommendations: Decrease energy density, increase micronutrient density and improve carbohydrate quality. Diets dominated by naturally fiber-rich plant food, whole grain and whole-meal flour are encouraged. <ul style="list-style-type: none"> <li>- Whole grain, 70 g for women and 90 g /day for men</li> <li>- Dietary fiber <math>\geq</math> 25g per day for women and <math>\geq</math> 35 g/day for men</li> <li>- Sugar &lt; 10 energy percent</li> </ul>
Swedish dietary guidelines (NFA, 2016)	<ul style="list-style-type: none"> <li>- Choose Keyhole labeled products<sup>1</sup></li> <li>- Choose bread, cereals, grains, pasta and rice with a lot of whole grain</li> </ul>
Guidelines for public meals in Sweden (NFA, 2017)	Preschool & school: <ul style="list-style-type: none"> <li>- Baking will contribute the appealing odor of newly baked bread</li> <li>- Good if the school provides possibilities to teach liking of whole-grain products</li> <li>- Provide different types of bread, at least half should be labeled with the Keyhole (School)</li> <li>- Serve whole grain products sometimes (Pre-school)</li> </ul> Elderly care: <ul style="list-style-type: none"> <li>- Type of bread served should be adjusted according to the elderly persons' needs and wishes</li> </ul>
Nutrition claims in the EU (EFSA, 2017)	High in fiber (bread with $\geq$ 6 g fiber/100 g) Source of fiber (bread with $\geq$ 3 g fiber/100 g)
Authorized health claims in the EU (EFSA, 2011b)	Rye fiber contributes to normal bowel function (in rye products high in fiber, see definition above)

<sup>1</sup>According to LIVSFS 2009:6, the keyhole symbol may be used for soft/dry crisp bread with  $\geq$ 25 /  $\geq$ 50% whole grain (on dry weigh) and per 100 g  $\leq$ 7 g fat,  $\leq$ 5 g sugars,  $\leq$ 0.5 g Na and  $\geq$ 5 /  $\geq$ 6 g dietary fiber. The regulation was updated in LIVSFS 2015:1 to 30% whole grain for soft bread, and specifications for rye bread were included. Rye bread labeled with the Keyhole should contain  $\geq$  30% rye flour,  $\geq$ 35% whole grain  $\geq$ 6 g fiber and salt  $\leq$ 1.2 g.

In addition to nutrition and health claims, other information that industry may communicate to consumers with regard to food is also regulated. According to EU food law, information on food packages should not be

misleading, and all the requirements are specified in Regulation (EU) No. 1169/2011 (European Commission, 2011). In the regulation, “food information” is defined as information concerning a food made available to the final consumer by means of a label or other accompanying material. According to the principle of quantitative ingredient declaration, ingredients that are emphasized on the product’s package or that could be considered an important ingredient based on tradition should be specified in the ingredient list (Regulation EU No. 1169/2011). It has been shown, however, that consumers seldom study this mainly back-of-package information (Sørensen, Clement, & Gabrielsen, 2012). Because of the endless possibilities to vary ingredients, classification of breads is a challenge. Except for the very recent regulation that a rye bread with a Keyhole label must contain 30% rye (LIVSFS 2015:1), there is no direct standardized definition of different bread types in Sweden, for example concerning how much rye a “rye bread” should contain or what should characterize a “sourdough bread.” In epidemiological studies, bread is sometimes described as “dark,” but due to the fact that what is classified as dark may vary, this decreases the validity of the results (Roswall et al., 2014). Similarly, there is no set definition of how much whole grain a “whole-grain bread” should contain (Ferruzzi et al., 2014; Korczak et al., 2016), although a sectoral agreement in Sweden implies that the cereal content of a “whole-grain bread” should include a minimum of 50% whole grain (Sveriges bagare och konditorer, 2014). It has been suggested that the term needs to be defined, especially for use in epidemiological studies (Serra-Majem & Bautista-Castaño, 2015). Little is known about what type of bread consumers would perceive as, for example a rye bread or whole-grain bread or what they would perceive as healthy attributes in a bread.

### Consumers’ health-related bread quality perceptions

A Pan-European survey of consumer attitudes toward food, nutrition and health based on representative samples in 15 countries showed that eating healthily was perceived to be among the top five influences on food choice in all countries, together with taste, freshness, price and family preferences (Lappalainen, Kearney, & Gibney, 1998). The importance of health in food choice is affected by, for example, the individuals’ health concerns and has especially been associated with women, older age groups and higher educational levels (Kearney, Kearney, Dunne, & Gibney, 2000; Ares & Gambaro, 2007; Sun, 2008). The Food Choice Questionnaire (FCQ) can be used to investigate the perceived importance of different motives for food choice one of which is *health*, together with *sensory appeal*, *natural*

*content, ethical considerations, price, mood, convenience, weight concerns and familiarity* (Steptoe, Pollard, & Wardle, 1995). The FCQ has been shown to be a suitable tool for exploring food choice motives in different European populations, but has not previously been applied in Sweden (Markovina et al., 2015).

Food can be described as affecting our health from different perspectives, such as nutritional, esthetic, social, cultural and symbolic meaning, as well as indirectly through ecological, social and other consequences (Siipi, 2013). The way in which consumers subjectively perceive the healthiness of a food may be different from the perspective of for example a nutritionist or dietician. Consumers have subjective ideas about what healthy food is and develop their own indicators of healthiness when making food purchase decisions. These are based on information accumulated over their lifetime, which is sometimes not in accordance with objective health considerations (Brunsø et al., 2002; Gomez, 2013). Consequently, gaining insights into how consumers evaluate the health-related quality dimension of food – that is, which cues they use to infer healthiness, and how they perceive the healthfulness of different foods – is important, for example, with regard to how health-promotion messages are interpreted and put into practice. Several research studies have focused on consumer perceptions of healthy eating from an overall perspective, but less is known about consumer perceptions of grain products, such as bread, and their perceived role in a healthy dietary pattern (Paquette, 2005; Bisogni, Jastran, Seligson, & Thompson, 2012).

Gunnarsson and Elam (2012) discuss how the ‘low-carb-high-fat’ (LCHF) movement achieved a level of public credence and credibility though it lacked an established scientific basis for its dietary advice. It is not clear whether the Swedish media debate about carbohydrate-rich foods and their health effects may have affected the consumption or perception of bread (Mann & Nye, 2009; Holmberg, 2015). A longitudinal intervention program in northern Sweden showed a trend break involving decreased reported intake of carbohydrates and an increased intake of fat beginning in 2004 which the researchers discussed and thought might be related to the LCHF movement (Johansson et al., 2012).

Previous research on consumers’ health-related perceptions of cereals has mainly focused on whole grain and fiber. A cross-European study showed that, on the whole, consumers perceived that whole grain products were healthier than refined grain products (Arvola et al., 2007). Consumers in Finland differentiated more between the whole-grain and refined product categories than consumers in the UK and Italy did, suggesting lower incentive to increase whole grain consumption in these countries. Another

study showed that Swedish adolescents (11-15 years) perceived fiber content in bread to be an important health attribute (Berg, Jonsson, Conner, & Lissner, 2002).

Although health may be perceived as important, the health dimension may, in the consumer's mind, be in conflict with other quality dimensions. A food tasting good and being healthy may, for example, be perceived as mutually exclusive (Roininen et al., 2001).

## Sensory qualities of bread in general and rye bread in particular

Because consumers most often do not compromise on sensory pleasure, to promote health it is crucial to focus not only on the health-related but also on the sensory qualities of food products (Verbeke, 2006). The next section gives a brief introduction to sensory food science and thereafter describes previous research on sensory characteristics and consumer liking of rye bread. Sensory analysis offers methods to reduce the gap between the objective and the subjective food quality described above and can also be used to reduce a potential gap between sensory and health-related quality attributes.

### Connecting the product to the person

Sensory food science is a discipline that deals with human sensory perceptions of and affective responses to foods, beverages and their components (Tuorila & Monteleone, 2009). Sensory evaluation is the central method of analysis in sensory food science and has been defined as a scientific method used to evoke, measure, analyze, and interpret reactions to the characteristics of foods and materials as they are perceived by the senses of sight, smell, touch, taste, and hearing (Stone & Sidel, 2004). Two types of sensory evaluation methods are descriptive and affective methods (Lawless & Heymann, 2010). Descriptive analyses are objective and analytical and they quantify the perceived intensities of products' sensory characteristics; affective testing is hedonic and attempts to quantify the degree of liking or disliking of a product among consumers.

Martens (1999) described the interdisciplinarity of sensory science and the interconnections to other research fields; this is illustrated in Figure 1. She describes how sensory science concerns product-person relations along a continuum and bridges various disciplines, e.g., from chemistry to cognitive psychology and marketing. The first interface, connecting

sensory science with natural science and technology, deals with product-person relations, linking the physiochemical properties of food to sensory properties. The second interface connecting sensory science to behavior science and the humanities deals with person-person relations, e.g., linking the descriptive responses to affective responses of consumers (Martens, 1999).

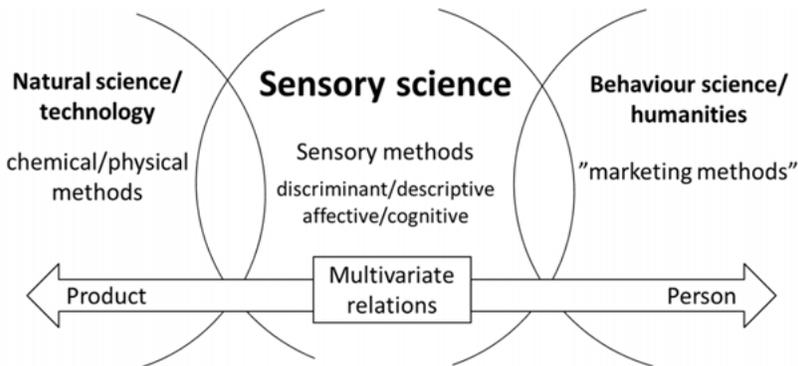


Figure 1. The interrelationship of sensory science and other disciplines. Modified from Martens (1999)

The sensory quality of bread (and other food products) is registered by the human senses of sight, touch, smell, taste and hearing. The attributes are typically perceived in the order of: appearance – e.g., the color, size, shape and surface texture of the bread; odor – volatile compounds sniffed through the nose, e.g., sour or roasted odor; texture – mechanical properties, e.g., chewiness; geometrical properties, such as, heterogeneity or moisture properties such as juiciness; and flavor – including aromas perceived via the posterior nares, taste caused by soluble substances in the mouth (e.g., salty, sour, sweet and bitter) and the chemical feeling factors (Meilgaard, Civille, & Carr, 2007). The stimulus hits the sense organ and is converted to a nerve signal that is sent to the brain. With previous experience in memory, the brain interprets, organizes, and integrates the incoming sensation into perceptions. Finally, a response is formulated based on the subject's perceptions.

Sensory food science contributes to a better understanding of reasons for acceptance or rejection of food and is a valuable tool in product development. The sensory perspective on healthful eating is also important and raises the question of how to best enhance liking of healthful foods (Drewnowski, 1997; Tuorila & Monteleone, 2009).

## Sensory characteristics of rye bread

Descriptive sensory analyses provide a complete sensory description of products, also called sensory profiles, which can be used to pinpoint differences among products, to identify associations with ingredients or other product variables and/or to determine which sensory attributes are important to consumer acceptance (Lawless & Heymann, 2010). A generic descriptive analysis usually consists of 8-12 panelists who have been trained, in the use of reference standards and in how to understand and agree on the meaning of the attributes employed. A quantitative scale is usually used for intensity ratings, and the panelists are not asked for their hedonic responses to the products. There are, however, several different methods to describe sensory attributes associated with a product, and more recently, untrained consumers have also been used to obtain sensory product profiles (Varela & Ares, 2014).

The sensory characteristics of bread depend on the ingredients and the process applied (Heiniö, 2006). Heiniö, Liukkonen, Katina, Myllymäki, and Poutanen (2003) studied the sensory attributes of different rye fractions in three test breads. One fifth (20%) of the wheat flour was replaced by a specific rye fraction. The endospermic fraction induced a very mild flavor in the mixed wheat bread, resembling pure wheat bread. A bitter, intense flavor and aftertaste was perceived as being most salient in the bread containing the bran fraction. The intermediate shorts fraction was the most important fraction in producing a cereal-like but not bitter flavor, and the color intensity of the bread samples increased from the endospermic layer to the bran layer (Heiniö et al., 2003). Most nutritional research on rye bread has been performed with rye bread baked with whole-grain rye, and the sensory characteristics of whole-grain and bran-rich cereal foods were recently reviewed in detail by Heiniö et al. (2016). Whole-grain products include the outer layers of the grain, which contain several non-volatile, flavor-active substances. Lignocellulosic layers, large particles and insoluble fiber may cause a hard and gritty texture in a product. High dietary fiber content decreases loaf volume, increases hardness of crumb, decreases crispiness, changes color and causes aftertaste in baked products. The color of bran is often dark, which is suggested to be caused by polyphenols, and is often associated with bitter or astringent taste (Heiniö et al., 2016). Sourdough has traditionally been used in rye bread baking and has been described as an essential ingredient for ensuring the baking properties of doughs containing more than 20% of rye flour (Arendt, Ryan, & Dal Bello, 2007). The solubility and swelling properties of pentosanes in rye increase at low pH values, and the texture of rye bread is thereby improved by sourdough fermentation. The acidification improves the

physical properties of the rye doughs by making them more elastic and extensible, and it contributes to acidic flavor notes (Arendt et al., 2007). In addition to the extraction rate of the rye flour and the method of fermentation, the sensory profiles of rye breads are also dependent on, for example, the inclusion of other ingredients such as wheat or other flours, seasonings and the baking conditions (Cauvain, 2015).

Most sensory descriptive analysis of bread has been performed on wheat bread (Callejo, 2011), and few have studied commercially available breads. Helleman, Tuorila, Salovaara, and Tarkkonen (1987) used quantitative descriptive analysis and direct similarity assessment to evaluate six rye breads, representing the widest possible range of rye breads on the Finnish market. A lexicon was developed to describe the appearance (e.g., dark crumb color), texture (e.g., hardness, toughness), odor (e.g., sour, musty, burnt) and taste (e.g., sourness, sweetness, and rye-like taste) of rye bread. As a group, the texture attributes discriminated the most between the samples. No previous studies have described the sensory properties of rye bread available on the Swedish market.

## Consumers' sensory quality perceptions

According to the philosophy of hedonism, pleasure is the ultimate goal of all human behavior. In food choice, the sensory quality perceived by consumers is one important determinant (Pettigrew, 2016). The affective or hedonic dimension of food is separate from its objective sensory dimensions. Thus, when someone states that they like a bread, this is not a descriptive statement regarding anything intrinsic to the bread itself. Rather it is an evaluative statement, based on an emotion that is elicited in the observer when he/she eats the bread (Lawless & Heymann, 2010).

So, why do we like what we like? We are born with a few innate preferences, a positive hedonic response to sweetness and a negative response to bitter and strong sour taste (Birch, 1999). Hereafter, liking of particular sensory qualities is largely acquired through experience (Mela, 2001). The socioeconomic and cultural environment is viewed as having the primary role in setting up the opportunities and contexts for particular sensory experiences, which in turn may alter the liking. The food exposure is associated with thoughts, social situations, post-ingestive effects and other factors that mediate the effect of the exposure itself (Mela, 2001). Genetic differences are also involved and explain individual differences in sensitivity to bitter substances such as 6-n-propylthiouracil (PROP). A higher sensitivity to bitter substances has been associated with a preference for milder tastes and more food dislikes (Birch, 1999). PROP sensitivity as

well as fungiform papillae density has been associated with bread liking (Bakke & Vickers, 2011).

Focus group studies have shown that expected and experienced sensory aspects of whole grain products are perceived as barriers to consumption (Kuznesof et al., 2012; McMackin, Dean, Woodside, & McKinley, 2012). Varied liking of whole meal bread has however been observed among consumers (Bakke & Vickers, 2007; Pohjanheimo, Paasovaara, Luomala, & Sandell, 2010; Challacombe, Seetharaman, & Duizer, 2011). Most research has focused on liking of bread made from wheat. Thus, studies on consumer perceptions of the sensory properties of rye bread are more scarce (Kihlberg, Johansson, Langsrud, & Risvik, 2005; Bakke & Vickers, 2007; Kihlberg & Risvik, 2007; Challacombe et al., 2011). Heiniö, Urala, Vainionpää, Poutanen, and Tuorila (1997) studied perceived identity and acceptance of Finnish rye bread among 79 Finnish subjects in relation to four recipe variables (ash content, wheat-rye flour ratio, acidity, and sodium content). Consumers' perceptions of a "rye bread" was largely affected by acidity and ash content whereas acceptance could not be satisfactorily explained by individual recipe variables. In a study by Pohjanheimo et al. (2010), the bread liking of consumers who embrace hedonistic and traditional values was explored using three rye bread samples. Hedonism correlated positively with bread softness and negatively with toughness. "Traditional consumers," on the other hand, were more approving of different types of bread. Consumers have different sensory specific preferences, and the association between liking and consumer background variables, such as demographics or psychographics e.g., values or food choice motives, may therefore be of value in marketing and food development (Kihlberg & Risvik, 2007; Pohjanheimo & Sandell, 2009).

Combining sensory descriptive data and hedonic responses provides valuable strategic data, such as information on the sensory drivers of liking or different consumer segments. This can be done using multivariate statistical methods such as different types of preference mapping techniques, which can provide perceptual maps representing the relationships among the tested products, their sensory profiles and individual differences in liking among consumers (Næs, Brockhoff, & Tomić, 2010).

It has been argued that the physical product should be regarded not only as a source of sensory pleasure, but also as an information source, and that it is important that the impressions communicated about a product before purchase, are upheld throughout consumption (Grunert, 2015). A food name such as "rye bread" can be described as a concept that is evaluated

using a mental checklist of components that the food, according to the consumer, should possess. These can be divided into propositional components, such as factual knowledge about, e.g., how much rye a “rye bread“ should contain, as well as sensory components, which involve immediate recall of the look, flavor, odor and texture of rye bread that one has previously encountered (Smith, Møgelvang-Hansen, & Hyldig, 2010). Preference mapping methods could therefore also be used to explore consumers’ sensory perceptions of the concept of a rye bread or healthiness in bread.

To conclude, this background section has described previous research on the health-related potential of rye bread, as well as different concepts and factors that may be related to the consumption of bread, such as quality, communication, sensory characteristics and consumer perceptions. The details of the four included studies are described below.

# Aim

The potential of rye bread to be a health-beneficial component in the Swedish diet was the starting point for the present thesis. The main aim was to investigate consumption patterns, health-related and sensory qualities and consumer perceptions of bread and more specifically commercial rye bread.

The specific aims for each study in the thesis were:

- I to compare bread consumption patterns among Swedish adults in relation to selected socio-demographic, geographic, and lifestyle-related factors. For selected consumer groups, the further aim was to investigate the intake of whole grain and rye bread and the context of bread consumption, that is, where and when bread is consumed.
- II to characterize commercial rye bread on the Swedish market using sensory descriptive analysis, fluidity index, chemical acidity and selected package information.
- III to compare liking for commercial rye bread among younger and older Swedish consumers in relation to socio-demographics, childhood bread-eating habits and food choice motives. Further, to describe consumers' sensory perceptions of a "rye bread" and healthiness in bread.
- IV to describe consumers' health-related perceptions of bread by exploring which health-related quality attributes consumers associate with bread and whether consumer perceptions differ as a function of age and educational level.

# Materials and methods

An overview of the included studies is provided in Figure 2 and a more detailed overview of the included methodologies in Table 2.

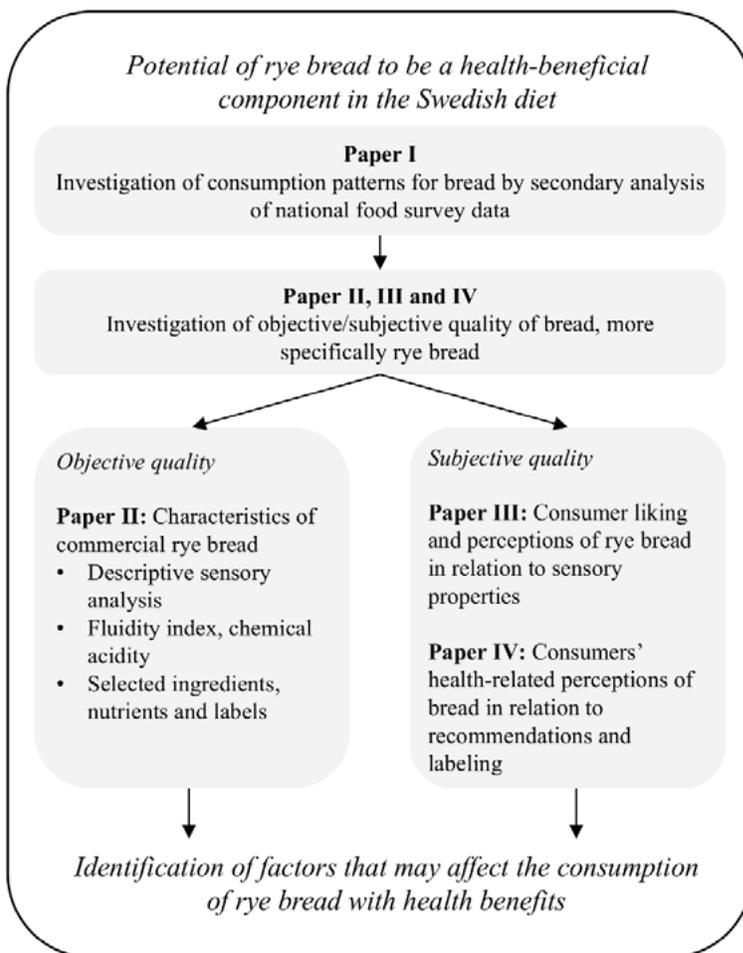


Figure 2. Overview of the four papers (I-IV) included in the thesis.

*Table 2.* An overview of the study design of the four included studies

Paper	Material	Data collection	Main variables	Main analyses
I	1435 adults 18-80 years	Secondary analysis of national dietary survey data	Bread consumption in relation to consumer background, context of bread consumption	Multiple Logistic Regression, Correspondence Analysis
II	24 commercial rye breads	Sensory descriptive analysis, chemical, analyses	Sensory attributes, fluidity index, chemical acidity of commercial rye breads	Principal Component Analysis, visual clustering, Analysis of Variance, Partial Least Squares Regression
III	398 adults, 18-80 years 9 breads selected from Study II	Consumer test	Liking and perceptions of rye bread in relation to sensory properties and consumer background variables	Analysis of Variance, Principal Component Regression, Discriminant Partial Least Squares Regression, Partial Least Squares Regression
IV	1134 adults 18-30 years	Questionnaire, pictures of bread	Open-ended descriptions of health-related perceptions of bread in relation to age and educational level	Content analysis, Correspondence Analysis, Chi-square

## Secondary analysis of food survey data (Paper I)

In Paper I, secondary analysis of data from the 2010-11 Swedish national dietary survey Riksmaten for adults was performed to provide more detailed insight into the consumption of bread. Riksmaten is a recurrent Swedish nationwide dietary survey performed by the NFA. The survey was carried out between May 2010 and July 2011. Sampling was done by proportional allocation based on vital statistics and stratified for gender, age and region. The main sample included 4,000 adults selected from the population registry, whereof 36% (n=1435) completed the four-day food record. Demographic data were collected from the Swedish population register and information on additional covariates, for example selected food frequency questions and physical activity level, was collected in a web-based questionnaire. The estimated food diary was self-administrated, computer-based and aimed to capture all food items eaten. The database (NFA, 2010-11) had a selection of 1,900 food items, including 62 different bread types representing breads available on the Swedish market. Bread

was registered in pieces or slices. Place and type of meal were also reported. Detailed descriptions of the study population and method are found in (Amcoff, 2012a; 2012b).

To study differences among respondents regarding types of bread consumed, the respondents were classified into groups according to amount and type of bread they reported eating relatively most of. Median intake was used to classify respondents into *high* or *low* bread consumers and the other bread type groups were: *Dry crisp bread*, often made from whole-grain rye and sometimes sifted flour; *White bread with no whole grain*; *Bread with <25% whole grain* and; *Whole-grain bread with  $\geq 25\%$  whole grain*.

The dry weight of all bread types was calculated to adjust for the lower water content in dry crisp bread, and intake was adjusted for total energy intake. The respondents were classified into main consumers of the respective bread types by using the proportional reported intake relative to the total amount of bread reported by each respondent. Thereafter the associations with selected socio-demographic, geographical and healthy lifestyle-related consumer characteristics were studied.

To gain further insight into the different consumption patterns between gender and age groups, a more detailed classification with 23 groups of bread was used. Selected consumer groups were further compared regarding total intake of whole grain and regarding consumption context as well as reported total intake of bread at different locations (home, restaurant/on the run) and type of meals.

## Characterization of commercial rye breads (Paper II)

In 2013, the Swedish market was scanned for breads containing a significant proportion of rye and/or a commercial name or label referring to rye content in the bread. To narrow the scope, dry crisp breads were excluded from this analysis. All breads were produced by large-scale bakeries and thereby available in all parts of Sweden. Among the 60 products identified, 24 were chosen and were, based on their ingredients, considered to represent a wide variety of commercially available rye bread. Information on ingredients and, more specifically, on the content of rye, whole grain, fiber, sodium, and sugar was collected from the packages or received from the bakeries when information was lacking. Front-of-package labeling regarding rye and sourdough was also recorded.

Sensory profiles of the breads were obtained using descriptive analysis (ISO, 1994; 2016). Eleven assessors, selected according to ISO standard

(2012) and with prior experience of descriptive analysis of rye bread, were trained for 25.5 hours. The panelists agreed upon and defined 15 sensory attributes to describe the samples in relation to their appearance, odor, flavor and texture (Table 3). The intensities of sensory attributes were scored on a continuous unstructured 10 cm line scale, from little (0) to much (10). The panelists also defined and agreed upon the tasting procedure, and breads were evaluated using both crumb and crust. The assessments were carried out in duplicates in a sensory laboratory at the Department of Food, Nutrition and Dietetics, Uppsala University, designed according to ISO standards (2007) with individual booths, using white light and the FIZZ software (Biosystems, Couternon, France). Details of the preparation and handling of the samples are described in the methods section of Paper II.

All bread samples (n=24) were also analyzed for fluidity index (FI) by Viscosens AB. The FI predicts the glyceamic properties of bread using an *in vitro* measure of physiologically relevant viscosity (Ekström et al., 2013). In this method, physiological digestion of the bread products is simulated using an *in vitro* procedure, after which the fluidity of the digesta is measured. White wheat bread (Dollarfranska, Lockarp) was used as a reference (FI = 100), and a lower FI in the commercial rye bread samples indicates a more beneficial glyceamic profile. Because there is at present no established FI threshold below which the glyceamic properties are considered to be healthful, two additional experimental rye breads – which have been shown to possess beneficial glyceamic properties using measures of postprandial insulin and glucose responses – were also analyzed for FI and included as controls (Rosén et al., 2009). One of the controls was an endosperm rye bread and the other a whole-grain rye bread, both with 75% rye flour and 25% wheat flour (Rosén et al., 2009). Sourdough is commonly used in rye bread and therefore, analysis of pH, TTA, lactate and acetate was also conducted for all 24 samples by CeLac Sweden AB. Sensory and health-related characteristics of the samples were studied and, thereafter, associations between these characteristics were investigated using multivariate statistical methods (see section, Main statistical analyses and clustering).

Table 3. Definition of sensory attributes for evaluation of 24 commercial rye breads using descriptive analysis (11 panelists, assessment in duplicates)

<b>Attributes</b>	<b>Abbrev.</b>	<b>Definitions<sup>1</sup></b>
<b><i>Appearance</i></b>		
Brown color	C-brown	Degree of brown color in the bread crumb
<b><i>Odor</i></b>		
Sour	O-sour	Degree of sour odor typical of sourdough in the crumb
Malty	O-malty	Degree of malty odor typical of malt syrup in the crumb
<b><i>Flavor</i></b>		
Sweet	F-sweet	Degree of sweet taste
Salt	F-salt	Degree of salty taste
Sour	F-sour	Degree of sour taste
Bitter	F-bitter	Degree of bitter taste
Rye	F-rye	Degree of aftertaste typical of rye kernels soaked overnight and boiled for one hour in water
Roasted cereals	F-roast	Degree of aftertaste typical of oven roasted whole rye kernels roasted sufficiently to cause burnt notes
<b><i>Texture, by finger</i></b>		
Compressibility	T-comp	Degree of resistance when pressed
Deformability	T-def	Degree of deformation of the crumb from pressure with one finger in the center of the bread sample
<b><i>Texture, mouth feel</i></b>		
Chewiness	T-chew	Effort and time needed to chew
Moisture absorption	T-moist-abs	The amount of saliva absorbed by the sample when chewing
Heterogeneity	T-hetero	Perceived amount of components bran and whole/pieces of kernels
Cohesiveness of mass	T-cohes	The degree to which the bread forms a coherent bolus during mastication

<sup>1</sup>Anchors, little (0) – much (10) on the continuous unstructured scale, for all attributes and the procedures used for evaluation of each attribute are further described in the methods section of Paper II.

## Consumer test of commercial rye breads (Paper III)

In Paper III, a consumer test was performed with a selection of nine of the samples from Paper II. Because 24 samples were considered too many to include in a consumer test, Principal Component Analysis (PCA) of the sensory data from Paper II was used to visually select a representative subset of samples (Helgesen & Næs, 1995). The bread samples were, cut into bite-size rectangular pieces (approximately 2.5 x 5.5 cm) including both the crumb and the crust, then wrapped in aluminum foil, labeled with randomly assigned 3-digit codes and placed in two transparent plastic boxes. Each pair of boxes corresponded to the random serving order of a specific questionnaire. More details on the preparation and handling of the samples in the consumer test can be found in the methods section of Paper III. Data were collected during three consecutive days in Uppsala, Sweden, in four test locations set up in different malls with the assistance of students at the department of Food, Nutrition and Dietetics, Uppsala University.

For each bread sample, the respondents first indicated overall liking on a nine-point balanced hedonic scale from dislike extremely (1) to like extremely (9). Second, the respondents were asked to indicate degree of agreement, from totally disagree (1) to totally agree (9) with three statements: *“I would gladly eat this bread often,”* *“This bread seems healthy”* and *“This is according to me a rye bread.”* Two additional questions were posed concerning how much rye flour/whole grain the respondents expected a bread labeled “rye bread” or “whole-grain bread” to contain. A 10 cm line scale was used with 0% “no”, 50% “half” and 100% “only rye/whole meal flour” as anchors.

Background questions included gender, year of birth, number of children < 18 years in the household, educational level, birth country and birth country of parents to study possible influences from other cultures. In a multiple-choice question, the respondents were also asked to indicate type of breads they mostly ate when growing up as well as today. The Food Choice Questionnaire (FCQ) was included to further characterize the consumers (Steptoe et al., 1995). This instrument consists of 36 statements designed to assess the reported importance of nine factors on food choice (convenience, ethics, familiarity, health, mood, natural, price, sensory, body weight). The subjects were asked to evaluate and rate the statement *“It is important that the food I eat on a typical day is...”* for each of the 36 items from “totally disagree” to “totally agree.” As in previous research, a seven-point scale, was used instead of the originally proposed four-point scale, to improve discrimination (Pohjanheimo et al., 2010; Carrillo, Varela, Salvador, & Fiszman, 2011). Figure 3 shows the data structure for Paper II and III.

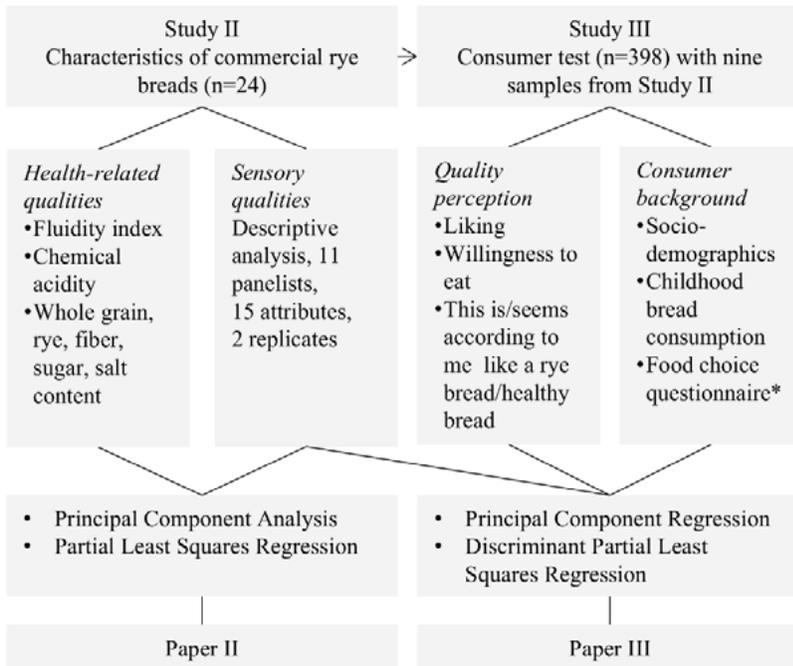


Figure 3. Data structure and main multivariate statistical methods used in Paper II and III. \*Steptoe et al, 1995.

## Questionnaire exploring consumers’ health-related perceptions of bread (Paper IV)

In the fourth study, consumers’ health-related perceptions of bread were investigated in a questionnaire using open-ended questions and pictures of six commercial breads. In November 2011, a total of 3,000 subjects, 18-80 years of age and chosen by random selection from the national population address register, were sent a postal invitation to participate in a web-based survey. Non-respondents later received an identical postal questionnaire, and thus data were collected in a web-based and a postal sequential mixed-mode survey (De Leeuw, 2005). The ambition was for most of the questionnaires to be completed online, enabling both financial and environmental savings.

First and foremost, open-ended questions were used to explore consumers’ health-related perceptions of bread. The goal of this approach was to try to understand how consumers respond without the assisted recall

provided by a set of predetermined response alternatives (Perreault Jr & Leigh, 1989). The approach has previously been used to study consumer perceptions of different foods (Péneau, Linke, Escher, & Nuessli, 2009; Hough & Ferraris, 2010; Symoneaux, Galmarini, & Mehinagic, 2012). The frequency of elicitation can be related to the importance of a concept in consumers' minds (Guerrero, Colomer, Guàrdia, Xicola, & Clotet, 2000).

The following questions were included to explore which bread types are perceived as healthy and which health effects are on the top of respondents' minds: *Are you aware of bread that, in your opinion, is good for health? If yes: Which type of bread are you thinking of? And: In what way is it, in your opinion, good for health?* Attribute elicitation, based on six pictures of commercial breads with and without their packaging, was used to further explore which product properties were important in evoking expectations of health-related bread quality (Bech-Larsen & Nielsen, 1999). The included breads were selected to achieve variation in the factors whole grain, cereal type, sugar content and fermentation method. The three most sold breads according to sales statistics were included: a sweet wheat-rye loaf with 25% whole grain (Lingongrova, Pågen AB), sifted wheat-rye loaf with syrup (Skogaholmslimpa, Fazer AB) and a roll with spelt and sunflower seeds (Frökusar, Fazer AB). Other breads included were a whole-grain rye sourdough roll (Rågkusar, Fazer AB), a Danish-style whole-grain rye bread (Skovmand, Fazer AB) and a white wheat toast with 25% whole grain (Äntligen, Pågen AB). Four of the samples were labeled with the Keyhole. Back-of-package information was available on the back of the paper questionnaire/by clicking a link on the online questionnaire. For elicitation, a simple sorting task was used. The respondents chose which of the six breads they expected to be *most* and *least healthy* (multiple choice). After choosing, they were asked to briefly justify their choices. This approach minimized the workload for the respondents while consumer-relevant properties were still captured. Background questions included gender, age, education level and bread-eating habits. The respondents were also asked whether they found it difficult to know which bread is the healthier choice (*yes/no*).

The open-ended answers were content analyzed and, based on the gathered data, categories were formed inductively (Spiggle, 1994; Varela & Ares, 2012). The open-ended answers were written in one or two words or in a short sentence and were primarily coded by the first author. Consumers answer open-ended questions in their own style and the answers were read through several times and spelling errors were corrected. The analysis was performed in Excel. Each row represented a specific respondent and relevant words with similar meaning were

identified and transferred to a separate column. For example, responses such as “contains a lot of fiber,” “fiber, fiber, fiber,” and “rich in fiber” were placed into a category named “fiber rich.” Thereafter the frequency of elicitation for each category could be calculated. In order to check reliability, a randomly sample of 10% was selected for all open-ended questions and coded by two of the co-authors, using the inductively formed categories. The frequency of each category was counted, and categories with a frequency of >20 were considered for all open-ended questions and were analyzed as a function of age and educational level.

## Main statistical analyses and clustering

Here, an overview of the statistical analyses used is presented, more detailed descriptions are found in the method sections of each of the four papers.

To study the association between the bread consumption groups and selected socio-demographic, geographical, and lifestyle-related factors in Paper I, five *Multiple Logistic Regression* models were calculated (Hair, 2010).

*Correspondence Analysis (CA)* was used in Paper I and IV. This is a descriptive/exploratory technique designed to provide a graphical illustrations of two-way contingency tables (Hair, 2010). In Paper I, *CA* was used to illustrate the bread type most commonly registered among gender and age groups. In Study IV, *CA* was used to i) illustrate patterns between elicited health-related attributes of bread and their perceived health effects and ii) to illustrate which attributes consumers used to describe bread samples that were perceived as most or least healthy.

In Paper II, the descriptive sensory data were primarily analyzed using a mixed-model three-way *Multivariate Analysis of Variance (MANOVA)*; subsequently, 3-way *Analysis of Variance (ANOVA)* was used on each descriptive variable. Thereafter, *Principal Component Analysis (PCA)* was performed on the mean value for each bread sample and sensory attribute. This was done to discover the relationships between the variables describing the samples and to investigate whether there were specific patterns in the dataset. *Principal Component Analysis* allows an overview of the data by extracting the most important information and finding dominant patterns among samples (Næs et al., 2010).

In Paper III, two separate internal preference mappings were performed for the younger (18-44 years) and older (45-80 years) consumer groups using *Principal Component Regression (PCR)*. Preference mapping is a

method used to relate sensory data to consumer acceptance data. By finding relationships in the data, important drivers of liking and the most liked/disliked products can be identified. In internal preference mapping, the consumer acceptance data are first analyzed by *PCA* and then individual sensory attributes are regressed onto the principal components (Næs et al., 2010).

Clustering was performed for the bread samples in Paper II and the younger, respectively the older consumer groups in Paper III. The segmentations were based on visual inspections of the principal components from the *PCA* and *PCR* in the respective papers (Endrizzi, Menichelli, Johansen, Olsen, & Næs, 2011). According to Endrizzi, Gasperi, Rødbotten, & Næs, 2014, visual segmentation has been shown to be useful when the grouping of samples is less clear, because automatic segmentation procedures may produce different groups depending on the method chosen.

*Partial Least Squares Regression (PLS)* was used in Paper II and III. For a more in-depth understanding of the association between the sensory and the health-related data (selected content variables, FI and chemical acidity) in Paper II, *PLS-2* was used on the correlation matrix. This analysis also served as a validation of the descriptive analysis, showing e.g. that sweet taste was associated with the total sugar content (Helgesen & Næs, 1995). The 15 sensory attributes were used as X variables and health-related data as Y variables. *Partial Least Squares Regression 1* was used to further study the relationship between the sensory variables and FI values, and in this analysis only FI served as the Y variable. Two separate *PLS-1* analyses were also used in Paper III to study the association between the nine commercial rye bread samples' sensory profiles (X variables) and the consumers' mean ratings for the statements “*This bread seems healthy*” and “*This is according to me a rye bread*” (Y variable). To characterize the identified consumer clusters in the younger and older consumer groups in Paper III, *Discriminant PLS* was applied. Cluster membership was used as dependent variables coded as dummy variables, and the consumer characteristics were used as explanatory variables and included; socio-demographic factors (age groups, gender, education, children <18 living at home, at least one parent born outside Sweden), bread type mostly eaten when growing up and food choice motives (measured with the FCQ).

The scores for each sub-scale in the FCQ were computed by averaging the unweighted ratings of the individual items. The FCQ was also analyzed in line with Pohjanheimo et al. (2010) using *Factor analysis* (Maximum likelihood with Varimax rotation), the aim being to combine the items into the nine subscales according to the original theory of Steptoe et al. (1995).

The internal reliability of each of the nine subscales was tested using *Cronbach's alpha* and *Inter-item correlation*. In Paper IV, inter-rater reliability was checked using *Krippendorff's Alpha* (Hayes & Krippendorff, 2007). In Paper IV, *Chi-square* with Yates' Correction for Continuity was used to compare frequency of elicited health-related attributes in relation to age (18-44 years vs. 45-80 years) and education (up to secondary school vs. university or university college degree). Here, the level of significance was set at  $P < 0.01$  to minimize the risk of type 1 errors due to multiple tests, otherwise,  $P < 0.05$  was used.

Software used to perform the analyses were: IBM SPSS Statistics version 19 (Paper I) and 22 (Paper III, IV), Addinsoft XLStat version 2014.3.07 (Paper II), The Unscrambler X version 10.3, Camo Software (Study II, III), SAS version 9.4, SAS Institute Inc. (Paper II & III).

## Ethical considerations

Because the studies in the present thesis did not include any biological material or any sensitive information, there was no need for approval from the Ethical Board in accordance with the Act Concerning the Ethical of Research Involving Humans (The Ministry of Education and Cultural Affairs, 2003). The dietary survey Riksmaten 2010-11 was approved by the Central Ethical Review Board in Uppsala, Sweden (Ref. 2010/060). The dietary survey data obtained for analysis was anonymized and only variables relevant to the study were withdrawn from the database.

The respondents in Paper III and IV gave their informed consent by responding to the questionnaires. For Paper IV the returned questionnaires were treated confidentially, and personal information from the National Address Register was stored separately from the raw data in a locked cabinet.

The sensory panelists in Study II gave their written consent to participate in the study. Here it was clearly stated that they could choose to withdraw from the study at any point with no need to explain why. Perhaps it should also be mentioned that some of the trained panelists included in the descriptive panel were students at the Department of Food, Nutrition and Dietetics. Participation was completely voluntary. One advantage was that the students were well acquainted with the sensory methodology and highly motivated. A potential disadvantage could be potential perceived power relations. The panel leader (Pernilla Sandvik) was, however, not responsible for grading these students.

The panelists were informed about the nature of the test samples and care was taken to avoid any microbiological risk or mental distress. Care was also taken in preparation of the samples for the consumer test (Paper III) to ensure the safety of the samples (Lawless & Heymann, 2010). Consumers who asked about the content of the samples due to intolerance or allergies were informed if this component was found in the samples and were consequentially excluded from the study. Participants were clearly informed that they could withdraw from the study at any time.

Study II-IV were partly financed by the commercial industrial bakery Fazer AB. This was in the setting of the research financing program Tvärlivs whose aim was to support Swedish food research. It was a joint funding program between Formas, Vinnova, The Swedish Retail Association (Svensk dagligvaruhandel), The Swedish Food Federation and Swedish Farmers' Foundation for Agricultural Research. Funding could only be applied for together with an industrial partner. Fazer AB has a commercial interest in rye bread, but contributed mainly financially to the present project and was not involved in the research process.

# Findings

## Consumption patterns for whole-grain and rye bread (Paper I)

The correspondence analysis provided a visualization of the frequency of reported intake of 23 different bread types among gender and age groups (18-30, 31-44, 45-64, 65-80). When visually inspecting the result, the first dimension clearly distinguished between the younger (18 - 44) and older (45 - 80) age groups. The older age groups were found together with dry crisp bread, whole-grain bread, and whole-grain rye bread, and the younger respondents are found together with, for example, tortillas, hamburger buns, and pita bread.

The logistic regression analyses relating main consumers of different bread types to consumer background variables also showed that there was a higher likelihood of being a mainly *whole-grain bread* and *dry crisp bread* consumer among the older age groups (45-80 years) compared to the younger (18-44 years), whereas the opposite was seen for eating mainly *white bread with no whole grain*. Respondents with children had a higher likelihood of being mainly *white bread* consumers (OR: 1.42; CI: 1.08-1.96) and also a reduced likelihood of eating mainly *dry crisp bread* (OR: 0.61; CI: 0.43-0.87). Country of birth was associated with eating mainly *whole-grain bread* with a higher likelihood for those born in a Nordic country other than Sweden (OR: 2.23; CI: 1.12-4.45). The trend for number of years in school was a lowered likelihood of being mainly a *white bread* consumer as well as eating more bread in total with more school years. The opposite was seen for mainly *whole-grain bread* consumers. Looking at geographical differences, region in Sweden turned out to be the most important factor for *dry crisp bread*, with a higher likelihood in northern Sweden (OR 3.24; CI: 2.17-4.83). Among the health-related lifestyle factors, more frequent candy and snacks intake was associated with being a *white bread* consumer (OR: 1.69; CI: 1.30-2.20), and the opposite was seen for mainly *whole-grain bread* consumers (OR: 0.62; CI: 0.47-0.81). More frequent intake of fruits and vegetables was associated with a lowered risk of eating mainly *white bread*, and the opposite relation held

for *whole-grain bread* and *dry crisp bread*. The trend was similar although not significant for a higher level of physical leisure activity. A higher *total bread intake* was also associated with a high level of physical leisure activity (OR 1.59; CI 1.02-2.49), whereas a high candy and snacks intake showed a lowered OR (0.77; CI: 0.69-0.98).

The reported total intake of whole grain was 38 g/day (SD 29) for low bread consumers, compared to 45 g/day (SD 33) for high bread consumers ( $P \leq 0.001$ ). On average, most of the bread (62%) was eaten at home, almost half of the bread consumed was reported for breakfast (42%) and approximately 20% was reported for lunch, dinner and snacks, respectively. Mainly *white bread* consumers ate significantly more bread at restaurants and “on the run” compared to mainly *whole-grain bread* consumers (18 g/day, SD 35, compared to 9 g/day, SD 24,  $P \leq 0.001$ ). Eating bread at restaurants and “on the run” was also significantly more common among the younger age groups.

## Sensory profiles, fluidity index and chemical acidity of commercial rye breads (Paper II)

The 24 commercial samples contained between 15-100% rye, 0-100% whole grain, between 3-15 g fiber, 1-12 g total sugars and 0.75-1.5 g salt per 100 g. Almost all of the samples ( $n=21$ ) listed sourdough or sourdough powder among the ingredients, and half of the samples ( $n=12$ ) contained extra added wheat gluten. Principal Component Analysis showed that the first two principal components (PC) explained about 79% of the variance in the sensory data from evaluation of the 24 commercial rye bread samples (Figure 4). Adding an extra PC increased the amount of explained variance to about 87%. According to the sensory space of PC 1-3, the 24 samples were divided into six main categories (A-F) based on their dominating sensory attributes.

- A. High chewiness and moisture (saliva) absorption with a roasted, somewhat sour and bitter flavor and a medium dark crumb color (Samples: A1-A5)
- B. High heterogeneity, compressibility and moisture (saliva) absorption, an acidic rye flavor and a dark brown crumb color (Samples: B1-B4)
- C. High cohesiveness of mass and very low moisture (saliva) absorption, low compressibility, high deformability, a mild flavor and light crumb color (Samples: C1-C4)

- D. Relatively high cohesiveness of mass and low chewiness with a roasted, somewhat bitter flavor, a clear malt odor and dark brown crumb color (Samples: D1-D4)
- E. High deformability and low compressibility, a mild somewhat rye-like and bitter flavor, relatively low sweetness and light brown crumb color (Samples: E1-E4)
- F. A clear cohesiveness of mass, rye flavor, sour odor and flavor and a lighter crumb color (Samples: F1-F3)

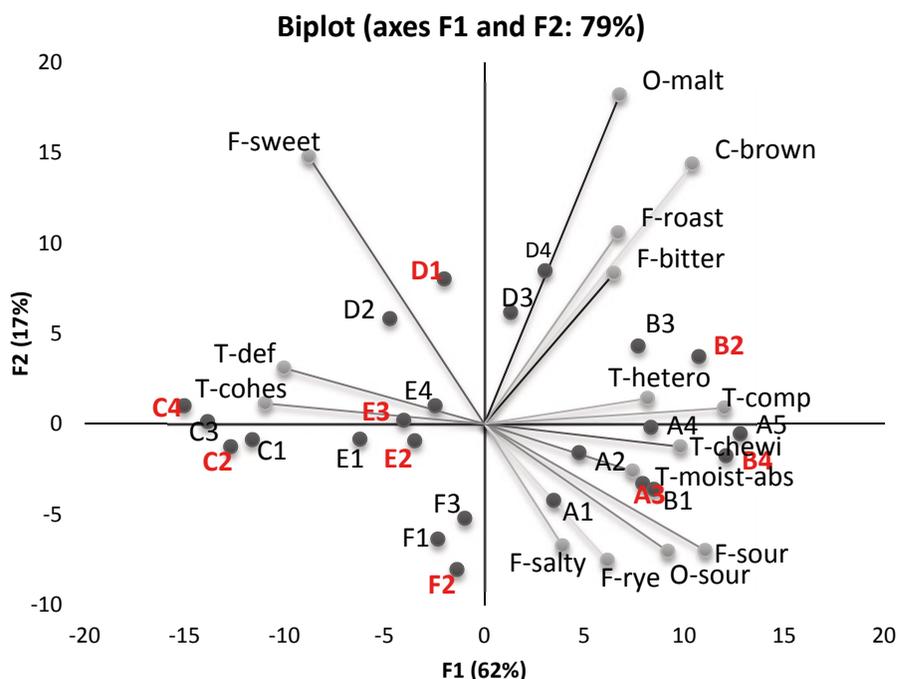
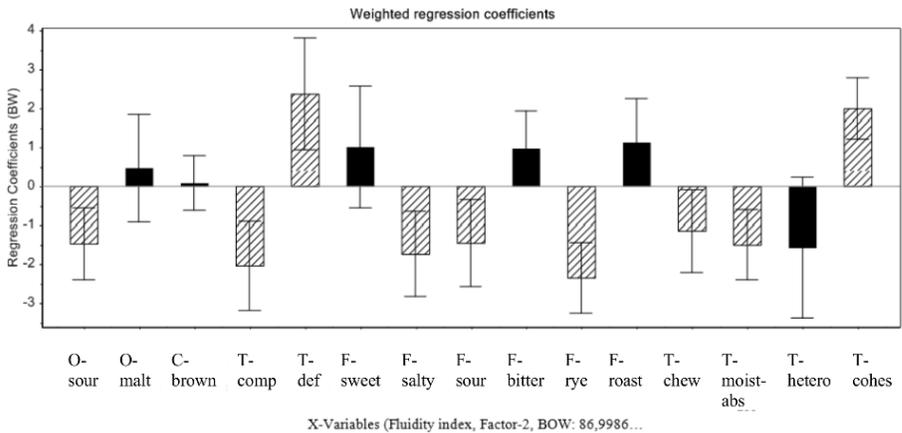


Figure 4. Bi-plots of Principal Component Analysis for 15 sensory parameters of 24 rye bread samples assessed in duplicate by 11 panelists in Paper II. C, Color; O, Odor; F, Flavor; T, Texture. Red samples selected for the consumer test (Paper III)

Bread with a front-of-package rye label contained between 20 and 100% rye flour. The FI of the 24 commercial rye breads varied from FI 50 to 100, where FI 100 is equivalent to the white wheat reference bread (Dollarfranska, Lockarp). The FI values for the endosperm rye and whole-grain rye control samples, which in previous research have displayed beneficial glycemic properties (Rosén et al., 2009), were 74 and 65, respectively. Samples in group A, B and F had FI below or in line with this and were, thereby, in this study considered to have a low FI (Table 5). The

pH of all samples (n=24) varied from 4.3 to 6.6, and TTA between 1.6 and 14.3. Regarding the total lactate and acetate content, the samples varied between 0.07 and 0.94 and 0.03 and 0.28 g per 100 g, respectively. Samples with a front-of-package sourdough label (n=14) varied in pH from 4.3 to 5.3 and TTA from 5.5 to 13.6.

Relationship between the sensory and the health-related variables were obtained by the use of PLS-2 analysis. The relationship obtained was good and the first two components explained 63% of the variance in the health-related variables (Y). Samples with a lower FI, high content of fiber, whole grain and acids, and low sugar content – primarily bread category A and B – were characterized by a higher moisture (saliva) absorption, chewiness, acidic flavor, and rye flavor. The sensory attributes brown color, roasted flavor, bitter flavor and malt odor were, however, less clearly related to these measurements on the first two components. PLS-1 was used to specifically relate FI values to the sensory attributes. FI values were well predicted by the sensory attributes, and the first two PLS components explained 88% of the variance in FI. A higher FI was significantly positively associated with cohesiveness of mass and deformability, while it was negatively associated with compressibility, chewiness, moisture (saliva) absorption, sour odor, salty, sour and rye flavor (Figure 5).



*Figure 5.* Prediction of fluidity index by sensory attributes in 24 rye bread samples. Weighted regression coefficients for Partial Least Squares Regression-1. Striped bar indicates significant attribute. O, odor; C, color; T, texture; F, flavor

*Table 5.* Mean values (standard deviations) for selected content variables, fluidity index and chemical acidity in rye bread categories A-F, classified according to their sensory characteristics (Paper II).

	A n=5	B n=4	C n=4	D n=4	E n=4	F n=4
Rye <sup>1</sup>	72 <sup>b</sup> (25)	99 <sup>a</sup> (3)	30 <sup>c</sup> (10)	34 <sup>c</sup> (23)	40 <sup>c</sup> (16)	44 <sup>c</sup> (20)
Whole grain <sup>1</sup>	75 <sup>a</sup> (27)	95 <sup>a</sup> (10)	6 <sup>c</sup> (13)	29 <sup>bc</sup> (6)	43 <sup>b</sup> (31)	20 <sup>bc</sup> (18)
Fiber <sup>1</sup>	11 <sup>a</sup> (3)	10 <sup>ab</sup> (1)	5 <sup>d</sup> (1)	7 <sup>cd</sup> (1)	9 <sup>bc</sup> (1)	6 <sup>d</sup> (1)
Total sugars <sup>1</sup>	4 (3)	5 (5)	8 (2)	9 (3)	6 (3)	3 (1)
FI <sup>2</sup>	64 <sup>c</sup> (8)	54 <sup>d</sup> (6)	94 <sup>a</sup> (6)	89 <sup>ab</sup> (6)	84 <sup>b</sup> (6)	71 <sup>c</sup> (4)
pH	4.6 <sup>c</sup> (0.2)	4.6 <sup>c</sup> (0.2)	5.8 <sup>a</sup> (0.5)	4.9 <sup>bc</sup> (0.3)	5.3 <sup>b</sup> (0.1)	4.7 <sup>c</sup> (0.2)
TTA <sup>3</sup>	10.9 <sup>a</sup> (2.9)	9.4 <sup>ab</sup> (0.4)	3.7 <sup>d</sup> (1.4)	7.3 <sup>bc</sup> (1.7)	5.7 <sup>cd</sup> (1.0)	7.3 <sup>bc</sup> (0.3)
Lactate <sup>3</sup>	0.7 <sup>a</sup> (0.2)	0.5 <sup>b</sup> (0.1)	0.1 <sup>d</sup> (0.0)	0.3 <sup>bc</sup> (0.2)	0.2 <sup>cd</sup> (0.1)	0.4 <sup>bc</sup> (0.0)
Acetate <sup>3</sup>	0.1 <sup>abc</sup> (0.0)	0.2 <sup>a</sup> (0.0)	0.0 <sup>c</sup> (0.0)	0.1 <sup>c</sup> (0.0)	0.1 <sup>bc</sup> (0.0)	0.2 <sup>ab</sup> (0.1)

<sup>1</sup>Rye: % of cereal, whole grain: dry weight, g/100g, fiber and total sugars: g/100g

<sup>2</sup>FI: Fluidity index, white wheat bread was used as reference, FI 100

<sup>3</sup>TTA: Total Titratable Acidity, Lactic acid and Acetate in g/100g

<sup>a-d</sup> Different superscript letters in a row indicate significant differences in bread categories based on Analysis of Variance with Post-hoc Fisher's LSD-test

## Liking and perceptions of rye bread among younger and older consumers (Paper III)

Because an age difference in rye bread consumption was so clearly displayed in Paper I, analysis of liking was performed separately for the two age groups 18-44 years and 45-80 years in Paper III. Of the 398 consumers participating in the test, 225 were classified into the younger (18-44 years, mean age 28, SD 7) and 173 into the older group (45-80 years, mean age 63, SD 10). Significantly more respondents in the younger group had eaten mainly white bread when growing up and more of the older respondents reported having eaten mainly dry crisp bread. The FCQ showed that, on average, both age groups rated *sensory appeal* as most important in relation to food eaten on a typical day. Next in importance were *natural content*, *health* and *price* for the younger group and *natural content*, *ethical considerations* and *health* for the older. *Familiarity* was on average the least important motive.

Significant differences in liking were found between the age groups for six out of the nine samples. The liking ratings corresponded well with answers to the statement “*I would gladly eat this bread often*” (Pearson correlation 0.84 for younger consumers and 0.86 among older consumers). The two internal preference mappings displayed different preference patterns for the two age groups. The younger group generally showed a preference for samples displaying a high cohesiveness of mass, deformability and sweetness (Category C). The older group showed a more disparate picture in their liking, with a tendency toward liking breads that display a higher chewing resistance, higher moisture (saliva) absorption and more rye and sour flavor (Samples in category A and B).

Based on their separate preference mappings, each age group was visually classified into three preference clusters with similar preference patterns, one “soft-white cluster,” one “intermediate cluster” and one “dark-chewy cluster.” Discriminant PLS showed that the clusters in the younger group differed according to gender, with male consumers more often in the “soft-white cluster” and females in the “dark-chewy cluster.” A higher educational level ( $\geq 3$  years of university) was associated with the “dark-chewy cluster,” and the “soft-white cluster” was associated with mainly having eaten white bread e.g., pan bread or rolls, and sweet loaf e.g., traditional sifted rye loaf, when growing up. Regarding the food choice motives, the factors *familiarity* and *convenience* were more important for the “soft-white cluster,” while *health*, *ethical considerations* and *naturalness* were more important in the “dark-chewy cluster.” In the older consumer group, fewer background variables differed significantly

between the clusters. The “dark-chewy cluster” was associated with a higher educational level and having at least one parent born outside Sweden. The only significant food choice motive was *familiarity*, which respondents in the “soft-white cluster” found significantly more important.

With regard to perceived healthiness and being “rye breads,” the respondents differentiated between the samples. The samples with the highest content of whole grain and rye (category A and B) were perceived as healthiest and the most as rye breads. Younger and older consumers displayed similar perceptions. The healthiness ratings of the samples were not correlated with willingness to eat in the younger consumer group, while they were significantly correlated in the older group (Pearson correlation 0.56). The PLS-1 was performed on all consumers together, and in the first component the sensory attributes (X) explained 94% of the variation in perceived healthiness (Y). Sensory attributes that were positively correlated with perceived healthiness in the bread samples were: brown color, sour and malty odor, sour and bitter flavor and rye and roasted aftertaste. With regard to texture, compressibility, chewing resistance, moisture (saliva) absorption and heterogeneity were positively correlated with perceived healthiness. Deformability, cohesiveness of mass and sweet taste were negatively correlated with the perception of healthiness in bread. In the PLS-1, relating the sensory profiles to the expectation of a “rye bread,” the first component explained 91% of the variation in perception of a rye bread (Y). The pattern was similar to perceived healthiness in bread. In response to the questions “How much rye flour/whole-grain should bread according to you contain to be labeled as a ‘rye bread’ / ‘whole-grain bread’?” the age groups answered similarly, with a mean around 70%; approximately 6% answered “no opinion.”

## Consumers’ health-related perceptions of bread (Paper IV)

The response rate was 38%, and a total of 1134 respondents were included in the analysis. One third (33%) reported to have reduced their intake of bread the last two years, while only 3% reported to have increased their intake. The majority (75%) of respondents answered *Yes* to the question “*Are you aware of bread that, in your opinion, is good for health?*” However, 33% of these respondents reported finding it challenging to identify the healthier alternative, whereof a significantly larger proportion of respondents had a low education level (38%) as compared to a higher education level (28%) (P=0.004).

Of the open-ended responses to the question “Which type of bread are you thinking of?” a total of 12 categories were identified: “coarse,” “fiber rich,” “whole grain,” “sourdough,” “crisp bread,” “dark color,” “no/less sugar,” “rye,” “seeds,” “a commercial brand,” “home-made” and “kernels.” Respondents with a university degree stated “no/less sugar” more often compared to the group with a lower education level (high education level 12% vs. low education level 7%,  $P=0.009$ ). The younger consumer group more often described healthy bread as containing “seeds” (younger group 11% vs. older group 3%,  $P<0.001$ ). The most common answers to the subsequent question “In what way is it, in your opinion, good for health,” – among 13 identified categories in total – were “good for the stomach,” “contains fiber,” “glycemic properties,” “good for the bowels” and “satiating.” Glycemic properties included descriptions such as “blood glucose control,” “low GI” and “slow carbohydrates.” Younger respondents stated “satiation” (younger group 21% vs. older group 8%) ( $P<0.001$ ) and “glycemic properties” (younger group 22% vs. older group 14%) ( $P=0.007$ ) more often than older respondents did, while older consumers more often stated “good for the stomach” (older group 33% vs. younger group 21%) ( $P<0.001$ ). Respondents with a university degree, in contrast to respondents without one, more often answered “glycemic properties” (high education level 21% vs. low education level 12%) ( $P=0.001$ ).

The correspondence analysis showed that “crisp bread,” “commercial brands,” and “rye” were often described as healthy because they contain fiber. “Fiber rich,” in turn, was described as “good for the stomach” and “good for the bowels.” “Satiating” was used to describe why “seeds,” “whole grain” and “fiber rich” were perceived as healthy in bread. “Glycemic properties” was often used when explaining why “sourdough” and “no/less sugar” were healthy in bread. The pattern was not as clear for “coarse,” “whole grain” and “dark color,” indicating that they were attributed a variety of health effects.

In the picture elicitation task, the majority of respondents (71%) chose the white toast bread (Äntligen) with 25% whole grain and a Keyhole symbol as the least healthy mainly due to it “being white.” The sifted wheat rye syrup loaf (Skogaholmslimpa) was chosen as one of the least healthy by 54%, mainly due to it “containing sugar/syrup.” The respondents disagreed on the healthiness of the sweet wheat-rye loaf with 25% whole grain (Lingongrova); more older respondents (older group 16% vs. younger group 10%) ( $P=0.001$ ) and less educated respondents (low education level 17% vs. high education level 9%) ( $P<0.001$ ) chose this as one of the healthiest. The roll with spelt and sunflower seeds (Frökusar) were chosen

as the healthiest by 39%, the Danish style whole grain rye bread (Skovmand) by 61% and the whole-grain rye sourdough roll (Rågekusar) by 54%. Similar attributes as in the above question regarding general characteristics of healthy bread were used to justify why these breads were perceived as healthy, however the attribute “tasty” was also mentioned.

# Discussion

## Principal findings

The principal findings of this thesis are listed below:

- Especially younger age and a lower educational level were associated with a lower intake of whole-grain and rye bread. Traditional as well as new bread consumption patterns were observed with younger respondents eating more fast food bread.
- Content as well as health-related and sensory qualities of rye bread on the Swedish market vary widely. A lower FI was observed in half of the samples. This was associated with a chewier and drier texture, rye, sour, and salty flavor in the commercial breads.
- Different preference patterns for rye breads on the Swedish market were observed in a younger compared to an older consumer group. The younger group mainly preferred soft, juicy, mild and sweet breads, which were not perceived as healthy. This liking was especially associated with being male, having a lower educational level, eating white bread in childhood and the importance of *familiarity* and *convenience* in food choices.
- Three out of four knew of bread that they considered healthy. Mainly coarse bread, whole-grain, fiber, sourdough and rye were perceived as being good for the stomach, satiation and blood sugar. One third of the respondents, but especially consumers with a lower educational level perceived it difficult to know which bread is healthy.

## A dietetic marketing perspective

The challenge of the high prevalence of lifestyle-related diseases and the potential of “our daily bread” to be one health-beneficial piece of the diet puzzle constitute the point of departure for the present thesis. The field of

dietetics has been described as striving towards, optimal nutrition status of individuals and groups (The Academy of Nutrition and Dietetics, 2016). By focusing on the health-related potential of a specific food, the incorporation of perspectives from social marketing and the application of consumer and sensory research methods, the present thesis perhaps could be described as having a *dietetic marketing perspective*. Rye bread is the food in focus, but this could be seen as an example of the proposed dietetic marketing perspective, which could also be used as a complement to or next step in nutritional health-promoting research on other specific food products with the potential to benefit health.

In social marketing, consumers are thought to more easily adopt a behavior if they receive benefits they consider valuable or if relevant barriers are removed (Pettigrew, 2016). Quality has been described as a core concept in building consumer value and was thereby a useful concept for the proposed dietetic marketing perspective. The main focus in the present thesis was on health-related and sensory qualities, which have also been described as the essential core of food quality as well as the two most important dimensions in consumers' quality perception of bread (Peri, 2006; Dewettinck et al., 2008). The relationship between objective quality – what the product offers, and subjective quality – what the consumer perceives, – has been described as highly important (Grunert, 2007). In line with Martens (1999) description, sensory analysis played a central role as a bridge between the objective product, – the rye bread – and the person in the present thesis.

Hedonic aspects are essential in food choice. Thus, in the transmission of nutrition knowledge to public health it is important to also include a sensory perspective (Tuorila & Monteleone, 2009). Partnerships between industry, government and academia have been emphasized as important to increasing the availability of desirable and healthful cereal foods (Ferruzzi et al., 2014). Figure 6 illustrates knowledge transmissions of relevance to supporting consumption of rye bread with potential health benefits, which has been addressed in the present thesis. The food – rye bread, for which previous research has identified potential health-benefits, is in the center of the pyramid. Subjective quality is represented at the top together with the consumers. Authorities communicate with consumers through, e.g., recommendations, guidelines and labeling and with industry also through regulations. Because consumer choice ultimately depends on what is available (Marshall, 2001), the left corner represents the food industry, where both producers, retailers and food service providers are included. Knowledge of consumption patterns, liking and consumer perceptions, can

be used by industry and authorities to modify and target communication and product development.

Social marketing includes thinking through elements such as who the target consumers are, what their preferences are, what the characteristics of the product are, how perceived costs/barriers can be reduced and how the product can be made available (Weinreich, 2010). In this section, the results of the four papers are discussed from these points of view.

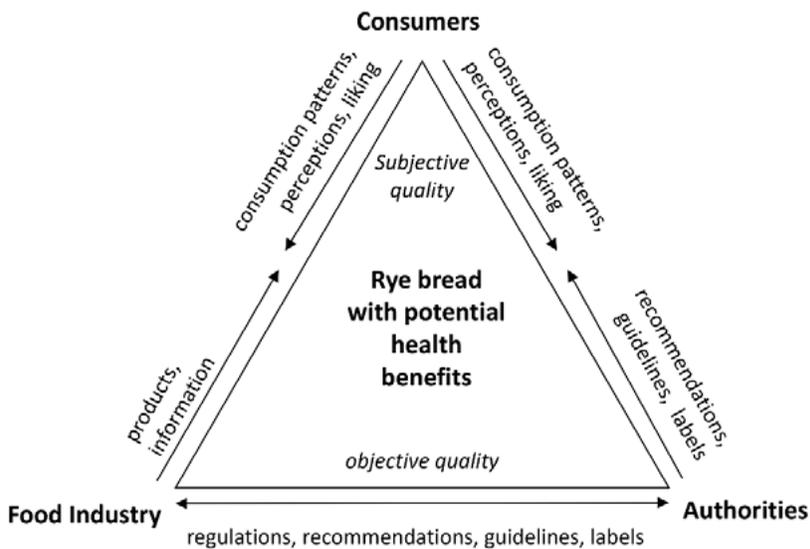


Figure 6. Interconnection between objective and subjective food quality among consumers, food industry and authorities, as addressed in the present thesis

## Identification of target consumers

Paper I showed that socio-demographic, geographic and lifestyle-related factors are associated with what type of bread is consumed. The older consumer groups (45-80 years) more often reported eating traditional bread types such as dry crisp bread, whole-grain bread and whole-grain rye bread with sourdough compared to the younger consumer groups (18-44 years). Similar differences in consumption patterns between age groups has previously been seen for the total intake of whole grain in several different

countries (Lang & Jebb, 2003). Paper III indicated that both food choice motives and childhood bread consumption habits were associated with liking and willingness to eat bread with a high rye content. The higher consumption seen in older age groups could thereby be associated with a continuing effect of age due to a change in food choice motives. But also a cohort explanation, that consumers born during a given period share experiences, memories and preferences (Furst, Connors, Bisogni, Sobal, & Falk, 1996; Lang, Thane, Bolton-Smith, & Jebb, 2003).

The finding in Paper I, indicating that lower educational level was related to higher consumption of bread in general as well as to a higher likelihood of eating mainly white bread was in line with earlier Scandinavian studies (Berg et al., 2008; Kyrø et al., 2011). This, however, indicates a difference in bread consumption compared with Finland, where whole-grain rye bread is related to lower occupational class (Prättälä, Helasoja, & Mykkänen, 2001). This result can also be related to Paper IV, where significantly more respondents with a lower educational level responded that they found it difficult to know which bread is healthier and to the results from Paper III, where a lower educational level was associated with the “white-soft” preference cluster. Having children in the household was also a factor associated with white bread consumption, which shows children’s impact on their parents’ bread consumption and is also in line with earlier studies (Worsley, 2003; Berg et al., 2008). In a family, food choices often are negotiated and conflicts may arise due to different values or preferences (Nørgaard & Brunsø, 2011). Paper III did however not show any effects on liking related to children in the household. Paper I and III indicated that influences from other cultures were associated with rye bread liking and consumption, as more of the older than the younger consumers were born or had parent(s) that were born in countries such as Finland and Denmark, where consumption of whole-grain rye bread has traditionally been higher (Prättälä et al., 2001; Mejborn, Bilfoft-Jensen, Trolle, & Tetens, 2008).

Food choice motives, especially in the younger consumer group, were associated with liking of rye bread (Paper III). Perceived importance of *sensory appeal* in food choice was equally high for all groups, but consumers who found *health*, *ethical considerations* and *natural content* important in food choice had a higher liking for whole-grain rye bread, while consumers who liked white-soft bread with less rye more often perceived *familiarity* and *convenience* important when making their food choices. This is in line with Pollard, Steptoe, and Wardle (1998), who reported that people to whom *natural content*, *ethical considerations*, *weight control*, and *health* were more important also ate more of the foods

regarded as healthy, such as brown bread. Pohjanheimo and Sandell (2009) also showed that *health*-motivated consumers had a higher preference for drinking yoghurts with a sourer taste. To conclude, the findings show that the consumer segments with the lowest consumption of bread with a high rye content are younger age groups, families with children, and groups with lower educational levels as well as consumers who find *convenience* and *familiarity* to be more important and *health*, *ethical considerations* and *natural content* less important food choice motives.

## Availability and sensory characteristics of rye bread with potential health benefits

Previous research has shown several potential health benefits of bread baked with rye (Åman et al., 2010; Poutanen & Åman, 2014). Most of the bread consumed today in Sweden is produced by industrial bakeries, and the available bread types therefore play an important role in the extent to which the potential health benefits of rye can be harvested.

In Sweden, there is no standard for what a *rye bread* should contain and, for this reason, the content and sensory characteristics of the samples studied in Paper II varied widely. It should be noted that dry crisp breads were not included in the characterization. The samples differed in their FI and almost half displayed an FI in line with or lower than the two control samples, which would indicate a relatively high availability of bread with more beneficial glyceamic properties for consumers to purchase. However, it should be noted that the FI-method mainly capture the viscosity mediated effects on glycaemia and the threshold for a low FI was in the present study based on two control samples with 75% sifted or whole-grain rye flour that had previously shown beneficial glyceamic profiles (Rosén et al., 2009). Further studies should validate the method as well as define thresholds for what should be considered a low FI. The samples classified as having a lower FI varied widely in their content, for example between 31-100% rye, 0-100% whole grain, 5-15 g fiber and 1-10 g sugar. This highlights the challenge of helping consumers identify bread with beneficial glyceamic properties, especially because no health claim has been authorized by EFSA. Almost all of the samples with a higher FI also contained added wheat gluten. The addition of wheat gluten has, for example been shown to diminish the insulin saving properties of rye bread (Nordlund, Katina, Mykkänen, & Poutanen, 2016).

When studying the association between the health-related characteristics and the sensory profiles of the samples, however, a clear

association was found. The FI corresponded to the sensory classification of the rye breads, and samples in three of the categories (A, B and F) displayed lower FI values. Samples in category A and B generally had a high rye content, high fiber content, low pH and were characterized by a dry and chewy texture with sour, bitter and roasted flavors. The samples in category A could be described as similar to traditional Finnish rye breads (Hellemann et al., 1987), with whole-meal rye flour and sourdough. Samples in category B included, for example, German-style pumpernickel bread (B2) and displayed a higher heterogeneity due to the content of whole or cut rye kernel. Category F, however, displayed a relatively low FI together with a softer texture, light color and sour flavor. Here, increased solubility of the arabinoxylans due to the sourdough fermentation may have been involved in lowering the FI (Katina et al., 2007). Samples in category C, D and E all displayed higher FI values than those of the controls and were characterized by a softer, less compact texture.

Physical structure has been described as the most important factor in determining the postprandial glycemic response of bread (Fardet et al., 2006). Correlations between the textural and glycemic properties of rye bread has previously been studied and discussed (Juntunen et al., 2003; Pentikäinen et al., 2014; Nordlund et al., 2016). Paper II showed that the objective sensory quality of rye bread described by a trained sensory panel was highly associated with the FI, especially with regard to texture. This result together with results from the consumer test (Paper III), where consumers successfully rated the healthiness of the samples based on tasting them, indicates that sensory attributes could be used to aid in the identification of commercial rye bread with potentially more beneficial glycemic properties. However, Paper III showed that the sensory properties associated with a more beneficial FI were also negatively related to liking, especially among the younger consumers, a barrier that is further discussed below.

## Sensory-related challenges and opportunities for consumption

Sensory responses are important in determining choice of different foods (Shepherd, 2001). Focusing on sensory pleasure has therefore been described as a key factor in promoting healthy eating (Tuorila & Monteleone, 2009; Pettigrew, 2016). Kotler (1971) described *desirable products* as those that combine immediate satisfaction with long-term benefits, and from a dietetic marketing perspective such a combination

would be optimal. Paper III showed that, especially among the younger adults, the rye breads with the most health potential were not well liked, although they were perceived as healthy and would better be categorized as *salutary products* (Kotler, 1971). The most liked rye breads in the younger group were soft, juicy and sweet and not perceived as healthy and would thereby be categorized as *pleasing products*. To enable increased consumption, the products either need to be reformulated to better match these consumers' preferences or consumer preferences need to be targeted to increase liking of the sensory properties of these rye breads.

### The product meets the consumer

Paper III showed significant differences in liking of the sampled rye breads, and different preference patterns were identified among younger and older consumers. The results for the younger group (18-44 years) were in line with research on wheat bread, where a low chewing resistance was the most liked by younger consumers (<30 years) (Kihlberg & Risvik, 2007). For consumers in the "white-soft clusters," it would be challenging to find rye breads that have a low FI and still are in line with their sensory preferences. The dry, chewy and compact texture and the sour flavor that characterized many of the rye breads with lower FI values were negatively associated with liking in the "white-soft-cluster." It has been shown, however, that liking of whole-grain bread can be increased by re-formulations of the product (Bakke & Vickers, 2007), and, Heiniö et al. (2016) recently reviewed different technological strategies that may be used. Wheat gluten is commonly added to bread to improve the bread volume and crumb texture when flours of lower-than-desirable protein content are used (Day, Augustin, Batey, & Wrigley, 2006). But, as previously mentioned, wheat gluten has been shown to diminish the beneficial effects on postprandial insulin response (Nordlund et al., 2016). This indicates that simply adding wheat gluten not would be the preferred solution. The outer part of the rye kernel contributes a more intense color, flavor and a coarser texture. Using endosperm rye flour would enable development of bread especially in line with younger consumers' preferences, that is bread with a mild flavor, softer texture, high rye content and beneficial glycemic properties (Heiniö et al., 2003; Rosén et al., 2009). Bread with a high endosperm rye content is not at all common on the Swedish market. Sample F2 contained the highest content of endosperm rye flour and also displayed a lower FI. Studying consumers' liking for this bread shows that it scored around five, "neither like nor dislike" on the nine-point hedonic scale, there were no differences in liking between the age groups and only small differences

were found between the different liking clusters. Experience and exposure play a role in sensory liking and a white soft bread with a sour taste was perhaps less familiar for the consumers (Mela, 2001).

Pleasing breads could also be made more desirable. In Paper III, for example, sample E2 – a whole-grain rye syrup roll – proved to be equally liked by both younger and older consumers and could perhaps be nutritionally optimized while keeping a sensory profile attractive to a wide consumer group. One strategy for making *pleasing* bread *desirable* is to add fiber or whole grain in smaller amounts. Although high fiber content is desirable from a health perspective, Rosén et al. (2009) showed that the benefits of rye products in relation to glycemic properties cannot be mimicked by adding rye bran to a white wheat background. Nordlund et al. (2016) also showed that adding bran to a whole meal sourdough bread increased the insulin response. The addition of bioprocessed rye bran to a wheat bread has however, been shown to induce similar, but not as pronounced beneficial effects on postprandial glucose response compared to rye bread (Lappi et al., 2014).

## Consumer meets the product

Another approach to increasing consumers' perceived value of the already existing breads rich in rye and whole grain would be to aim to increase liking for these breads. Paper III showed that the bread type reported to have been eaten in childhood, food choice motives and socio-demographics were related to liking of rye bread in both the younger and the older group, and the patterns were similar. Exposure in younger ages is related to liking in adulthood and preferences established in childhood have been shown to be important in predicting preferences later in life (Cooke, 2007; Köster, 2009). An earlier national dietary survey of Swedish children reported that the type of breads mainly consumed were classified as white bread (Enghardt Barbieri, Pearson, & Becker, 2006). This information, together with the results from the present study, would suggest that the liking of whole-grain rich rye bread with a chewy texture and sour flavor could further decrease in coming generations. We are born with a preference for sweetness and an aversion to bitter and strong sour tastes, but apart from these, most of the sensory preferences in humans are learned through repeated exposure to particular sensory events and their associated consequences (Mela, 2001). Through repeated exposure, children learn to like foods that are not inherently palatable or calorific, but typically, children must try foods eight to fifteen times before their acceptance increases (Birch, 1999; Cooke, 2007).

Educational level differentiated both the younger and older clusters (Paper III), and a lower educational level was also associated with a lower intake of whole-grain bread in Paper I. The association between a lower education level and the food choice motive *familiarity* is in line with earlier research, and one suggested explanation is that this group cannot afford to take chances with food selection, that is to buy unfamiliar products that might not be accepted by the family (Steptoe & Wardle, 1999). A recent qualitative study also showed that children's taste aversion is one important factor influencing low-income consumers' food decisions. Economically constrained parents minimized financial loss in the form of food waste by purchasing what their children would eat, while avoiding experimenting with new items or reintroducing foods that their children initially turned down (Daniel, 2016).

A discrepancy between sensory liking and food intake may occur, however, and one explanation for this may be the importance of other factors, for example healthiness in food choice (Drewnowski, 1997). Because exposure and experiences are important determinants of liking, this could subsequently lead to increased liking (Mela, 2001). Changes in a person's food choice motives during the life course could therefore also have an effect on liking. Among adults, a four-month dietary intervention with provision of whole-grain products was shown to have a significant impact on whole grain consumption 12 months' post-intervention (however, liking was not studied), demonstrating the possibility to affect consumption by exposure (Brownlee, Kuznesof, Moore, Jebb, & Seal, 2013). Younger consumers in the "dark-chewy cluster," with a higher liking for samples that were also perceived as the healthiest, also rated *health* as a more important food choice motive compared to younger consumers in the "white-soft cluster." The older consumers generally displayed a higher liking for the whole-grain rye breads and also scored the importance of health in food choice higher on the FCQ-scale compared to the younger. In terms of ranking however, health was rated as the fourth most important factor among the older consumers while it was the second most important among the younger consumers. A higher consumption of healthy food (fish) among older age groups was shown to be mediated by an increased interest in health in this group (Olsen, 2003). In the present study, the importance of health in food choice did not differentiate as much between the older clusters as between the younger. Difference in type of bread consumed in childhood between the younger and older consumer group therefore offered a better explanation for the difference in rye bread liking among the younger and older consumers.

## Challenges and opportunities for communication of health-related bread characteristics

One explanation for the finding that one out of four consumers was not aware of any bread they considered healthy and that one third reported to have reduced their bread intake (Paper IV) may be that the healthiness of carbohydrate-rich food such as bread has been questioned in Sweden, mainly in the media and blogosphere over the course of the past decade (Holmberg, 2015). Consequently, increasing these consumers' awareness of different types of bread and of their contribution to a healthy diet would be desirable. Particularly because consumers who ate less bread also had a lower total intake of whole grain (Paper I), indicating that they did not sufficiently compensate with other whole grain-rich food types.

Paper III and IV investigated what Smith et al. (2010) describes as the propositional and sensory components consumers expect of "rye bread" and "healthy bread." The respondents' definitions of "healthy bread" were based on their own interpretations, and primarily nutritional qualities were proposed. Despite their use of lay language, the respondents' answers were generally well in line with current scientific descriptions and recommendations of bread from a health perspective (Poutanen et al., 2014; NFA, 2016). For several of the mentioned health effects, however, there are no approved health claims, for example regarding satiation or glycemic properties, nor are there any recommendations for considering glycemic properties in the NNR 2012 (Nordic Council of Ministers, 2014). Still, the above-mentioned attributes are on consumers' minds, and consumers must therefore rely on their own cues when trying to identify bread with these health benefits. It should also be mentioned that the need to communicate the association between reduced postprandial glycaemia and health to the general public through channels such as national dietary guidelines, food composition tables and food labels has recently been stressed (Augustin et al., 2015).

Symbolic information such as pictures or words referring to the above properties may have a misleading effect on the perceived healthiness of food (Sutterlin & Siegrist, 2015). In a recent study among older Americans ( $\geq 65$  years) for example, almost half (46%) misidentified bread as being whole-grain bread (Violette et al., 2016). According to EU food law, information on food packages should not be misleading (Regulation No. 1169/2011). Paper IV showed that particularly attributes such as sourdough, kernels and rye, which are not regulated, can increase consumers' perception of the healthiness of bread if such cues are used on the packaging. Quantitative indication of ingredients must be declared on the package, for ingredients that for example are emphasized on the

labeling in words, pictures or graphics (European Commission, 2011). However, an eye-tracking study measuring consumers' visual gaze on food packages showed that the product's name was most likely to attract visual attention, while less visual gaze was focused on health-related claims, ingredient lists and signpost labels (Sørensen et al., 2012). Findings from Paper III also showed that consumers expected a *rye bread* and a *whole-grain bread* to contain around 70% rye/whole-grain flour, considerably more than many of the commercial samples in Paper II. Paper IV also indicated that consumers associated sourdough with beneficial glycemic properties. Paper II, however, showed that a sourdough label on the package not was a reliable indication, because the amount of sourdough included was sometimes small, as indicated by the pH and TTA values in these samples.

Dry crisp bread was commonly described to be healthy by the consumers in Paper IV, and it is also recommended by the NFA as one way to increase whole grain intake (NFA, 2016). The nutritional qualities of crisp bread may differ, however. In Sweden, crisp bread is most often (but not always) made out of whole-grain rye flour, and commercial rye crisp bread has shown beneficial glycemic properties compared to wheat crisp bread (Johansson et al., 2015). Dry crisp bread is a very traditional Swedish bread type, but the consumption has been decreasing (BOA, 2016). Both Paper I and III also showed that younger consumers chose to eat dry crisp bread to a lower extent than older consumers do.

The white wheat toast (Äntligen) with 25% whole-grain in the picture elicitation task (Paper IV) was classified as the least healthy by 71% of respondents despite having a Keyhole symbol, which guarantees certain levels of whole grain, fiber, sugar and salt in the product. Moreover, the Keyhole symbol was not mentioned in the respondents' descriptions of healthy bread. Prior research also has shown limited or no effect of the Keyhole label on consumer judgments of food healthfulness (Grunert, Fernández-Celemín, Wills, genannt Bonsmann, & Nureeva, 2010; Orquin, 2014). Respondents in Paper IV who classified the brown wheat-rye bread as the healthiest (more often older respondents and those with a lower education level) – despite the bread's lack of a Keyhole symbol and its high sugar content – may have been focusing more on the bread's dark color. Some of the elicited attributes related to the perceived healthiness of bread were intrinsic, and these were mainly related to texture (“coarse,” “airy/fluffy texture”) and color (“dark,” “white”). Although color may not be a reliable cue since it may be obtained by dark syrup, Paper II showed that some sensory attributes – foremost texture (e.g., chewiness), but also

flavor (e.g., sourness) – could serve as quality indicators of the FI of commercial rye bread.

The consumers' healthiness ratings of breads, based only on intrinsic characteristics of the products in Paper III, could be described as fairly accurate, because the samples with more whole grain, rye, fiber and less sugar were rated as healthier. This was in spite of the lack of any information on the packaging, which is generally available to the consumer. These findings indicate that although the bread products most often cannot be tasted before purchase, sensory information could aid consumers in identifying healthier rye bread. Grunert (2015) also argued that it is important that the impressions communicated about a product before purchase are upheld throughout consumption (e.g., healthiness or the concept of a rye bread) and that the physical products should be seen not only as a source of sensory pleasure, but also as an information source. In Paper III, the association between sensory attributes and consumers' perceptions of a rye bread and a healthy bread were studied. The results showed that the consumers had clear expectations of the sensory components of a "rye bread" and bread perceived as healthy. The sensory qualities were thereby clearly connected to these attributes in the consumers' mind. Result from Paper III and IV also underline that if making pleasing breads more desirable, extrinsic quality cues are important to communicate healthfulness to consumers, since the sensory components in the bread may not be in line with what the consumer perceive as a healthy bread. The white toast with 25% whole grain and a Keyhole label in Paper IV were for example perceived as the least healthy by the most respondents.

## Implications in relation to the 4 Ps

The results from the four studies may be useful in finding strategies to support increased consumption of rye bread with health benefits in interventions, or more specifically, for example, in policy and product development or dietary counseling. In this section, the 4 Ps (Product, Price, Place, Promotion) are applied to structure possible implications of the included papers and how these could be used in a dietetic marketing mix to encourage and facilitate healthy eating behavior. Here, both downstream (individual) and upstream (environmental) factors and different stakeholders are included (Hoek & Jones, 2011; Wymer, 2011).

The **Product** in this case could be described as rye bread with potential health benefits. Paper III showed that commercial rye breads with beneficial glycemic properties, as predicted by the FI, were available, but

that these were mainly characterized by a chewy and dry texture and sour flavor. Product development should focus especially on aligning the sensory properties of rye bread that has health benefits with the liking patterns of consumers in the “soft-white clusters,” keeping in mind how technological optimizations may affect the glycemic properties. Here, one important task for research is to provide industry with tools and knowledge concerning how the sensory properties of rye bread may be altered to fit consumer preferences while maintaining the health-beneficial potential of rye. Younger consumers and mainly white bread consumers also ate more fast food bread and bread on the run; thus, this could be a potential product category to target. It could also be further explored how using endosperm rye flour in bread making, may create soft and mild rye bread with beneficial glycemic properties. The whole-grain rye syrup roll (E2) in Paper III showed relatively high liking among both age-groups. It contained 63% rye and 68% whole grain, but also had a high total sugar content and relatively high FI. The sensory profile of this bread could, however, be used as a starting point for developing healthy rye bread with a high liking among a broad consumer groups. To help consumers identify rye bread, labeling should not be misleading, especially with regard to the use of attributes that consumers perceive as healthy and that not are regulated, such as coarse, rye and sourdough. It should also be kept in mind that consumers expected a rye bread and a “whole-grain bread” to contain around 70% rye/whole grain.

**Price** is defined here as the cost that the target audience associates with adopting the behavior, and sensory liking was shown to be a major obstacle, to consumption of the healthiest bread, especially among younger consumers (Paper III). Although research on consumer responses has revealed trends in and effects on liking, actual product development is the task of the industry. This requires investments and is thereby also a cost for industry (Tuorila, 2000), especially because most new food products have been described to fail to survive the first year on the marketplace (Fuller, 2011). Another measure could be to try to shift consumer preferences toward more whole grain-rich rye breads, e.g., by exposure at younger ages that reaches all socioeconomic groups. Bread is most often eaten with some type of spread and filling, which are put in the mouth at the same time. Tuorila, Lehtovaara, and Matuszewska (1990) showed that unsalted bread was considered acceptable if accompanied by other items that were acceptable, such as a cheese. Thereby optimal combinations of bread and fillings may be used as one strategy to increase the liking for sour whole grain-rich rye bread in the “white-soft clusters.” One third of the consumers found it challenging to know which bread is healthier,

indicating a search cost. For this reason, developing ways to present information so that consumers can process it more quickly and easily should be warranted.

With regard to **Place**, providing whole-grain rye bread in the free public school meal could perhaps narrow the socioeconomic gap in bread consumption. Traditionally, dry crisp bread has often been served in schools. Further enabling the consumption of different bread types in for example, preschool and/or in the free public school meal provided in Sweden and other countries could be one way to increase the exposure in childhood among all sociodemographic groups and thereby broaden the liking. Another opportunity could be sensory education in school, which has also been shown to reduce neophobia and would thereby also be beneficial (Mustonen & Tuorila, 2010). Sensory education is a training concept based on sensory perception and experiences and their impact on the processes of discovering new foods and learning eating habits (Sandell et al., 2016). Provision of whole grain and rye-rich bread in fast food settings would also be warranted. At primary healthcare centers, health professionals are expected to be able to give basic lifestyle-related advice, e.g., related to healthy dietary habits (NBHW, 2017). Therefore, how to identify and choose bread in relation to both health-related needs and sensory liking could be valuable information in healthcare contexts.

In relation to **Promotion** there is a need to increase consumer awareness of how different types of bread contribute to a healthy diet and how to identify these breads in the shopping situation; this need is especially marked among consumers with a lower education level. Consumers perceived glycemic properties and satiety to be important health-related attributes of bread (Paper IV), however these cannot be communicated and it should be considered how the consumers interest in these qualities could be addressed. Standards or regulations determining when certain attributes can be emphasized on the package could perhaps be useful. In NFA's guidelines for the school meal, baking bread in the school kitchen is encouraged. Here is an opportunity to develop optimized rye bread recipes with a step-wise increase in rye/whole grain/sourdough to be distributed to production kitchens, not only in schools but also to other food service providers. The association between sensory and health-related properties could be used in communication with consumers. Sensory product information may help ensure alignment between the consumers' expectations and sensory experiences. Helping and guiding consumers to different choices is important in creating customer satisfaction, and communicating products' sensory profile in the buying and consumption moment will help the consumer find what he or she likes and prefers,

especially in the case of new products (Swahn, Mossberg, Öström, & Gustafsson, 2012). It could however also be a cue for health-related quality. Figure 7 shows a prototypical example of what this communication could look like, based on the sensory profiles of the commercial rye bread in Paper II. Conventional sensory profiling with a trained panel has been described as the gold standard for profiling products (Lawless & Heymann, 2010). The method may, however, be relatively time consuming and expensive, and alternative more rapid methods such as flash profiling could also be applied for this purpose (Varela & Ares, 2012).

	A3		C4		D4
Chewy	●●○	Chewy	●○○	Chewy	●○○
Juicy	○○○	Juicy	●●●	Juicy	●●○
Sour	●●●	Sour	○○○	Sour	●●○
Sweet	○○○	Sweet	●●●	Sweet	●●●
Rye	●●○	Rye	○○○	Rye	●○○
Roasted	●●○	Roasted	○○○	Roasted	●●○

Figure 7. Prototypical example of how selected sensory attributes of rye bread from group A, C and D, described by a trained sensory panel in Paper II, may be communicated to the consumer

## Methodological considerations

The path that has led to completion of the present thesis has been full of crossroads, challenges and choices and several methodological considerations should be raised and discussed. The response rate was rather low, both in the national food survey Riksmaten 2010-11, on which secondary analyses were performed in Paper I, and in the survey of Paper IV. A downward trend has been seen in several national survey studies in recent years (Morton, Cahill, & Hartge, 2006; Tolonen et al., 2006; Dickson-Spillmann & Siegrist, 2011), and a similarly low response rate (37%) was observed in the Norwegian national food survey from the same period (Totland et al., 2012). In Riksmaten 2010-11, selected individuals received a letter of invitation and were thereafter contacted by telephone, however 20% were not possible to get in contact with. In line with previous studies, the rate of non-responders was higher among lower educational levels and among immigrants (Korkeila et al., 2001; Simunaniemi, Andersson, & Nydahl, 2009). Even so, a large sample was included in both papers. However, the participating respondents may have had a special

interest in bread or health, which may have biased the results by giving a more positive picture of the consumption and health perceptions. Strengths of the analyzed data in Paper I were that detailed food records over four days were collected from all over Sweden, and both gender and age groups were well represented in relation to the Swedish population. In Paper IV, the open-ended answers are not considered to be representative of the Swedish population, but do represent answers from a wide group of Swedish consumers between 18-80 years of age in all parts of Sweden. With regard to Paper III, the responding consumers were not included by random selection, but did represent a wide range of consumers in relation to socio-demographic factors, despite being recruited from the same geographical area.

Already collected food consumption data were used for analysis in Paper I. Here it is relevant to mention that, prior to my doctoral studies I worked at the NFA and was involved in the planning and data collection and thereby was very familiar with the data. When interpreting the results in Paper I, it is important to keep in mind potential measurement errors in dietary assessment surveys, for example that food records are reactive dietary assessment instruments that may alter the dietary behavior of the subjects (Gibson, 2005). The web-based database method used in Riksmaten was newly developed, and two recent validation studies of the method concluded that it functioned reasonably well with regard to total energy intake, but that the ability to capture whole grain intake was relatively weak (Nybacka et al., 2016; Nybacka et al., 2016). The focus of Paper I was not specifically on whole grain intake, but on types of bread and where and when bread was consumed.

One challenge was that there is no standardized bread classification in Sweden. In Paper I, the respondents were asked to identify the bread in the database most similar to the bread they had consumed. Although the bread types listed aimed to reflect those on the Swedish market, there is a risk that bread was perceived differently. Classification of bread was also challenging in an earlier study (Binkley & Golub, 2011), where the categories ended up being “white” or “dark.” In the present analysis, it was possible to make a rough classification of the included bread types and some more detailed analyses regarding specific bread types. When deciding which breads should be included in Paper II, broad inclusion criteria were applied. Few breads in Sweden contain 100% rye, and it has been suggested that for category appraisals the products included should represent a wide range of existing products (Moskowitz & Maier, 2007). Thus the samples contained between 15-100% rye flour. Paper II explored and characterized commercial rye bread on the Swedish market. In contrast

to studies using a classical experimental design, such as a factorial design in which products are developed according to specific ingredient specifications (Helgesen & Næs, 1995), this paper was based on commercially available varieties of rye bread. The associations between the sensory and health-related properties should not be considered causal relationships, but representations of patterns for the sensory and health-related characteristics of rye bread on the Swedish market. Other recent research has also explored taste and nutrient relationships among commercial foods (van Dongen, van den Berg, Vink, Kok, & de Graaf, 2012; van Langeveld et al., 2017).

The *in vitro* measurement of FI values enabled sampling and comparison of more products on the market than would have been possible if measurements of postprandial blood glucose and insulin levels had been performed. The FI ranks products according to their glycemic properties, mainly based on the viscosity of the digesta (Östman et al., 2006), and has been shown to be highly correlated with the GI, GP and insulin response (Ekström et al., 2013). However, this is no guarantee for the effect on glycaemia and mainly the effect of viscosity in the bread that is related to the glycemic properties is captured. To obtain specific blood glucose or insulin values, a study including human subjects must be performed.

Freezing the samples in Paper II and III may have affected their sensory properties, but was considered necessary in the handling the samples and also ensured that the samples were equally fresh for each testing day. The same procedure was used for the samples in both the descriptive analysis and the consumer test.

In Paper IV, the respondents could not touch the bread packages or taste the bread, and their answers therefore reflect quality perceptions based on overall visual attributes. The choices represent the combined effect of cues such as brand, color, packaging and labels together with the respondents' previous experiences. Ingredient and nutritional information for the samples were available on the last page of the questionnaire or by clicking a link in the web-based questionnaire. The reason for this was not to have this information too easily available, because in the buying situation the consumer needs to pick up the product and read this information on the back of the package. It is unknown how many of the respondents used this information.

In Paper III, the type of bread generally consumed while growing up was self-reported and represented the consumer's own recalled experiences. Bread is often eaten with spreads and fillings, but the samples in this study were tasted alone, as consumers may like different fillings. This and other situational and contextual factors characterized by a less

natural eating situation in the specific test may also have affected the liking (King, Meiselman, Hottenstein, Work, & Cronk, 2007).

The FCQ used to study food choice motives in Paper III is a widely used questionnaire that has shown good reliability (Markovina et al., 2015). In line with the original scale, a nine-factor solution was identified in the present study. Cronbach's alpha is a reliability coefficient that assesses the consistency of a scale, and a value between 0.6-0.7 is considered the lower limit of acceptability (Hair, 2010). In the present study, the factor weight control showed the lowest Cronbach's alpha, at 0.69. Another reliability measurement, item-total correlation, indicates that the item is measuring the same construct as is measured by the other items in the same subscale. Item-total correlations <0.4 for some items in the FCQ have been seen in other studies and described as low. In the present study, two items out of the 36 had an item-total correlation of 0.38, while it has previously been as high as nine (Fotopoulos, Krystallis, Vassallo, & Pagiaslis, 2009). Suggested explanation for this is that the different FCQ items might have different connotations in different cultures or that a shift has occurred in the meaning attributed to food characteristics since development of the questionnaire (Eertmans, Victoir, Notelaers, Vansant, & Van den Bergh, 2006; Pohjanheimo et al., 2010).

## Future perspectives

Further research on how bread could be described and classified, especially in dietary surveys, would be valuable to improve the validity of this type of investigation. How we can design epidemiological, dietary and other surveys to obtain as high response rates as possible is also important to further investigate, especially targeting groups with, e.g., low educational level, where the response rate often is particularly low.

How the identification of bread from a health perspective can be simplified for consumers through labeling or other means should also be studied. In such research, the health-attributes that consumers find important should be considered. Several health claims applications for rye bread have been rejected by EFSA, and further research should also take into account EFSA study design requirements in relation to assessment of health claims proposals. In future dietary intervention studies it is also valuable to include a sensory perspective. The FI and other *in vitro* prediction models could be further explored as tools for quality control of the glycemic properties in industrial product development of bread.

Conducting longitudinal studies of sensory liking, from a life-course perspective, would be challenging, but could give further insight into the cohort versus/combined attitudinal effect on liking. Potential long-term effects on liking from exposure in younger ages would also be interesting to further investigate. Strategies to increase the liking of sourdough whole-grain bread could also be further explored, especially among younger consumers who do not perceive health as an important factor in food choice. The potential effects of food pairing or modified oral processing, such as how slow or fast it is being chewed and eaten, are two topics that could be investigated. In an effort to cater to these consumers' preferences, the potential of bread with a high content of endosperm rye flour, preferably with a less sour flavor could further be explored.

In relation to the decreasing consumption of crisp bread, and the lower consumption seen among younger consumers, more knowledge about consumers' perception and liking of crisp bread would also be valuable.

## Conclusion

The potential of bread made from rye to be a health-beneficial component in the Swedish diet was the starting point for the present thesis. The main aim was to investigate consumption patterns, health-related and sensory qualities and consumer perceptions of bread, more specifically commercial rye bread. Concepts from social marketing were adopted and the thesis was described as having a dietetic marketing perspective. A target food with health potential – rye bread – was in focus. Food quality was an important concept in identifying barriers to and opportunities for consumption of rye bread with potential health benefits, and sensory analysis was used as a key methodology to bridge the gap between the product, the rye bread, and the person.

The consumer groups with the lowest consumption of whole-grain and rye bread were younger age groups, families with children, and groups with lower educational levels as well as consumers who rated *convenience* and *familiarity* as important food choice motives (Paper I and III). Younger respondents also reported eating more fast-food bread and bread outside the home, a habit found also among the *white bread* consumers.

There is no definition of rye bread in Sweden, and Paper II showed that the health-related and sensory qualities of the commercial rye bread varied widely. Based on their sensory profiles, the sampled rye breads (n=24) could be classified into six groups with distinctive sensory characteristics. Although consumers in Paper III expected a *rye bread* to contain 70% rye, samples with a front-of-pack rye label could contain as little as 20% rye. Almost half of the samples were classified as having a lower fluidity index (FI), which would indicate more beneficial glycemic properties; these contained between 31–100% rye, displaying pH 4.3–4.8. The sensory profiles of the samples were highly associated with the FI and showed that foremost texture, such as chewiness, and flavor, such as sourness and rye flavor, were correlated with a lower, more beneficial FI. However, especially among younger consumers, the samples with the most beneficial FI were the least liked (Paper III). This liking pattern was particularly associated with eating mostly white bread and sweet loaf during childhood, food choice motives, such as lower importance of *health*, *naturalness* and

*ethical considerations* and more importance of *convenience* and *familiarity*, as well as lower educational level. Differences observed in consumption and liking of bread rich in rye in different age groups may be explained both by a change in attitudes but also a cohort effect, in that different cohorts grow up in different contexts. Due to a lower consumption of these bread types, this would indicate that liking of sourdough whole-grain rye bread could further decrease among coming generations. This calls for strategies to broaden acceptance for different types of rye breads, and schools could provide one arena in which sensory learning can take place, both in teaching and during school meals. This also calls for product development of rye breads whose sensory quality is in line with these consumers' preferences, but that still possess the beneficial attributes of rye, for example through the use of endosperm rye flour.

Paper IV showed that three out of four consumers knew of bread that they considered healthy. Beneficial glycemic properties, satiety and gut health were perceived as important health-related qualities in bread, but about one third of these, and more of those consumers who had a lower educational level, found it challenging to identify healthier bread. At the moment there are no health claims related to, e.g., the potential beneficial glycemic properties of rye bread or its satiating properties. In, for example, dietary counseling to simply recommend a *rye bread* or a *sourdough bread* would perhaps not be sufficient given the lack of regulation of labeling. Paper II and III also indicated that the use of sensory profiles in marketing could help the consumer not only find what he or she likes, but also identify healthier bread.

Results from the present study have identified some barriers to and opportunities for consumption of rye bread with potential health benefits. Many different factors are, however involved in what we eat. To harvest the potential of rye in public health, partnerships between industry, authorities and academy are essential, but also the integration and cross-fertilization between different academic disciplines.

# Svensk sammanfattning

## Bakgrund

Hälften av Sveriges befolkning har idag övervikt eller fetma och enligt Världshälsoorganisationen stod livsstilssjukdomar såsom typ 2 diabetes och hjärt- och kärlsjukdomar år 2010 för 86% av dödsfallen i Europa. Detta är sjukdomar som kan påverkas genom levnadsvanorna och däribland vad man äter. Hela kostmönstret har betydelse, men kostmönstret består av enskilda livsmedel och bröd har traditionellt sett varit och är fortfarande en viktig del i den svenska kosten. I den senaste nationella matvaneundersökningen av vuxna i Sverige, Riksmaten 2010-11 rapporterade 98% av deltagarna att de hade ätit bröd under den fyra dagar långa kostregistreringen, i genomsnitt 2-4 skivor per dag.

Det är dock näringsmässiga skillnader mellan olika typer av bröd. Forskning har visat att bröd bakat med råg har flera potentiella hälsofördelar. Det kan bland annat bidra till ett mer välglerat blodsocker- och insulinsvar, något som i sin tur kan bidra till att förebygga och behandla t.ex. typ 2 diabetes och hjärt- och kärlsjukdomar. För att rågbröd ska kunna bidra med denna potentiella effekt på hälsan måste dock rågbröd med dessa egenskaper finnas tillgängliga, väljas och ätas. Studier har visat att konsumenter anser sensorisk acceptans, oftast benämnt smak, och hälsa vara de viktigaste kvalitetsegenskaperna för bröd. Dessa spelar därmed in vid val av bröd. Betydelsen av kolhydratiska livsmedel såsom bröd i en hälsosam kost har sedan 2000-talet ifrågasatts såväl i traditionell media som sociala medier något som kan ha påverkat svenska konsumenters uppfattningar om och konsumtion av bröd. Kunskap om konsumentens uppfattningar av bröd, speciellt rågbröd är dock begränsade. Rågbröd har i forskning ofta beskrivits vara en viktig komponent i en hälsosam nordisk kost. Det finns dock få studier, varav inga från Sverige av kommersiella rågbröd, dess upplevda smak och hälsoegenskaper. Denna avhandling bidrar med kunskap om brödkonsumtion och rågbröd ur ett konsumentperspektiv samt identifierar möjligheter och barriärer för konsumtion av rågbröd med potentiella hälsofördelar.

## Syfte

Syftet med denna avhandling var att undersöka konsumtionsmönster för bröd i Sverige, hälsorelaterade- och sensoriska kvaliteter hos kommersiella rågbröd samt konsumenters sensoriska acceptans och hälsorelaterade uppfattningar om bröd.

## Metod och material

I avhandlingen ingår fyra delstudier. I Studie I, analyserades brödkonsumtionen i Sverige baserat på den nationella matvaneundersökningen Riksmaten 2010-11. Här studerades framförallt vilken typ av bröd som konsumerades av vem, liksom när och var det konsumerades. I analysen ingick 1435 konsumenter (svarsfrekvens 36%) mellan 18-80 år som under fyra dagar rapporterade allt de åt och drack. Respondenterna delades in i olika grupper utefter vilken typ av bröd de ätit mest av och sedan undersöktes med hjälp av logistisk regression sambandet mellan grupptillhörighet och bakgrundsfaktorer såsom socio-demografi och livsstil. Grupperna baserades på vilken typ av bröd respondenten rapporterat mest av och grupperna var: i) bröd utan fullkorn, ii) bröd med mindre än 25% fullkorn, iii) bröd med mer än 25% fullkorn eller iii) knäckebröd. En jämförelse gjordes också mellan de som åt mer respektive mindre bröd totalt sett. Med hjälp av korrespondensanalys studerades också mer i detaljer vilka brödsorter, uppdelat på 23 brödtyper som oftast rapporterats i relation till kön och åldersgrupper.

I studie II undersöktes rågbröd på den svenska marknaden. Då det inte finns någon riktlinje för hur mycket råg ett *rågbröd* ska innehålla inkluderades bröd som var märkta med råg eller innehöll rågmjöl. Totalt 60 bröd, bakade av industriella bagerier och tillgängliga i hela landet identifierades och av dessa valdes ett representativt urval av 24 bröd ut att ingå i studien. Med hjälp av en utvald och tränad sensorisk panel (n=11) togs sensoriska profiler fram för bröden. Panelen identifierade och definierade 15 egenskaper för att ge en beskrivning av brödets utseende, lukt, konsistens och smak. För att studera brödets potentiella effekter på blodsocker- och insulinsvar användes en metod kallad fluidity index (FI). Metoden mäter viskositet i brödet som är av relevans för att påverka blodsocker- och insulinsvar och resultatet sätts i relation till ett vitt vetebröd (FI=100). Fluidity index mättes också för två kontrollbröd för att jämföra resultaten från provbröden med. Dessa innehöll 75% råg och har i en tidigare studie visat på ett gynnsamt blodsocker- och insulinsvar (Rosén et al., 2009). Även pH liksom innehållet av organiska syror mättes. Dessa bildas vid surdegjäsning och kan i tillräckligt stor mängd också ha en gynnsam effekt på blodsockersvaret. Potentiella samband mellan de sensoriska och de hälsorelaterade egenskaperna (FI, pH, innehåll av organiska syror råg, fullkorn, socker, salt, fiber) studerades med hjälp av en multivariat statistisk metod (Partial Least Squares Regression).

I studie III valdes nio av bröden från studie II ut till ett konsumenttest. Totalt 398 konsumenter provsmakade bröden och fick ange grad av gillande samt tog ställning till tre påståenden för varje bröd: "*Jag skulle*

*gärna äta detta bröd ofta*”, *”brödet verkar hälsosamt”* och *”det här är enligt mig ett rågbröd”*. Bakgrundsinformation om konsumenterna samlades också in såsom kön, ålder samt vilken typ av bröd man oftast åt under uppväxten. Enkäten ”The Food Choice Questionnaire” användes för att undersöka hur viktiga respondenterna upplevde olika faktorer såsom hälsa, smak och bekvämlighet vara vid val av mat. I analysen jämfördes två breda åldersgrupper, respondenter mellan 18-44 år och 45-80 år. Åldersgrupperingarna baserades bland annat på resultat från Studie I. Principalkomponentregression och Partial Least Squares Regression användes för att studera samband mellan gillande och uppfattningar om bröden och dess sensoriska egenskaper. Olika segment av konsumenter identifierades i relation till deras preferenser och dessa segment karaktäriserades sedan med hjälp av den insamlade bakgrundsinformationen, med den statistiska metoden Discriminant Partial Least Squares Regression.

I studie IV undersöktes konsumenternas hälsorelaterade uppfattningar om bröd. Totalt 1134 vuxna personer besvarade en enkät där framförallt öppna frågor användes för att studera vilka egenskaper som uppfattas som hälsosamt i bröd (svarsfrekvens 38%). Studiedeltagarna tillfrågades om de kände till något bröd som de ansåg var hälsosamt samt om så var fallet, vilket och varför. Även bilder på sex kommersiella bröd, med och utan förpackning visades. Studiedeltagaren ombads att på ett enkelt sätt sortera bröden genom att först välja ut vilket/vilka som uppfattades som mest hälsosamma och därefter vilket/vilka som uppfattades som minst hälsosamma samt att därefter kort motivera sina val. Svaren kodades och analyserades och de mest frekvent förekommande svaren identifierades. Skillnad i svarsfrekvens mellan åldersgrupper och utbildningsnivå studerades. Korrespondensanalys användes för att visuellt studera associationer mellan egenskaper som uppfattas som hälsosamt i bröden samt på vilket sätt de anses vara bra för hälsan.

## **Resultat**

Analysen av rapporterad brödkonsumtion i Riksmaten 2010-11 (Studie I) visade på skillnader i vilken typ av bröd som äts framförallt i relation till ålder och utbildningsnivå, men även på traditionella konsumtionsmönster såsom att mest knäckebröd äts i Norrland och deltagare födda i ett annat nordiskt land åt mer fullkornsbröd. Fler respondenter i de yngre grupperna (18-44 år), respondenter med en lägre utbildningsnivå, med barn i hushållet samt de som åt mindre frukt och grönt rapporterades oftare äta i huvudsak bröd utan fullkorn. Äldre åldersgrupper (45-80 år) rapporterade oftare att

de ätit knäckebröd, fullkornsbröd och fullkornsrågbröd med surdeg medan yngre oftare åt bröd utan fullkorn och snabbmatsbröd utanför hemmet.

Baserat på de sensoriska profilerna kunde de kommersiella rågbröden i Studie II delas in i sex grupper (A-F) med olika sensorisk karaktär. FI-analyserna indikerade att hälften av dessa bröd potentiellt skulle kunna ha en mer gynnsam effekt på blodsocker- och insulinsvar. Detta eftersom de hade ett FI i linje med eller lägre än två kontrollbröd som i tidigare *in vivo* studier visat på dessa egenskaper ( $FI \leq 74$ ). Högt tuggmotstånd, en kompakt konsistens och syrlig smak var relaterat till ett lägre, mer gynnsamt FI. Flera av bröden påvisade en låg halt av råg och surdeg trots att de var märkta som råg- eller surdegsbröd.

Studie III visade att yngre vuxna (18-44 år) tyckte bäst om rågbröd med en mjuk konsistens och en mild smak. Detta var dessutom särskilt förknippat med att vara man samt att främst ätit vitt bröd eller söt limpa som barn. Äldre konsumenter (45-80 år) visade generellt ett större gillande för fullkornsrågbröd. Bröd med en mörkbrun färg, högt tuggmotstånd, syrlig och besk smak upplevdes som mest hälsosamma och uppfattades också mest som rågbröd av konsumenterna.

I studie IV visade resultatet att tre av fyra kände till bröd som de ansåg vara hälsosamt. Främst grovt bröd, fullkornsbröd, fiber, surdeg och råg uppfattades som bra för magen, ge mättnad och blodsockerregleringen. Hembakat bröd uppfattades också som hälsosamt. Svårighet att veta vilket bröd som är hälsosamt var ett vanligt upplevt hinder, särskilt bland konsumenter med en lägre utbildningsnivå. Ofta användes attribut relaterade till färg och textur snarare än information om näringsinnehåll eller nyckelhålmärkning för att beskriva brödets hälsosamhet.

## **Diskussion och slutsatser**

Resultaten från de fyra delstudierna diskuteras i relation till begrepp från social marknadsföring vilket är ett ramverk som används i folkhälsointerventioner. I social marknadsföring appliceras metoder som tillämpas inom marknadsföring med syfte att förbättra folkhälsan. Synen här är att för att kunna förändra ett beteende bör det inte uppfattas som en uppoffring av konsumenten utan att hen istället får något av värde. Ett viktigt första steg är att identifiera faktorer som skulle kunna påverka beteendet såsom möjligheter och barriärer för konsumtion av rågbröd med potentiella hälsofördelar. Målet inom dietetik är att sträva mot en optimal nutritionsstatus hos både individet och grupper och sammankopplat med begrepp från social marknadsföring vill jag beskriva det som att denna avhandling har ett dietetiskt marknadsföringsperspektiv. Ett viktigt steg är att identifiera olika målgrupper, i detta fall, grupper som har en låg

konsumtion av fullkorns- och rågbröd. De konsumentgrupper som har lägst konsumtion av fullkorns- och rågbröd var yngre åldersgrupper, familjer med barn och grupper med lägre utbildningsnivå samt konsumenter som tycker bekvämlighet och igenkänning är viktigt vid val av mat (Studie I och III). Studie I identifierade traditionella brödkonsumtionsmönster, men också nyare konsumtionsmönster där yngre konsumenter åt mer snabbmatsbröd samt mer bröd utanför hemmet. En utveckling av snabbmatsbröd skulle därför kunna vara en väg att förbättra brödkonsumtionen framförallt hos yngre. En lägre utbildningsnivå var också relaterad till en lägre sensorisk acceptans för fullkornsrågbröd samt upplevelsen av att det är svårt att veta vilket bröd som egentligen är hälsosamt. En fjärdedel av konsumenterna i studie IV kände inte till något bröd som de ansåg var hälsosamt. Framförallt bland personer med en lägre utbildningsnivå finns därmed ett behov att öka medvetenheten om hur man identifierar hälsosammare brödtyper.

Tillgängligheten av rågbröd med potentiella hälsofördelar såsom ett gynnsamt FI är en viktig faktor för möjligheten till konsumtion. Det finns ingen definition av vad som får benämnas rågbröd i Sverige och Studie II visade att det var en stor variation beträffande de hälsorelaterade och sensoriska egenskaperna hos rågbröd på den svenska marknaden. Även om konsumenterna i Studie III förväntade sig att ett bröd kallat "Rågbröd" bör innehålla 70% råg visade studie II att det kunde innehålla så lite som 20% råg. Mätningar av FI indikerade att nästan hälften av proverna hade mer gynnsamma glykemiska egenskaper. Ett jämnare blodsocker nämndes av många konsumenter som en viktig hälsoegenskap hos bröd. Bröd får i dagsläget inte ha någon märkning som indikerar ett gynnsamt blodsockersvar och är därför inte helt lätta att identifiera. Konsumenterna använder istället egna ledtrådar som *surdeg*, *råg*, *grovt*, *mörkt* vilka uppfattas som hälsosamma men där färre eller inga riktlinjer för märkning finns, något som kan vilseleda. Textur (såsom högt tuggmotstånd) och smak (såsom syrlighet) kunde relateras till ett lägre, mer gynnsamt FI, vilket skulle kunna vägleda konsumenterna. Yngre konsumenter hade, jämfört med äldre en lägre sensorisk acceptans för bröden med mer råg, fullkorn och surdeg. Studien understryker vikten av att tidigt vänja sig vid bröd med mer tuggmotstånd och syrlig smak men också sambandet mellan sensoriska preferenser och attitydkomponenter såsom faktorer som konsumenten uppfattar som viktiga vid matval (såsom hälsa och bekvämlighet).

Forskare har nyligen beskrivit ett behov av att kommunicera information om kopplingen mellan glykemiska effekter och hälsa, till konsumenterna och till vårdpersonal genom t.ex. kostråd och märkning på

förpackningar. Denna studie har identifierat hinder och möjligheter för konsumtion av en typ av livsmedel som kan ha dessa hälsofördelar, rågbröd. Resultaten betonar vikten av att också inkludera ett sensoriskt perspektiv på hälsosamt ätande. Resultaten kan användas för att ur ett folkhälsoperspektiv bättre kunna dra nytta av de hälsofördelar som har påvisats för råg. Studien understryker också att många olika faktorer är involverade i vilken typ av bröd som konsumeras och att en samverkan mellan livsmedelsindustri, myndigheter och forskning därför är viktigt, liksom en samverkan mellan olika forskningsdiscipliner.

# Acknowledgement

During my time as a PhD student, I have had the privilege of meeting many interesting and inspiring people. I wish to express my sincere gratitude to everyone who has supported me in different ways during this journey, especially the individuals mentioned below.

First of all, I would like to thank all the participating consumers and the enthusiastic members of my sensory panel. You have been an essential part of this work!

I am grateful for the constant support and enthusiasm of my supervisors. **Margaretha Nydahl** thank you, especially for your pragmatic and structured ways, **Iwona Kihlberg** for your commitment to sensory science, and **Ingela Marklinder** for your dedication to sourdough rye bread.

I am also grateful to **Tormod Næs** and **Anna Karin Lindroos** for their inspiration and support. **Christina Berg** and **Einar Risvik** for contributing critique and inspiration at my halfway seminar as well as **Åsa Öström** who participated as the external reviewer at my final seminar.

To all colleagues at the Department of Food, Nutrition and Dietetics: Thank you for interesting seminars, discussions and support both in the art of doing research as well as in teaching. I'm especially grateful to **Ylva Mattsson Sydner**, Head of the Department, but also to all other past and present colleagues.

Thank you also all past and present doctoral students as well as friends at the department for your support, fruitful discussions and delicious dinner nights: **Malin Skinnars Josefsson**, **Nicklas Neuman**, **Marie Lange**, **Evelina Liljeberg**, **Karolin Bergman**, **Maria Somaraki**, **Gita Berg** and **Aravinda Berggren-Clausen**, **Christine Persson Osowski**, **Emma Oljans**, **Anna-Mari Simunaniemi**, **Karin Höijer** and **Anette Pettersson**. And last but not least, **Elin Lövestam**, my constant office-mate, thanks especially for acknowledging the importance of fika and sparkling wine!

I am very grateful to **Stiftelsen Kronprinsessan Margaretas Memorial Foundation** for financing my position as a doctoral student at the department. I am also grateful for funds from **Stiftelsen Louise Fehrs memorial foundation** as well as to **Formas Vinnova** and **Fazer AB** for financing parts of the project through the research program Tvärlivs. I am

also thankful to **Sasakawa Young Leader Fellowship Foundation**, which enabled my stay at University of California Davis, as well as to Professor **Michael O'Mahony**, who welcomed me there for a fun and truly inspiring semester at the heart of where sensory science developed as a scientific discipline. Thank you also to Dr. **Rie Ishii** who invited me to participate in her sensory laboratory and most importantly, helped me with everything practical during my stay. My fellow PhD students there, especially **Vivian Xia** and **Jason Zhang**, made my stay even better and of course my roommate **Johnny Pipinos**, in the house with the craziest interior.

**All my fun and supportive friends**, you sure know how to cheer up a stressed out PhD student. These years would have been less fun without you, thank you!

I am also lucky to have such a great family – people who never miss an opportunity to hang out with baby Ines and here I should also include my friend **Louise**: your help has been invaluable this last year. Thank you to my mother **Eva** and father **Leif** for your constant support and for caring just the right amount about what I have been doing. My brother **Patrik**, thank you for being the best brother one can have, and always just a phone call away. Thank you also to my family-in-law, **Ingrid**, **Anders** and **Johanna** for your support.

Last but definitely not least I am forever thankful to the two most doctoral-thesis-writing-stress-reducing parts of my life, my dearest **Olof** and our daughter **Ines**. Thank you for your tremendous support and encouragement and for filling every day with love and warmth.

# References

- Adamsson, V., Reumark, A., Cederholm, T., Vessby, B., Risérus, U., & Johansson, G. (2012). What is a healthy Nordic diet? Foods and nutrients in the NORDIET study. *Food & Nutrition Research*, *56*(1), doi: 10.3402/fnr.v56i0.18189.
- Adlercreutz, H. (2010). Can rye intake decrease risk of human breast cancer? *Food & Nutrition Research*, *54*(1), doi: 10.3402/fnr.v54i0.5231.
- Alberti, K. G., Zimmet, P., Shaw, J., & IDF Epidemiology Task Force Consensus Group (2005). The metabolic syndrome—a new worldwide definition. *The Lancet*, *366*(9491), 1059-1062.
- Amcoff, E., Edberg, A., Enghardt Barbieri, H., Lindroos, A K., Näläsen, C., Pearson, M., & Warensjö Lemming, E. (2012a). Livsmedels- och näringsintag bland vuxna i Sverige - Resultat från matvaneundersökning utförd 2010–11 [Food and nutrient intake among adults in Sweden]. Uppsala: National Food Agency.
- Amcoff, E., Edberg, A., Enghardt Barbieri, H., Lindroos, A K., Näläsen, C., Pearson, M., & Warensjö Lemming, E. (2012b). Riksmaten - vuxna 2010-11 Livsmedels- och näringsintag bland vuxna i Sverige - metodrapport [Food and nutrient intake among adults in Sweden, methodological report]. Uppsala: National Food Agency.
- Anderson, J. W., Baird, P., & Davis, R. H. Jr., Ferreri, S., Knudtson, M., Koraym, A.,... Williams, C.L. (2009). Health benefits of dietary fiber. *Nutrition Reviews*, *67*(4), 188-205.
- Andreasen, A. R. (1994). Social Marketing: Its Definition and Domain. *Journal of Public Policy & Marketing*, *13*(1), 108-114.
- Arendt, E. K., Ryan, L. A. M., & Dal Bello, F. (2007). Impact of sourdough on the texture of bread. *Food Microbiology*, *24*(2), 165-174.
- Ares, G., & Gambaro, A. (2007). Influence of gender, age and motives underlying food choice on perceived healthiness and willingness to try functional foods. *Appetite*, *49*(1), 148-158.
- Arvola, A., Lähteenmäki, L., Dean, M., Vassallo, M., Winkelmann, M., Claupein, E., . . . Shepherd, R. (2007). Consumers' beliefs about whole and refined grain products in the UK, Italy and Finland. *Journal of Cereal Science*, *46*(3), 197-206.
- Atkinson, F. S., Foster-Powell, K., & Brand-Miller, J. C. (2008). International tables of glycemic index and glycemic load values: 2008. *Diabetes Care*, *31*(12), 2281-2283.
- Augustin, L. S. A., Kendall, C. W. C., Jenkins, D. J. A., Willett, W. C., Astrup, A., Barclay, A. W., . . . Poli, A. (2015). Glycemic index, glycemic load and glycemic response: An International Scientific Consensus Summit from the International Carbohydrate Quality Consortium (ICQC). *Nutrition, Metabolism and Cardiovascular Diseases*, *25*(9), 795-815.
- Aune, D., Chan, D. S. M., Lau, R., Vieira, R., Greenwood, D. C., Kampman, E., & Norat, T. (2011). Dietary fibre, whole grains, and risk of colorectal cancer: systematic review and dose-response meta-analysis of prospective studies. *BMJ*, *343*, doi: 10.1136/bmj.d6617.

- Aune, D., Keum, N., Giovannucci, E., Fadnes, L. T., Boffetta, P., Greenwood, D. C., . . . Norat, T. (2016). Whole grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: systematic review and dose-response meta-analysis of prospective studies. *BMJ*, *353*, doi: 10.1136/bmj.i2716.i.
- Bakke, A., & Vickers, Z. (2007). Consumer liking of refined and whole wheat breads. *Journal of Food Science*, *72*(7), S473-S480.
- Bakke, A., & Vickers, Z. (2011). Effects of bitterness, roughness, PROP taster status, and fungiform papillae density on bread acceptance. *Food Quality and Preference*, *22*(4), 317-325.
- Bech-Larsen, T., & Nielsen, N. A. (1999). A comparison of five elicitation techniques for elicitation of attributes of low involvement products. *Journal of Economic Psychology*, *20*(3), 315-341.
- Becker, W., Busk, L., Mattisson, I., & Sand, S. (2012). Råd om fullkorn 2009 - Bakgrund och vetenskapligt underlag [Advice on wholegrain 2009 - Background and scientific evidence]. Uppsala: National Food Agency.
- Berg, C. M., Lappas, G., Strandhagen, E., Wolk, A., Torén, K., Rosengren, A., . . . Lissner, L. (2008). Food patterns and cardiovascular disease risk factors: The Swedish INTERGENE research program. *The American Journal of Clinical Nutrition*, *88*(2), 289-297.
- Berg, M. C., Jonsson, I., Conner, M. T., & Lissner, L. (2002). Relation between breakfast food choices and knowledge of dietary fat and fiber among Swedish schoolchildren. *Journal of Adolescent Health*, *31*(2), 199-207.
- Binkley, J. K., & Golub, A. (2011). Consumer demand for nutrition versus taste in four major food categories. *Agricultural Economics*, *42*(1), 65-74.
- Birch, L. L. (1999). Development of food preferences. *Annual Review of Nutrition*, *19*(1), 41-62.
- Bisogni, C. A., Jastran, M., Seligson, M., & Thompson, A. (2012). How people interpret healthy eating: contributions of qualitative research. *Journal of Nutrition Education and Behavior*, *44*(4), 282-301.
- Björck, I., Liljeberg, H., & Östman, E. (2000). Low glycaemic-index foods. *British Journal of Nutrition*, *83*(Suppl 1), 149-155.
- BOA (2016). Food consumption and nutritive values, data up to 2015. Report *JO 44 SM 1501*. Jönköping: National Board of Agriculture.
- Bondia-Pons, I., Nordlund, E., Mattila, I., Katina, K., Aura, A.-M., Kolehmainen, M., . . . Poutanen, K. (2011). Postprandial differences in the plasma metabolome of healthy Finnish subjects after intake of a sourdough fermented endosperm rye bread versus white wheat bread. *Nutrition Journal*, *10*(1), doi: 10.1186/1475-2891-10-116.
- Brownlee, I. A., Kuznesof, S. A., Moore, C., Jebb, S. A., & Seal, C. J. (2013). The impact of a 16-week dietary intervention with prescribed amounts of whole-grain foods on subsequent, elective whole grain consumption. *British Journal of Nutrition*, *110*(05), 943-948.
- Brunso, K., Fjord, T. A., & Grunert, K. G. (2002). *Consumers' food choice and quality perception*. Aarhus: The Aarhus School of Business.
- Callejo, M. J. (2011). Present situation on the descriptive sensory analysis of bread. *Journal of Sensory Studies*, *26*(4), 255-268.
- Campbell, Å. (1950). *Det svenska brödet: en jämförande etnologisk-historisk undersökning* [The Swedish bread: a comparative ethnological-historical study]. Stockholm: Svensk bageritidskrift.

- Carrillo, E., Varela, P., Salvador, A., & Fiszman, S. (2011). Main factors underlying consumers' food choice: A first step for the understanding of attitudes toward "healthy eating". *Journal of Sensory Studies*, 26(2), 85-95.
- Carroll, A. B. (2016). Carroll's pyramid of CSR: taking another look. *International Journal of Corporate Social Responsibility*, 1(1), 3.
- Carlsson-Kanyama, A., & Lindén, A.-L. (2001). Trends in food production and consumption: Swedish experiences from environmental and cultural impacts. *International journal of sustainable development*, 4(4), 392-406.
- Cauvain, S. (2015). Other cereals in breadmaking. In S. Cauvain & Young, L. (Eds.), *Technology of Breadmaking*. Cham: Springer International Publishing.
- Cawley, J. (2004). An economic framework for understanding physical activity and eating behaviors. *American journal of preventive medicine*, 27(3), 117-125.
- Challacombe, C. A., Seetharaman, K., & Duizer, L. M. (2011). Sensory characteristics and consumer acceptance of bread and cracker products made from red or white wheat. *Journal of Food Science*, 76(5), S337-S346.
- Cooke, L. (2007). The importance of exposure for healthy eating in childhood: a review. *Journal of Human Nutrition and Dietetics*, 20(4), 294-301.
- Cust, A. E., Skilton, M. R., van Bakel, M. M. E., Halkjaer, J., Olsen, A., Agnoli, C., . . . Slimani, N. (2009). Total dietary carbohydrate, sugar, starch and fibre intakes in the European Prospective Investigation into Cancer and Nutrition. *European Journal of Clinical Nutrition: 63(Suppl. 4)*, S37-S60.
- Da Silva, E. C., & Mazzon, J. A. (2016). Developing social marketing plan for health promotion. *International Journal of Public Administration*, 39(8), 577-586.
- Daniel, C. (2016). Economic constraints on taste formation and the true cost of healthy eating. *Social Science & Medicine*, 148, 34-41.
- Day, L., Augustin, M., Batey, I., & Wrigley, C. (2006). Wheat-gluten uses and industry needs. *Trends in Food Science & Technology*, 17(2), 82-90.
- De Leeuw, E. D. (2005). To mix or not to mix data collection modes in surveys. *Journal of Official Statistics*, 21(2), 233-255.
- Dewettinck, K., Van Bockstaele, F., Kühne, B., Van de Walle, D., Courtens, T. M., & Gellynck, X. (2008). Nutritional value of bread: Influence of processing, food interaction and consumer perception. *Journal of Cereal Science*, 48(2), 243-257.
- Dickson-Spillmann, M., & Siegrist, M. (2011). Consumers' knowledge of healthy diets and its correlation with dietary behaviour. *Journal of Human Nutrition and Dietetics*, 24(1), 54-60.
- Drewnowski, A. (1997). Taste preferences and food intake. *Annual Review of Nutrition*, 17(1), 237-253.
- Eertmans, A., Victoir, A., Notelaers, G., Vansant, G., & Van den Bergh, O. (2006). The Food Choice Questionnaire: Factorial invariant over western urban populations? *Food Quality and Preference*, 17(5), 344-352.
- EFSA. (2010). Scientific Opinion on the substantiation of health claims related to whole grain (ID 831...1431) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. *EFSA Journal*, 8(10), 1766-1782.
- EFSA. (2011a). Scientific Opinion on the substantiation of health claims related to: flavonoids and ascorbic acid in fruit juices, including berry juices (ID 1186)... rye bread (ID 1179)...and soups (ID 1132, 1133) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. *EFSA Journal*, 9(4), 2082-2320.
- EFSA. (2011b). Scientific Opinion on the health claims related to rye fibre and changes in bowel function (ID 825), reduction of post prandial glycaemic responses (ID 826) and maintenance of normal blood LDL-cholesterol concentrations (ID 827) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. *EFSA Journal*, 9(6), 2258-2276.

- EFSA. (2014). Scientific Opinion on the substantiation of a health claim related to high fibre sourdough rye bread and reduction of post-prandial glycaemic responses pursuant to Article 13(5) of Regulation (EC) No 1924/2006. *EFSA Journal*, *12*(10), 3837-3848.
- EFSA. (2017). *Nutrition claims*. Retrieved 2017.03.01, from: [http://ec.europa.eu/food/safety/labelling\\_nutrition/claims/nutrition\\_claims\\_en](http://ec.europa.eu/food/safety/labelling_nutrition/claims/nutrition_claims_en).
- Ekström, L., Björck, I., & Östman, E. (2013). On the possibility to affect the course of glycaemia, insulinaemia, and perceived hunger/satiety to bread meals in healthy volunteers. *Food & Function*, *4*(4), 522-529.
- Endrizzi, I., Gasperi, F., Rødbotten, M., & Næs, T. (2014). Interpretation, validation and segmentation of preference mapping models. *Food Quality and Preference*, *32*, 198-209.
- Endrizzi, I., Menichelli, E., Johansen, S. B., Olsen, N. V., & Næs, T. (2011). Handling of individual differences in rating-based conjoint analysis. *Food Quality and Preference*, *22*(3), 241-254.
- Enghardt Barbieri, H., Pearson, M., & Becker, W. (2006). Riksmaten–barn 2003. Livsmedels–och näringsintag bland barn i Sverige [Riksmaten-Children 2003. The food and nutritional intake among children in Sweden]. Uppsala: National Food Agency.
- European Commission. (2011). Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers. *Official Journal*, L 304/18.
- Fagerlind, A. (2012). Fler bagerier efter surdegstrend [More bakeries after sourdough trend]. *Svenska Dagbladet*. Retrieved: 2016.10.10, from <http://www.svd.se/fler-bagerier-efter-surdegstrend>.
- Fardet, A., Leenhardt, F., Lioger, D., Scalbert, A., & Remesy, C. (2006). Parameters controlling the glycaemic response to breads. *Nutrition Research Reviews*, *19*(1), 18-25.
- Ferruzzi, M. G., Jonnalagadda, S. S., Liu, S., Marquart, L., McKeown, N., Reicks, M., . . . Webb, D. (2014). Developing a standard definition of whole-grain foods for dietary recommendations: Summary report of a multidisciplinary expert roundtable discussion. *Advances in Nutrition*, *5*(2), 164-176.
- Feurst, O. (1991). *Kost och hälsa i marknadsföringen: en analys av system och processer i vilka våra matvanor formas: med betoning på livsmedelsannonsers spegling av kostideal och konsumtion 1950-85* [Food and health in marketing] (Doctoral dissertation, Department of Business Administration). Stockholm: Stockholm University.
- Fotopoulos, C., Krystallis, A., Vassallo, M., & Pagiaslis, A. (2009). Food Choice Questionnaire (FCQ) revisited. Suggestions for the development of an enhanced general food motivation model. *Appetite*, *52*(1), 199-208.
- Frølich, W., Åman, P., & Tetens, I. (2013). Whole grain foods and health - a Scandinavian perspective. *Food & Nutrition Research*, *57*(1), doi: 10.3402/fnr.v57i0.18503.
- Fuller, G. W. (2011). *New food product development: from concept to marketplace* (Vol. 3). Boca Raton: CRC Press.
- Furst, T., Connors, M., Bisogni, C. A., Sobal, J., & Falk, L. W. (1996). Food choice: A conceptual model of the process. *Appetite*, *26*(3), 247-266.
- Gibson, R. S. (2005). *Principles of nutritional assessment*. New York: Oxford University Press.
- Gomez, P. (2013). Common biases and heuristics in nutritional quality judgments: a qualitative exploration. *International Journal of Consumer Studies*, *37*(2), 152-158.

- Grier, S., & Bryant, C. A. (2005). Social marketing in public health. *Annual Review of Public Health, 26*, 319-339.
- Grunert, K., Fernández-Celemín, L., Wills, J. M., genannt Bonsmann, S. S., & Nureeva, L. (2010). Use and understanding of nutrition information on food labels in six European countries. *Journal of Public Health, 18*(3), 261-277.
- Grunert, K. G. (2007). How consumers perceive food quality. In: L. Frewer & van Trijp, H. (Eds.), *Understanding consumers of food products*. Cambridge: Woodhead Publishing Ltd.
- Grunert, K. G. (2015). The common ground between sensory and consumer science. *Current Opinion in Food Science, 3*, 19-22.
- Grunert, K. G., Bech-Larsen, T., & Bredahl, L. (2000). Three issues in consumer quality perception and acceptance of dairy products. *International Dairy Journal, 10*(8), 575-584.
- Gråsten, S. M., Juntunen, K. S., Mättö, J., Mykkänen, O. T., El-Nezami, H., Adlercreutz, H., . . . Mykkänen, H. M. (2007). High-fiber rye bread improves bowel function in postmenopausal women but does not cause other putatively positive changes in the metabolic activity of intestinal microbiota. *Nutrition Research, 27*(8), 454-461.
- Gråsten, S. M., Juntunen, K. S., Poutanen, K. S., Gylling, H. K., Miettinen, T. A., & Mykkänen, H. M. (2000). Rye bread improves bowel function and decreases the concentrations of some compounds that are putative colon cancer risk markers in middle-aged women and men. *The Journal of Nutrition, 130*(9), 2215-2221.
- Guerrero, L., Colomer, Y., Guàrdia, M. D., Xicola, J., & Clotet, R. (2000). Consumer attitude towards store brands. *Food Quality and Preference, 11*(5), 387-395.
- Gunnarsson, A., & Elam, M. (2012). Food Fight! The Swedish Low-Carb/High Fat (LCHF) Movement and the Turning of Science Popularisation Against the Scientists. *Science as Culture, 21*(3), 315-334.
- Hair, J. F. (2010). *Multivariate data analysis: a global perspective*. Upper Saddle River, N.J: Pearson Education.
- Hayes, A. F., & Krippendorff, K. (2007). Answering the call for a standard reliability measure for coding data. *Communication Methods and Measures, 1*(1), 77-89.
- Heiniö, R. (2006). Sensory attributes of bakery products. In Y.H. Hui (Ed.) *Bakery products: science and technology*, Ames: Blackwell Publishing.
- Heiniö, R. L., Liukkonen, K. H., Katina, K., Myllymäki, O., & Poutanen, K. (2003). Milling fractionation of rye produces different sensory profiles of both flour and bread. *LWT - Food Science and Technology, 36*(6), 577-583.
- Heiniö, R. L., Noort, M. W. J., Katina, K., Alam, S. A., Sozer, N., de Kock, H. L., . . . Poutanen, K. (2016). Sensory characteristics of wholegrain and bran-rich cereal foods – A review. *Trends in Food Science & Technology, 47*, 25-38.
- Heiniö, R. L., Urala, N., Vainionpää, J., Poutanen, K., & Tuorila, H. (1997). Identity and overall acceptance of two types of sour rye bread. *International Journal of Food Science and Technology, 32*(2), 169-178.
- Helgesen, H., & Næs, T. (1995). Selection of dry fermented lamb sausages for consumer testing. *Food Quality and Preference, 6*(2), 109-120.
- Hellemann, U., Tuorila, H., Salovaara, H., & Tarkkonen, L. (1987). Sensory profiling and multidimensional scaling of selected finnish rye breads. *International Journal of Food Science and Technology, 22*(6), 693-700.
- Hlebowicz, J., Jonsson, J. M., Lindstedt, S., Bjorgell, O., Darwich, G., & Almer, L. O. (2009). Effect of commercial rye whole-meal bread on postprandial blood glucose and gastric emptying in healthy subjects. *The Nutrition Journal, 8*(26), doi: 10.1186/1475-2891-8-26.

- Hoek, J., & Jones, S. C. (2011). Regulation, public health and social marketing: a behaviour change trinity. *Journal of Social Marketing, 1*(1), 32-44.
- Holma, R., Hongisto, S.-M., Saxelin, M., & Korpela, R. (2010). Constipation is relieved more by rye bread than wheat bread or laxatives without increased adverse gastrointestinal effects. *The Journal of Nutrition, 140*(3), 534-541.
- Holmberg, C. (2015). Politicization of the Low-Carb High-Fat Diet in Sweden, promoted on social media by non-conventional experts. *International Journal of E-Politics, 6*(3), 27-42.
- Hongisto, S. M., Paajanen, L., Saxelin, M., & Korpela, R. (2006). A combination of fibre-rich rye bread and yoghurt containing *Lactobacillus GG* improves bowel function in women with self-reported constipation. *European Journal of Clinical Nutrition, 60*(3), 319-324.
- Hosseini, Z., Whiting, S. J., & Vatanparast, H. (2016). Current evidence on the association of the metabolic syndrome and dietary patterns in a global perspective. *Nutrition Research Reviews, 29*(2), 152-162.
- Hough, G., & Ferraris, D. (2010). Free listing: A method to gain initial insight of a food category. *Food Quality and Preference, 21*(3), 295-301.
- Isaksson, H., Fredriksson, H., Andersson, R., Olsson, J., & Åman, P. (2009). Effect of rye bread breakfasts on subjective hunger and satiety: a randomized controlled trial. *Nutrition Journal, 8*(1), doi: 10.1186/1475-2891-8-39.
- Isaksson, H., Rakha, A., Andersson, R., Fredriksson, H., Olsson, J., & Åman, P. (2011). Rye kernel breakfast increases satiety in the afternoon - an effect of food structure. *Nutrition Journal, 10*(1), doi: 10.1186/1475-2891-10-31.
- ISO. (1994). 11035 Sensory analysis - Identification and selection of descriptors for establishing sensory profile by a multidimensional approach. Geneva: International organization of standardization.
- ISO. (2007). 8589-Sensory analysis-General guidance for the design of test rooms. Geneva: International Organization for Standardization.
- ISO. (2012). 8586-Sensory analysis- General guidelines for the selection, training and monitoring of selected assessors and expert sensory assessors. Geneva: International Organization for Standardization.
- ISO. (2016). 13299 Sensory analysis -- Methodology -- General guidance for establishing a sensory profile. Geneva: International organization of standardization.
- Jenkins, D. J., Goff, D. V., Wolever, T. M., Taylor, R. H., Barker, H., Fielden, H., . . . Jenkins, A. L. (1981). Glycemic index of foods: a physiological basis for carbohydrate exchange. *The American Journal of Clinical Nutrition, 34*(3), 362-366.
- Johansson, D. P., Lee, I., Risérus, U., Langton, M., & Landberg, R. (2015). Effects of unfermented and fermented whole grain rye crisp breads served as part of a standardized breakfast, on appetite and postprandial glucose and insulin responses: A randomized cross-over trial. *PLoS ONE, 10*(3), doi: 10.1371/journal.pone.0122241.
- Johansson, I., Nilsson, L., Stegmayr, B., Boman, K., Hallmans, G., & Winkvist, A. (2012). Associations among 25-year trends in diet, cholesterol and BMI from 140,000 observations in men and women in Northern Sweden. *Nutrition Journal, 11*(1), doi: 10.1186/1475-2891-11-40.
- Juntunen, K. S., Laaksonen, D. E., Autio, K., Niskanen, L. K., Holst, J. J., Savolainen, K. E., . . . Mykkänen, H. M. (2003). Structural differences between rye and wheat breads but not total fiber content may explain the lower postprandial insulin response to rye bread. *The American Journal of Clinical Nutrition, 78*(5), 957-964.

- Juntunen, K. S., Niskanen, L. K., Liukkonen, K. H., Poutanen, K. S., Holst, J. J., & Mykkänen, H. M. (2002). Postprandial glucose, insulin, and incretin responses to grain products in healthy subjects. *The American Journal of Clinical Nutrition*, 75(2), 254-262.
- Kallio, P., Kolehmainen, M., Laaksonen, D. E., Pulkkinen, L., Atalay, M., Mykkänen, H., . . . Niskanen, L. (2008). Inflammation markers are modulated by responses to diets differing in postprandial insulin responses in individuals with the metabolic syndrome. *The American Journal of Clinical Nutrition*, 87(5), 1497-1503.
- Katina, K., Laitila, A., Juvonen, R., Liukkonen, K. H., Kariluoto, S., Piironen, V., . . . Poutanen, K. (2007). Bran fermentation as a means to enhance technological properties and bioactivity of rye. *Food Microbiology*, 24(2), 175-186.
- Katina, K., & Poutanen, K. (2013). Nutritional aspects of cereal fermentation with lactic acid bacteria and yeast. In: M. Gobetti & Gänzle, M. (Eds.) *Handbook on Sourdough Biotechnology*. New York: Springer.
- Kearney, M., Kearney, J., Dunne, A., & Gibney, M. (2000). Sociodemographic determinants of perceived influences on food choice in a nationally representative sample of Irish adults. *Public Health Nutrition*, 3(2), 219-226.
- Kihlberg, I., Johansson, L., Langsrud, O., & Risvik, E. (2005). Effects of information on liking of bread. *Food Quality and Preference*, 16(1), 25-35.
- Kihlberg, I., & Risvik, E. (2007). Consumers of organic foods - value segments and liking of bread. *Food Quality and Preference*, 18(3), 471-481.
- King, S. C., Meiselman, H. L., Hottenstein, A. W., Work, T. M., & Cronk, V. (2007). The effects of contextual variables on food acceptability: A confirmatory study. *Food Quality and Preference*, 18(1), 58-65.
- Korczak, R., Marquart, L., Slavin, J. L., Ringling, K., Chu, Y., O'Shea, M., . . . Jacques, P. (2016). Thinking critically about whole-grain definitions: summary report of an interdisciplinary roundtable discussion at the 2015 Whole Grains Summit. *The American Journal of Clinical Nutrition*, 104(6), 1508-1514.
- Korkeila, K., Suominen, S., Ahvenainen, J., Ojanlatva, A., Rautava, P., Helenius, H., & Koskenvuo, M. (2001). Non-response and related factors in a nation-wide health survey. *European Journal of Epidemiology*, 17(11), 991-999.
- Kotler, P. (1971). What consumerism means for marketers. *Harvard Business Review*, 50(3), 48-57.
- Kotler, P., & Zaltman, G. (1971). Social marketing: an approach to planned social change. *Journal of Marketing*, 35(3), 3-12.
- Kuznesof, S., Brownlee, I. A., Moore, C., Richardson, D. P., Jebb, S. A., & Seal, C. J. (2012). WHOLEheart study participant acceptance of wholegrain foods. *Appetite*, 59(1), 187-193.
- Kyrø, C., Skeie, G., Dragsted, L. O., Christensen, J., Overvad, K., Hallmans, G., . . . Olsen, A. (2012). Intake of whole grain in Scandinavia: Intake, sources and compliance with new national recommendations. *Scandinavian Journal of Public Health*, 40(1), 76-84.
- Kyrø, C., Skeie, G., Dragsted, L. O., Christensen, J., Overvad, K., Hallmans, G., . . . Olsen, A. (2011). Intake of whole grains in Scandinavia is associated with healthy lifestyle, socio-economic and dietary factors. *Public Health Nutrition*, 14(10), 1787-1795.
- Köster, E. P. (2009). Diversity in the determinants of food choice: A psychological perspective. *Food Quality and Preference*, 20(2), 70-82.
- Landberg, R., Andersson, S. O., Zhang, J. X., Johansson, J. E., Stenman, U. H., Adlercreutz, H., . . . Hallmans, G. (2010). Rye whole grain and bran intake compared with refined wheat decreases urinary C-Peptide, plasma insulin, and

- prostate specific antigen in men with prostate cancer. *The Journal of Nutrition*, 140(12), 2180-2186.
- Landberg, R., Kolehmainen, M., Poutanen, K., Mykkänen, H., & Hallmans, G. (2014). Rye products and prevention of type 2 diabetes In K. Poutanen & Åman, P. (Eds.), *Rye and Health*. St. Paul, Minnesota: AACC International.
- Lang, R., & Jebb, S. A. (2003). Who consumes whole grains, and how much? *Proceedings of the Nutrition Society*, 62(1), 123-127.
- Lang, R., Thane, C. W., Bolton-Smith, C., & Jebb, S. A. (2003). Consumption of whole-grain foods by British adults: findings from further analysis of two national dietary surveys. *Public Health Nutrition*, 6(05), 479-484.
- Lappalainen, R., Kearney, J., & Gibney, M. (1998). A pan EU survey of consumer attitudes to food, nutrition and health: an overview. *Food Quality and Preference*, 9(6) 467-478.
- Lappi, J., Mykkänen, H., Knudsen, K. E. B., Kirjavainen, P., Katina, K., Pihlajamäki, J., . . . Kolehmainen, M. (2014). Postprandial glucose metabolism and SCFA after consuming wholegrain rye bread and wheat bread enriched with bioprocessed rye bran in individuals with mild gastrointestinal symptoms. *Nutrition Journal*, 13(104), doi: 10.1186/1475-2891-13-104.
- Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food: principles and practices*. New York: Springer.
- Lee, N. R., & Kotler, P. (2016). *Social marketing: changing behaviors for good* (Vol. 5). Thousand Oaks: Sage.
- Lefebvre, R. C. (2011). An integrative model for social marketing. *Journal of Social Marketing*, 1(1), 54-72.
- Leinonen, K., Liukkonen, K., Poutanen, K., Uusitupa, M., & Mykkänen, H. (1999). Rye bread decreases postprandial insulin response but does not alter glucose response in healthy Finnish subjects. *European Journal of Clinical Nutrition*, 53(4), 262-267.
- Leinonen, K. S., Poutanen, K. S., & Mykkänen, H. M. (2000). Rye bread decreases serum total and LDL cholesterol in men with moderately elevated serum cholesterol. *The Journal of Nutrition*, 130(2), 164-170.
- Liljeberg, H., & Björck, I. (1994). Bioavailability of starch in bread products. Postprandial glucose and insulin responses in healthy subjects and in vitro resistant starch content. *European Journal of Clinical Nutrition*, 48(3), 151-163.
- Liljeberg, H., Lönner, C., & Björck, I. (1995). Sourdough fermentation or addition of organic acids or corresponding salts to bread improves nutritional properties of starch in healthy humans. *The Journal of Nutrition*, 125(6), 1503-1511.
- Linné, C. V. (1964 [1757]). *Om brödet som födoämne: De pane dietetico: akademisk avhandling under Linnés presidium* (Doctoral thesis), Uppsala: Uppsala University.
- LIVSFS 2009:6 (2009). Regulations amending the National Food Agency's regulations (SLVFS 2005:9) on the use of a particular symbol. Uppsala: National Food Agency.
- LIVSFS 2015:1 (2015). Regulations amending the National Food Agency's regulations (SLVFS 2005:9) on the use of a particular symbol. Uppsala: National Food Agency.
- Maghsoudi, Z., & Azadbakht, L. (2012). How dietary patterns could have a role in prevention, progression, or management of diabetes mellitus? Review on the current evidence. *Journal of Research in Medical Sciences*, 17(7), 694-709.
- Magnusdóttir, O. K., Landberg, R., Gunnarsdóttir, I., Cloetens, L., Åkesson, B., Rosqvist, F., . . . Savolainen, M. J. (2014). Whole grain rye intake, reflected by a Biomarker, is associated with favorable blood lipid outcomes in subjects with

- the metabolic syndrome—A randomized study. *PLoS ONE*, 9(10), doi: 10.1371/journal.pone.0110827.
- Mann, J., & Nye, E. R. (2009). Fad diets in Sweden, of all places. *The Lancet*, 374(9692), 767-769.
- Markovina, J., Stewart-Knox, B. J., Rankin, A., Gibney, M., de Almeida, M. D. V., Fischer, A., . . . Frewer, L. J. (2015). Food4Me study: Validity and reliability of Food Choice Questionnaire in 9 European countries. *Food Quality and Preference*, 45, 26-32.
- Marshall, D. (2001). Food availability and the European consumer. In: L. Frewer, Risvik, E., & Schifferstein (Eds.) *Food, people and society*. Berlin: Springer.
- Martens, M. (1999). A philosophy for sensory science. *Food Quality and Preference*, 10(4-5), 233-244.
- McMackin, E., Dean, M., Woodside, J. V., & McKinley, M. C. (2012). Whole grains and health: attitudes to whole grains against a prevailing background of increased marketing and promotion. *Public Health Nutrition*, 16(4), 743-751
- Meilgaard, M. C., Civille, G. V., & Carr, B. T. (2007). *Sensory evaluation techniques*. Boca Raton: CRC.
- Mejborn, H., Bilfoft-Jensen, A., Trolle, E., & Tetens, I. (2008). Fuldkorn. Definition og vidensgrundlag for anbefaling af fuldkornsindtag i Danmark [Wholegrain. Definition and Scientific Background for Recommendations of Wholegrain Intake in Denmark]. Soeborg: Technical University of Denmark, National Food Institute.
- Mela, D. J. (2001). Why do we like what we like? *Journal of the Science of Food and Agriculture*, 81(1), 10-16.
- Morton, L. M., Cahill, J., & Hartge, P. (2006). Reporting participation in epidemiologic studies: A survey of practice. *American Journal of Epidemiology*, 163(3), 197-203.
- Moskowitz, H. R., & Maier, A. (2007). Category appraisal and ingredient search: identifying key sensory factors and product features at the early development stage. In: J. H. Beckley, Foley, M., Topp, E.J., Huang, J.C., & Prinyawiwatukul, W. (Eds.), *Accelerating New Food Product Design and Development*. Ames: Blackwell Publishing.
- Mustonen, S., & Tuorila, H. (2010). Sensory education decreases food neophobia score and encourages trying unfamiliar foods in 8–12-year-old children. *Food Quality and Preference*, 21(4), 353-360.
- Næs, T., Brockhoff, P. B., & Tomić, O. (2010). *Statistics for sensory and consumer science*. Chichester, West Sussex: Wiley.
- NBHW (2017). National Guidelines for Methods of Preventing Disease – summary. Retrieved 2017.03.01, from: <http://www.socialstyrelsen.se/nationalguidelines/nationalguidelinesformethodsofpreventingdisease>. Stockholm: National Board of Health and Welfare.
- NFA (2010-11). *The Swedish Food Composition Database*. Uppsala: National Food Agency.
- NFA (2016). Find your way to eat greener, not too much and be active. Retrieved 2016.12.30, from <https://www.livsmedelsverket.se/globalassets/english/food-habits-health-environment/dietary-guidelines/kostrad-eng.pdf>. Uppsala: National Food Agency.
- NFA (2017). Public meals. Retrieved 2017.02.26, from <https://www.livsmedelsverket.se/matvanor-halsa--miljo/maltider-i-var-d-skola-och-omsorg/>. Uppsala: National Food Agency.
- Nordic Council of Ministers. (2014). *Nordic Nutrition Recommendations 2012: Integrating nutrition and physical activity*. S.l.: Nordic Council of Ministers.

- Nordlund, E., Katina, K., Mykkänen, H., & Poutanen, K. (2016). Distinct characteristics of rye and wheat breads impact on their in vitro gastric disintegration and in vivo glucose and insulin responses. *Foods*, 5(2), doi: 10.3390/foods5020024.
- Nørgaard, M. K., & Brunso, K. (2011). Family conflicts and conflict resolution regarding food choices. *Journal of Consumer Behaviour*, 10(3), 141-151.
- Notaker, H. (2009). *Food culture in Scandinavia*. Westport, Conn: Greenwood Press.
- Nybacka, S., Bertéus Forslund, H., Wirfält, E., Larsson, I., Ericson, U., Warensjö Lemming, E., . . . Lindroos, A. K. (2016). Comparison of a web-based food record tool and a food-frequency questionnaire and objective validation using the doubly labelled water technique in a Swedish middle-aged population. *Journal of Nutritional Science*, 5, e39.
- Nybacka, S., Lindroos, A. K., Wirfält, E., Leanderson, P., Landberg, R., Ericson, U., . . . Bertéus Forslund, H. (2016). Carotenoids and alkylresorcinols as objective biomarkers of diet quality when assessing the validity of a web-based food record tool and a food frequency questionnaire in a middle-aged population. *BMC Nutrition*, 2(1), 53.
- Olsen, A., Egeberg, R., Halkjær, J., Christensen, J., Overvad, K., & Tjønneland, A. (2011). Healthy aspects of the nordic diet are related to lower total mortality. *The Journal of Nutrition*, 141(4), 639-644.
- Olsen, S. O. (2003). Understanding the relationship between age and seafood consumption: the mediating role of attitude, health involvement and convenience. *Food Quality and Preference*, 14(3), 199-209.
- Orquin, J. L. (2014). A Brunswik lens model of consumer health judgments of packaged foods. *Journal of Consumer Behaviour*, 13(4), 270-281.
- Oude Ophuis, P. A. M., & Van Trijp, H. C. M. (1995). Perceived quality: A market driven and consumer oriented approach. *Food Quality and Preference*, 6(3), 177-183.
- Overby, N. C., Sonestedt, E., Laaksonen, D. E., & Birgisdottir, B. E. (2013). Dietary fiber and the glycemic index: a background paper for the Nordic Nutrition Recommendations 2012. *Food & Nutrition Research*, 57(1), doi: 10.3402/fnr.v57i0.20709.
- Paquette, M.-C. (2005). Perceptions of healthy eating: state of knowledge and research gaps. *Canadian Journal of Public Health/Revue Canadienne de Sante'e Publique*, 96(Suppl. 3), S15-S19.
- Péneau, S., Linke, A., Escher, F., & Nuessli, J. (2009). Freshness of fruits and vegetables: consumer language and perception. *British Food Journal*, 111(3), 243-256.
- Pentikäinen, S., Sozer, N., Närväinen, J., Ylätaalo, S., Teppola, P., Jurvelin, J., . . . Poutanen, K. (2014). Effects of wheat and rye bread structure on mastication process and bolus properties. *Food Research International*, 66, 356-364.
- Peri, C. (2006). The universe of food quality. *Food Quality and Preference*, 17(1-2), 3-8.
- Perreault Jr, W. D., & Leigh, L. E. (1989). Reliability of nominal data based on qualitative judgments. *Journal of Marketing Research*, 26(2), 135-148.
- Pettigrew, S. (2016). Pleasure: An under-utilised 'P' in social marketing for healthy eating. *Appetite*, 104, 60-69.
- PHA (2016). Folkhälsan i Sverige [Public health in Sweden]. Retrieved: 2016.02.15, from: <https://www.folkhalsomyndigheten.se/pagefiles/23257/Folkhalsan-i-Sverige-2016-16005.pdf>. Östersund: The Public Health Agency of Sweden.
- Pohjanheimo, T., Paasovaara, R., Luomala, H., & Sandell, M. (2010). Food choice motives and bread liking of consumers embracing hedonistic and traditional values. *Appetite*, 54(1), 170-180.
- Pohjanheimo, T., & Sandell, M. (2009). Explaining the liking for drinking yoghurt: The role of sensory quality, food choice motives, health concern and product information. *International Dairy Journal*, 19(8), 459-466.

- Pollard, T. M., Steptoe, A., & Wardle, J. (1998). Motives underlying healthy eating: using the food choice questionnaire to explain variation in dietary intake. *Journal of Biosocial Science*, 30(02), 165-179.
- Poutanen, K., & Åman, P. (Eds.) (2014). *Rye and Health*. St. Paul, Minnesota: AACC International.
- Poutanen, K., Flander, L., & Katina, K. (2009). Sourdough and cereal fermentation in a nutritional perspective. *Food Microbiology*, 26(7), 693-699.
- Poutanen, K., Sozer, N., & Della Valle, G. (2014). How can technology help to deliver more of grain in cereal foods for a healthy diet? *Journal of Cereal Science*, 59(3), 327-336.
- Prättälä, R., Helasoja, V., & Mykkänen, H. (2001). The consumption of rye bread and white bread as dimensions of health lifestyles in Finland. *Public Health Nutrition*, 4(3), 813-819.
- Rimer, B. K., & Glanz, K. (2005). Theory at a glance: a guide for health promotion practice. National Cancer Institute, US Department of Health and Human Services; 2005. Retrieved: 2017.01.30, from: <http://www.cancer.gov/cancertopics/cancerlibrary/theory.pdf>.
- Roininen, K., Tuorila, H., Zandstra, E. H., de Graaf, C., Vehkalahti, K., Stubenitsky, K., & Mela, D. J. (2001). Differences in health and taste attitudes and reported behaviour among Finnish, Dutch and British consumers: a cross-national validation of the Health and Taste Attitude Scales (HTAS). *Appetite*, 37(1), 33-45.
- Rosén, L. (2011). *Metabolic properties of rye products - Focusing on insulinaemia, glycaemic profile and appetite regulation in healthy subjects*. (Doctoral thesis, Division of Applied Nutrition and Food Chemistry). Lund University.
- Rosén, L., Silva, L., Andersson, U., Holm, C., Östman, E., & Björck, I. (2009). Endosperm and whole grain rye breads are characterized by low post-prandial insulin response and a beneficial blood glucose profile. *Nutrition Journal*, 8(1), doi: 10.1186/1475-2891-8-42.
- Rosén, L. A., Östman, E., & Björck, I. M. (2011). Effects of cereal breakfasts on postprandial glucose, appetite regulation and voluntary energy intake at a subsequent standardized lunch; focusing on rye products. *Nutrition Journal*, 10(7), doi: 10.1186/1475-2891-10-7.
- Roswall, N., Olsen, A., Boll, K., Christensen, J., Halkjær, J., Sørensen, T. I. A., . . . Tjønneland, A. (2014). Consumption of predefined 'Nordic' dietary items in ten European countries – an investigation in the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort. *Public Health Nutrition*, 17(12), 2650-2659.
- Räsänen, L. (2007). Of all foods bread is the most noble: Carl von Linné (Carl Linnaeus) on bread. *Scandinavian Journal of Food & Nutrition*, 51(3), 91-99.
- Sandell, M., Mikkelsen, B. E., Lyytikäinen, A., Ojansivu, P., Hoppu, U., Hillgrén, A., & Lagström, H. (2016). Future for food education of children. *Futures*, 83, 15-23.
- Serra-Majem, L., & Bautista-Castaño, I. (2015). Relationship between bread and obesity. *British Journal of Nutrition*, 113(Suppl 2), S29-S35.
- Shepherd, R. (2001). Does taste determine consumption? Understanding the psychology of food choice. In: L. Frewer, Risvik, E., & Schifferstein (Eds.) *Food, people and society*. Berlin: Springer.
- Siipi, H. (2013). Is Natural Food Healthy? *Journal of Agricultural and Environmental Ethics*, 26(4), 797-812.
- Simunaniemi, A. M. (2011). *Consuming and Communicating Fruit and Vegetables: A Nation-Wide Food Survey and Analysis of Blogs among Swedish Adults*. (Doctoral Thesis, Digital Comprehensive Summaries of Uppsala Dissertations

- from the Faculty of Social Sciences, 70). Uppsala: Acta Universitatis Upsaliensis.
- Simunaniemi, A. M., Andersson, A., & Nydahl, M. (2009). Fruit and vegetable consumption close to recommendations. A partly web-based nationwide dietary survey in Swedish adults. *Food & Nutrition Research*, 53, doi: 10.3402/fnr.v53i0.2023.
- Smith, V., Møgelvang-Hansen, P., & Hyldig, G. (2010). Spin versus fair speak in food labelling: A matter of taste? *Food Quality and Preference*, 21(8), 1016-1025.
- Sobal, J., Bisogni, C. A., Devine, C. M., & Jastran, M. (2006). A conceptual model of the food choice process over the life course. In: R. Shepherd & Raats, M. (Eds.) *The psychology of food choice*. Cambridge, MA; Wallingford, Oxfordshire, UK: CABI in association with the Nutrition Society.
- Sørensen, H. S., Clement, J., & Gabrielsen, G. (2012). Food labels – an exploratory study into label information and what consumers see and understand. *The International Review of Retail, Distribution and Consumer Research*, 22(1), 101-114.
- Spiggle, S. (1994). Analysis and Interpretation of Qualitative Data in Consumer Research. *Journal of Consumer Research*, 21(3), 491-503.
- Steenkamp, J. B. E. M. (1990). Conceptual model of the quality perception process. *Journal of Business Research*, 21(4), 309-333.
- Step toe, A., Pollard, T. M., & Wardle, J. (1995). Development of a measure of the motives underlying the selection of food: the Food Choice Questionnaire. *Appetite*, 25(3), 267-284.
- Step toe, A., & Wardle, J. (1999). Motivational factors as mediators of socioeconomic variations in dietary intake patterns. *Psychology & Health*, 14(3), 391-402.
- Stone, H., & Sidel, J. L. (2004). *Sensory evaluation practices*. San Diego: Academic Press.
- Sun, Y. H. C. (2008). Health concern, food choice motives, and attitudes toward healthy eating: The mediating role of food choice motives. *Appetite*, 51(1), 42-49.
- Sutterlin, B., & Siegrist, M. (2015). Simply adding the word "fruit" makes sugar healthier: the misleading effect of symbolic information on the perceived healthiness of food. *Appetite*, 95, 252-261.
- Sveriges bagare och konditorer. (2014). Märk väl. [Label correctly] Retrieved 2016.02.15, from: [http://np.netpublicator.com/np/n86510149/141118\\_Markval\\_webb.pdf](http://np.netpublicator.com/np/n86510149/141118_Markval_webb.pdf).
- Swahn, J., Mossberg, L., Öström, Å., & Gustafsson, I.-B. (2012). Sensory description labels for food affect consumer product choice. *European Journal of Marketing*, 46(11-12), 1628-1646.
- Symoneaux, R., Galmarini, M. V., & Mehinagic, E. (2012). Comment analysis of consumer's likes and dislikes as an alternative tool to preference mapping. A case study on apples. *Food Quality and Preference*, 24(1), 59-66.
- The Academy of Nutrition and Dietetics. 2016. *Definition of Terms List*. Accessed: 2016.12.15, from: <http://www.eatrightpro.org/~media/eatrightpro%20files/practice/scope%20standards%20of%20practice/academydefinitionoftermslist.ashx>.
- The Ministry of Education and Cultural Affairs. (2003). The Act concerning the Ethical Review of Research Involving Humans *In SFS 2003: 460*. Sweden.
- Tolonen, H., Helakorpi, S., Talala, K., Helasoja, V., Martelin, T., & Prättälä, R. (2006). 25-Year Trends and Socio-Demographic Differences in Response Rates: Finnish Adult Health Behaviour Survey. *European Journal of Epidemiology*, 21(6), 409-415.
- Totland, T., Melnæs, B., Lundberg-Hallén, N., Helland-Kigen, K., Lund-Blix, N., & Myhre, J. (2012). Norkost 3. En landsomfattende kostholdsundersøkelse blant

- menn og kvinner i Norge i alderen 18–70 år, 2010–2011 [A nationwide food consumption survey among men and women in Norway aged 18-70 years, 2010 to 2011]. Oslo: Norwegian Directorate of Health.
- Tuorila, H. (2000). Pressure to change and resistance against it: consumer perceptions and acceptance of nutritionally modified foods. *Agricultural and Food Science*, 9(2), 165-176.
- Tuorila, H., Lehtovaara, A., & Matuszewska, I. (1990). Sandwiches and milk with varying fat and sodium contents: What is the best combination? *Food Quality and Preference*, 2(4), 223-231.
- Tuorila, H., & Monteleone, E. (2009). Sensory food science in the changing society: Opportunities, needs, and challenges. *Trends in Food Science & Technology*, 20(2), 54-62.
- van der Kamp, J. W., Poutanen, K., Seal, C. J., & Richardson, D. P. (2014). The HEALTHGRAIN definition of 'whole grain'. *Food & Nutrition Research*, 58.
- van Dongen, M. V., van den Berg, M. C., Vink, N., Kok, F. J., & de Graaf, C. (2012). Taste–nutrient relationships in commonly consumed foods. *British Journal of Nutrition*, 108(1), 140-147.
- van Langeveld, A. W. B., Gibbons, S., Koelliker, Y., Civile, G. V., de Vries, J. H. M., de Graaf, C., & Mars, M. (2017). The relationship between taste and nutrient content in commercially available foods from the United States. *Food Quality and Preference*, 57, 1-7.
- Varela, P., & Ares, G. (2012). Sensory profiling, the blurred line between sensory and consumer science. A review of novel methods for product characterization. *Food Research International*, 48(2), 893-908.
- Varela, P., & Ares, G. (2014). *Novel techniques in sensory characterization and consumer profiling*. Boca Raton: CRC Press.
- Verbeke, W. (2006). Functional foods: Consumer willingness to compromise on taste for health? *Food Quality and Preference*, 17(1), 126-131.
- Violette, C., Kantor, M. A., Ferguson, K., Reicks, M., Marquart, L., Laus, M. J., & Cohen, N. (2016). Package information used by older adults to identify whole grain foods. *Journal of nutrition in gerontology and geriatrics*, 35(2), 146-160.
- Vyth, E. L., Steenhuis, I. H., Roodenburg, A. J., Brug, J., & Seidell, J. C. (2010). Front-of-pack nutrition label stimulates healthier product development: a quantitative analysis. *International Journal of Behavioral Nutrition and Physical Activity*, 7(1), doi: 10.1186/1479-5868-7-65.
- Weinreich, N. K. (2010). *Hands-on social marketing: a step-by-step guide to designing change for good*. Thousand Oaks, Sage Publications.
- WHO (2016a). Noncommunicable diseases. Retrieved: 2016.12.05, from <http://www.euro.who.int/en/health-topics/noncommunicable-diseases/noncommunicable-diseases>. Genève: World Health Organization
- WHO (2016b). WHO obesity and overweight fact sheet. Retrieved: 2016.11.25, from: <http://www.who.int/mediacentre/factsheets/fs311/en/>. Genève: World Health Organization
- Worsley, A. (2003). The behavioural and demographic contexts of white bread consumption. *British Food Journal*, 105(10), 695-699.
- Wymer, W. (2011). Developing more effective social marketing strategies. *Journal of Social Marketing*, 1(1), 17-31.
- Ye, E. Q., Chacko, S. A., Chou, E. L., Kugizaki, M., & Liu, S. (2012). Greater whole-grain intake is associated with lower risk of type 2 diabetes, cardiovascular disease, and weight gain. *The Journal of Nutrition*, 142(7), 1304-1313.
- Zimmet, P., Alberti, K. G. M. M., & Shaw, J. (2001). Global and societal implications of the diabetes epidemic. *Nature*, 414(6865), 782-787.

- Åman, P., Andersson, A., Rakha, A., & Andersson, R. (2010). Rye, a healthy cereal full of dietary fiber. *Cereal Foods World*, 55(5), 231-234.
- Östman, E., Rossi, E., Larsson, H., Brighenti, F., & Björck, I. (2006). Glucose and insulin responses in healthy men to barley bread with different levels of (1→3; 1→4)- $\beta$ -glucans; predictions using fluidity measurements of in vitro enzyme digests. *Journal of Cereal Science*, 43(2), 230-235.

# Acta Universitatis Upsaliensis

*Digital Comprehensive Summaries of Uppsala Dissertations  
from the Faculty of Social Sciences 138*

Editor: The Dean of the Faculty of Social Sciences

A doctoral dissertation from the Faculty of Social Sciences, Uppsala University, is usually a summary of a number of papers. A few copies of the complete dissertation are kept at major Swedish research libraries, while the summary alone is distributed internationally through the series Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Sciences. (Prior to January, 2005, the series was published under the title “Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Sciences”.)

Distribution: [publications.uu.se](http://publications.uu.se)  
urn:nbn:se:uu:diva-316598



ACTA  
UNIVERSITATIS  
UPSALIENSIS  
UPPSALA  
2017