Rye bread in Sweden

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

PERNILLA SANDVIK
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

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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.


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).

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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.
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## Abbreviations

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<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>EFSA</td>
<td>European Food Safety Authority</td>
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<td>FCQ</td>
<td>Food Choice Questionnaire</td>
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<td>FI</td>
<td>fluidity index</td>
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<td>GI</td>
<td>glycemic index</td>
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<td>GP</td>
<td>glycemic profile</td>
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<td>NFA</td>
<td>National Food Agency</td>
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<td>NCD</td>
<td>non-communicable diseases</td>
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<td>NNR</td>
<td>Nordic Nutrition Recommendations</td>
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<tr>
<td>PCA</td>
<td>Principal Component Analysis</td>
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<td>PCR</td>
<td>Principal Component Regression</td>
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<td>PLS</td>
<td>Partial Least Squares Regression</td>
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<td>WG</td>
<td>whole grain</td>
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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 18th 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 19th 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 Riksmat 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 (Brunsø, 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; Magnusdottir 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 assessing 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, Steenhuys, 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 health claims relevant to rye bread

<table>
<thead>
<tr>
<th>Authority</th>
<th>Recommendation, guideline, nutrition or health claim</th>
</tr>
</thead>
</table>
| 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.  
- Whole grain, 70 g for women and 90 g/day for men  
- Dietary fiber ≥ 25 g per day for women and ≥ 35 g/day for men  
- Sugar < 10 energy percent |
| Swedish dietary guidelines (NFA, 2016) | - Choose Keyhole labeled products<sup>1</sup>  
- Choose bread, cereals, grains, pasta and rice with a lot of whole grain |
| Guidelines for public meals in Sweden (NFA, 2017) | Preschool & school:  
- Baking will contribute the appealing odor of newly baked bread  
- Good if the school provides possibilities to teach liking of whole-grain products  
- Provide different types of bread, at least half should be labeled with the Keyhole (School)  
- Serve whole grain products sometimes (Pre-school)  
Elderly care:  
- Type of bread served should be adjusted according to the elderly persons’ needs and wishes |
| Nutrition claims in the EU (EFSA, 2017) | High in fiber (bread with ≥6 g fiber/100 g)  
Source of fiber (bread with ≥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 ≥25/ 
≥50% whole grain (on dry weigh) and per 100 g ≤7 g fat, ≤5 g sugars, ≤0.5 g Na and ≥5/ ≥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 ≥30% rye flour, ≥35% whole grain ≥6 g fiber and salt ≤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 though 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. Hellemann, 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

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

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 ≥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 glycemic 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 glycemic profile. Because there is at present no established FI threshold below which the glycemic properties are considered to be healthful, two additional experimental rye breads – which have been shown to possess beneficial glycemic 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)

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Abbrev.</th>
<th>Definitions¹</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Appearance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown color</td>
<td>C-brown</td>
<td>Degree of brown color in the bread crumb</td>
</tr>
<tr>
<td><strong>Odor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sour</td>
<td>O-sour</td>
<td>Degree of sour odor typical of sourdough in the crumb</td>
</tr>
<tr>
<td>Malty</td>
<td>O-malty</td>
<td>Degree of malty odor typical of malt syrup in the crumb</td>
</tr>
<tr>
<td><strong>Flavor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet</td>
<td>F-sweet</td>
<td>Degree of sweet taste</td>
</tr>
<tr>
<td>Salt</td>
<td>F-salt</td>
<td>Degree of salty taste</td>
</tr>
<tr>
<td>Sour</td>
<td>F-sour</td>
<td>Degree of sour taste</td>
</tr>
<tr>
<td>Bitter</td>
<td>F-bitter</td>
<td>Degree of bitter taste</td>
</tr>
<tr>
<td>Rye</td>
<td>F-rye</td>
<td>Degree of aftertaste typical of rye kernels soaked overnight and boiled for one hour in water</td>
</tr>
<tr>
<td>Roasted cereals</td>
<td>F-roast</td>
<td>Degree of aftertaste typical of oven roasted whole rye kernels roasted sufficiently to cause burnt notes</td>
</tr>
<tr>
<td><strong>Texture, by finger</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressibility</td>
<td>T-comp</td>
<td>Degree of resistance when pressed</td>
</tr>
<tr>
<td>Deformability</td>
<td>T-def</td>
<td>Degree of deformation of the crumb from pressure with one finger in the center of the bread sample</td>
</tr>
<tr>
<td><strong>Texture, mouth feel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chewiness</td>
<td>T-chew</td>
<td>Effort and time needed to chew</td>
</tr>
<tr>
<td>Moisture absorption</td>
<td>T-moist-abs</td>
<td>The amount of saliva absorbed by the sample when chewing</td>
</tr>
<tr>
<td>Heterogeneity</td>
<td>T-hetero</td>
<td>Perceived amount of components bran and whole/pieces of kernels</td>
</tr>
<tr>
<td>Cohesiveness of mass</td>
<td>T-cohes</td>
<td>The degree to which the bread forms a coherent bolus during mastication</td>
</tr>
</tbody>
</table>

¹Anchors, 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, Rød botten, & 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≤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<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).

<table>
<thead>
<tr>
<th></th>
<th>A n=5</th>
<th>B n=4</th>
<th>C n=4</th>
<th>D n=4</th>
<th>E n=4</th>
<th>F n=4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye1</td>
<td>72b</td>
<td>99a</td>
<td>30c</td>
<td>34c</td>
<td>40c</td>
<td>44c</td>
</tr>
<tr>
<td></td>
<td>(25)</td>
<td>(3)</td>
<td>(10)</td>
<td>(23)</td>
<td>(16)</td>
<td>(20)</td>
</tr>
<tr>
<td>Whole grain1</td>
<td>75a</td>
<td>95a</td>
<td>6c</td>
<td>29bc</td>
<td>43b</td>
<td>20bc</td>
</tr>
<tr>
<td></td>
<td>(27)</td>
<td>(10)</td>
<td>(13)</td>
<td>(6)</td>
<td>(31)</td>
<td>(18)</td>
</tr>
<tr>
<td>Fiber1</td>
<td>11a</td>
<td>10ab</td>
<td>5d</td>
<td>7cd</td>
<td>9bc</td>
<td>6d</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>(1)</td>
<td>(1)</td>
<td>(1)</td>
<td>(1)</td>
<td>(1)</td>
</tr>
<tr>
<td>Total sugars1</td>
<td>4</td>
<td>5</td>
<td>8</td>
<td>9</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>(5)</td>
<td>(2)</td>
<td>(3)</td>
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</tr>
<tr>
<td>FI2</td>
<td>64c</td>
<td>54d</td>
<td>94a</td>
<td>89ab</td>
<td>84b</td>
<td>71c</td>
</tr>
<tr>
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<td>(6)</td>
<td>(6)</td>
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<td>5.3b</td>
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<tr>
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<td>(0.5)</td>
<td>(0.3)</td>
<td>(0.1)</td>
<td>(0.2)</td>
</tr>
<tr>
<td>TTA3</td>
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<td>9.4ab</td>
<td>3.7d</td>
<td>7.3bc</td>
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</tr>
<tr>
<td></td>
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<td>(1.4)</td>
<td>(1.7)</td>
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<td>(0.3)</td>
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<td>0.5b</td>
<td>0.1d</td>
<td>0.3bc</td>
<td>0.2cd</td>
<td>0.4bc</td>
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<td>(0.0)</td>
<td>(0.2)</td>
<td>(0.1)</td>
<td>(0.0)</td>
</tr>
<tr>
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<td>0.1abc</td>
<td>0.2a</td>
<td>0.0c</td>
<td>0.1c</td>
<td>0.1bc</td>
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</tr>
<tr>
<td></td>
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<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.1)</td>
</tr>
</tbody>
</table>

1Rye: % of cereal, whole grain: dry weight, g/100g; fiber and total sugars: g/100g
2FI: Fluidity index, white wheat bread was used as reference, FI 100
3TTA: Total Titratable Acidity, Lactic acid and Acetate in g/100g

a-d 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 (≥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 (Rågkusar) 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 (Aman 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 glycemic 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 glycemic 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 glycemic 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 (≥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).

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**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.


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 matvaneundersökningsn 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 ubeft vilken typ av bröd de åtit mest av och sedan undersökt 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 gruppena 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 ät 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 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

I studie IV undersöcktes 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 åts framförallt i relation till ålder och utbildningsnivå, men även på traditionella konsumtionsmönster såsom att mest knäckebröd åts 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 ofta åta i huvudsak bröd utan fullkorn. Äldre åldersgrupper (45-80 år) rapporterade ofta 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 <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 åtit 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 näringsinhåll eller nyckelhålsmärkning 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 uppfattning av konsument 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


Forskare har nyligen beskrivet ett behov av att kommunicera information om kopplingen mellan glykemiska effekter och hälsa, till konsumenter 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 folkhällopspektiv 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 Olijans**, **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** and **Formas Vinnova** as well as to **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.
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