

# MASTER'S THESIS

Food, Nutrition and Health

2012

## An “Ideal” Bread

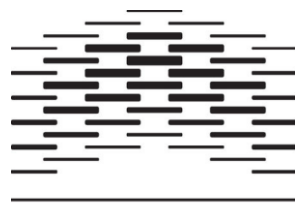
- A Literature Review

## A Bread Baking Intervention

- An Outcome and Process Evaluation

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# ABSTRACT

**INTRODUCTION:** Despite frequent discussions about the health-related value of carbohydrate-rich foods, the grocery stores offer a wide range of bread varieties. In this context, there are several actors (e.g. Fedon Lindberg, Birger Svihus and Ingers rugbrød) claiming that they have the recipe for the "ideal" bread. However, their breads are very different, and the argumentation why they are healthy is clearly embedded in very different nutrition philosophies; i.e. low glycemic index/low carb (Lindberg), low energy (Svihus) and high fiber (Ingers rugbrød).

**PURPOSE:** The purpose with the present thesis was therefore to elaborate a more holistic view on what an "ideal" bread really is.

**METHODS:** Four main criterias for an "ideal" bread were set. The "ideal" bread recipe should be; (1) healthy, (2) sensory appealing, (3) environmental beneficial, and (4) practical. To set some exact criteria in relation to the health aspect, it was decided that the resulting bread recipe should fulfil the *Keyhole* requirements (minimum 25 percent whole grains and 5 gram dietary fiber/100 g, as well as maximum 5 g sugar, 0.5 g salt and 7 g fat per 100 g), and achieve at least three cakes on the *Bread scale* (i.e. a whole grain bread). A literature review was conducted, and bread baking books were searched for a suitable recipe to be modified to fit with the criteria.

**RESULTS AND CONCLUSION:** The resulting bread recipe had a high coarseness (78 percent), relatively much dietary fiber (7.6g/100g), low amounts of salt (0.2g/100g) and fat (3.5g/100g), and no added sugar. Due to a high water content, which among others led to a sensory appealing texture, the bread also had a relatively low energy-density.

By basing the recipe on local grains (i.e. rye and oat), environmental considerations were furthermore taken into account. With regard to the practical aspects, an easy and time-efficient fermentation method was identified (i.e. long and cold fermentation (up to 24 hours at approximately 4°C)).

All in all, instead of having an exclusive health focus, it should in the case of an "ideal" bread be strived for a broader approach where all the aspects surrounding its production and consumption, is taken into account.



# LIST OF ABBREVIATIONS

|                       |   |
|-----------------------|---|
| <b>AA</b>             | Arachidonic acid                            |
| <b>AICR</b>           | American Institute for Cancer Research      |
| <b>ALA</b>            | $\alpha$ -linoleic acid                     |
| <b>CBP</b>            | Chorleywood Bread Process                   |
| <b>CH<sub>4</sub></b> | Methane                                     |
| <b>CO<sub>2</sub></b> | Carbon dioxide                              |
| <b>CRP</b>            | C-reactive protein                          |
| <b>DHA</b>            | Docosahexaenoic acid                        |
| <b>dl</b>             | Decilitre                                   |
| <b>EFSA</b>           | European Food Safety Authority              |
| <b>EPA</b>            | Eicosapentaenoic acid                       |
| <b>FAO</b>            | Food and Agriculture Organization           |
| <b>FDA</b>            | Food and Drug Administration                |
| <b>g</b>              | Grams                                       |
| <b>GI</b>             | Glycemic index                              |
| <b>GMO</b>            | Genetically modified organism               |
| <b>HCN</b>            | Hydrogen cyanide                            |
| <b>HDL</b>            | High-density lipoprotein                    |
| <b>IARC</b>           | International Agency for Research on Cancer |
| <b>kcal</b>           | Kilocalorie                                 |
| <b>kg</b>             | Kilogram                                    |
| <b>kJ</b>             | Kilojoule                                   |
| <b>LA</b>             | Linoleic acid                               |
| <b>LAB</b>            | Lactic acid bacteria                        |
| <b>LCA</b>            | Life cycle assessment                       |
| <b>LCHF</b>           | Low-carb-high-fat                           |
| <b>LDL</b>            | Low-density lipoprotein                     |
| <b>mg</b>             | Milligram                                   |
| <b>MR</b>             | Maillard reaction                           |
| <b>MRP</b>            | Maillard reaction product                   |
| <b>MUFA</b>           | Monounsaturated fatty acid                  |

|                        |   |
|------------------------|---|
| <b>n</b>               | Number                                      |
| <b>N<sub>2</sub>O</b>  | Nitrous oxide                               |
| <b>n-3</b>             | Omega-3 fatty acids                         |
| <b>n-6</b>             | Omega-6 fatty acids                         |
| <b>NOK</b>             | Norwegian krone                             |
| <b>NSP</b>             | Non-starch polysaccharide                   |
| <b>OBK</b>             | Norwegian Bread and Cereals Marketing Board |
| <b>PUFA</b>            | Polyunsaturated fatty acid                  |
| <b>RS</b>              | Resistant starch                            |
| <b>SCFA</b>            | Short-chained fatty acid                    |
| <b>SIFO</b>            | National Institute for Consumer Research    |
| <b>TWI</b>             | Tolerable weekly intake                     |
| <b>TXA<sub>2</sub></b> | Thromboxane                                 |
| <b>µg</b>              | Microgram                                   |
| <b>UN</b>              | United Nations                              |
| <b>WCRF</b>            | World Cancer Research Fund                  |
| <b>WGA</b>             | Wheat germ agglutinin                       |



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# 1.0 INTRODUCTION

Bread can be said to be embedded in the Norwegian food culture (Frølich, 2007), but currently bread is also one of our most hotly debated foods. While some claim we are better off without it (Lutz, Allan & Veiersted, 2010), others, among them the health authorities, recommend whole grain bread as an important component of a balanced and healthy diet (Nasjonalt råd for ernæring, 2011). The grocery stores offer a wide range of breads and many actors claim they have the recipe for the "ideal" bread. But who's right? What is actually an "ideal" bread? Or should we eat bread at all?

The main objective of the present thesis is to conduct a literature review and use this to develop a recipe for an "ideal" bread. Additionally, the thesis incorporates an article (which will be sent to the scientific journal *Public Health Nutrition*) and a poster (to be presented at the Nordic Nutrition Conference in Reykjavik, June 2012) focusing on the outcome and process evaluation of a bread baking intervention. The article and the poster are developed in cooperation with master student Line Jensen. Both have contributed equally to this work.

## 2.0 THEORY

### 2.1 *The "low-carb" debate*

In 1967, Wolfgang Lutz, an Austrian doctor, released the book *Leben ohne Brot* which by many is considered to mark the start of a new dietary trend throughout the western world; the low-carb/high-fat (LCHF) diet (Lutz et al., 2010). A couple of year's later, Robert Atkins launched his book *Dr. Atkins Diet Revolution* (Atkins, 1972) which sold millions of copies worldwide. In Norway, LCHF was put on the agenda in the early 2000 when Fedon Lindberg introduced us to a "new" term; *glycemic index* (GI), and recommended a diet low in easily absorbable carbohydrates from e.g. bread, pasta and potatoes (Bugge, Lavik & Lillebø, 2008).

Briefly explained, a LCHF diet can be viewed as a diet high in fat and proteins and rather low in carbohydrates. However, this composition varies with different types of LCHF (table 2-1). Modern low-carbohydrate weight-loss diets are for example really high in fat (51-78 percent) and low in carbohydrates (4-26 percent), whereas other variants, e.g. the Paleo diet that is

based on the diet of our Palaeolithic ancestors (the hunters and gatherers)<sup>1</sup>, contain less fat (28-47 percent) and more carbohydrates (22-40 percent) (Cordain, 2011). Moreover, while most LCHF weight loss diets are focusing on incorporating as much fat as possible into the diet (e.g. fatty meats and high fat dairy products) (Lutz et al., 2010), the Paleo diet is on the other hand focusing on including a moderate amount of beneficial health-promoting fatty acids, i.e. those present in fish and seafood, nuts and olive oil (i.e. unsaturated fats) (Cordain, 2011). These points illustrate that we cannot juxtapose all forms of LCHF. In the following, a general view on LCHF is therefore chosen.

**Table 2-1** Macronutrient composition of the Paleo diet, a typical western diet and a low-carbohydrate weight loss diet

|                                  | <b>Protein</b> | <b>Carbohydrate</b> | <b>Fat</b> |
|----------------------------------|----------------|---------------------|------------|
| <b>The Paleo diet</b>            | 19-35 %        | 22-40 %             | 28-47 %    |
| <b>Low-carb weight loss diet</b> | 18-23 %        | 4-26 %              | 51-78 %    |
| <b>Typical western diet</b>      | 15 %           | 49 %                | 34 %       |

Adapted from Cordain (2011)

The agricultural revolution for approximately 10 000 years ago introduced us to grains and animal husbandry, but was at the same time followed by a marked decline in the public health status (Bjørnstad, 2010; Cordain, 1999; Cordain et al., 2005). There are several explanations for this drop. In a LCHF setting, the explanation is that we're not genetically adapted to a diet rich in among others grains<sup>2</sup>. Grain-based foods are therefore viewed as one of the main causes for the epidemic of the so-called “diseases of civilization” (i.e. cardiovascular diseases, type 2 diabetes, obesity and cancers) that we are observing in the western, and increasingly in the non-western world today. LCHF diets with minimal amounts of grains are therefore regarded as an essential factor in curing the majority of lifestyle diseases and restore our health (Bjørnstad, 2010; Cordain, 1999; Cordain et al., 2005; Cordain, 2011; Eaton et al., 2002).

Furthermore, most LCHF adherents argue that meat is one of the most important sources of nutrients in our diet. On the contrary, grains are regarded as anti-nutritional due to a wrong

<sup>1</sup> A diet that is rich in lean meats, poultry, fish, seafood, nuts, seeds, fruits, berries and non-starchy vegetables. Foods based on cereals, legumes, dairy products and processed foods are excluded (Cordain, 2011).

<sup>2</sup> Some LCHF adherents are also focusing on dairy products, refined vegetable oils, alcohol, salt and fatty domestic meat as causal factors in this context (Cordain et al., 2005; Eaton et al., 2002).

balance of omega-6 (n-6) to omega-3 (n-3) fatty acids (i.e. a high n-6 to n-3 ratio; approximately 22:1), a low level of essential amino acids like lysine, and a high concentration of anti-nutritional components like phytate<sup>3</sup> which forms insoluble complexes with different minerals (e.g. iron, zinc and calcium) and render them unavailable for digestion and absorption in the gastrointestinal tract. Moreover, grains are considered as relatively energy-rich compared to their contents and bioavailability of essential nutrients (Cordain, 1999; Cordain, 2011). Cordain (1999) is especially emphasizing grains shortcomings when it comes to the content of calcium, vitamin A, B<sub>12</sub> and C, as well as the bioavailability of vitamin B<sub>6</sub>, biotin, iron, zinc, copper and magnesium. However, despite these points (which underlines that grains are not the *most optimal* food we can eat), and the fact that the evolutionary theories surrounding LCHF may seem logical, there are also several factors that should make us sceptical towards such a diet. These factors are actually emphasizing that grains should be chosen at the expense of meat.

First of all, consumption of meat, and especially red meat, which consists an important part of many LCHF diets<sup>4</sup>, has several times been associated with an increased risk of different cancers. According to a report from the World Cancer Research Fund (WCRF) and the American Institute for Cancer Research (AICR) there is *convincing* evidence that red meat (i.e. beef, pork, lamb and goat) increases the risk of cancer in the colorectum, while there is *limited*, but *suggestive* evidence, for an increased cancer risk in oesophagus, lungs, pancreas and endometrium (WCRF/AICR, 2007). Such findings indicate that we should reduce the intake of red meat rather than increasing it, as also set out in the official dietary guidelines recommending an intake limited to 500 grams (g) per week (Nasjonalt råd for ernæring, 2011).

Furthermore; nowadays our food consumption is no longer just a concern about palatability and health aspects. The environmental and sustainable perspectives are playing an increasingly larger role. Globally, the food industry is one of the most polluting sectors, and conventional meat production can be considered as one of the main contributors in this context<sup>5</sup> (Carlsson-Kanyama, Ekström & Shanahan, 2003). Compared with grains, meat

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<sup>3</sup> Phytate is considered as the primary anti-nutritional component present in grains, but tannins, fiber and lectins (e.g. wheat germ agglutinin (WGA)) are also perceived as potential anti-nutritional factors (Cordain, 1999).

<sup>4</sup> In the Paleo diet, lean meats constitute a little more than half the calorie intake (Cordain, 2011).

<sup>5</sup> The livestock sector accounts for 18 percent of the worlds total greenhouse gas emissions (measured in CO<sub>2</sub>-equivalents) (Steinfeld et al., 2006).

production results in significantly higher greenhouse gas emissions<sup>6</sup>. This is best illustrated by estimates indicating that beef production leads to emissions with a global warming potential equivalent to 25.3 kilogram (kg) carbon dioxide (CO<sub>2</sub>) per kg beef, whereas the corresponding estimate for wheat production is found to be only 0.8 g (Framtiden i våre hender, 2011).

Most of this difference can be ascribed to the higher levels of inputs (e.g. of fossil energy, acreage and water) required in the production of meat. In average, it is estimated that production of one kilocalorie (kcal) animal protein requires 25 kcal fossil energy (versus only 2.2 kcal in the case of plant proteins), as well as water amounts hundred times the amounts needed during the production of grains (Carlsson-Kanyama et al., 2003; Nymoén, Bere, Haugen & Meltzer, 2009; Pimentel & Pimentel, 2003). Moreover, it takes approximately three kg of grains to produce one kg meat (Nellemann et al., 2009). In this context, it was in 2003 estimated that the amount of grains used to feed the American livestock was enough to feed about 840 million people living on a plant-based diet (Pimentel & Pimentel, 2003). Despite the fact that vegetable proteins in general have a lower biological value compared to animal proteins, these points illustrate that LCHF from an energy/protein view is relatively inefficient. The energy inputs are much larger than the energy we end up with. From an environmental perspective, this is unfavourable (Pimentel & Pimentel, 2003; Torjusen & Vittersø, 1998).

According to Offergaard (2011), a diet is sustainable when it can be *universalized*, meaning that; “it can be followed by every human on earth for an unlimited time without destructions of our common present and future livelihoods”<sup>7</sup> (translated from Norwegian). Based on today’s consumption patterns with relatively high and ever increasing<sup>8</sup> intakes of meat (approximately 74 kg per capita per year (Helsedirektoratet, 2011)), it is estimated that each Norwegian occupies approximately 3300 square meters of cultivation area - one-and-a-half times as much area available per person on earth (Hille & Germiso, 2011). In other words; our current food habits are relatively unsustainable. As a consequence, our focus should be shifted in such a way that choosing foods low in the food chain, e.g. grains and grain-based foods, becomes our main choice and practice. In addition to reduce the climate-related emissions

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<sup>6</sup> Mainly methane (CH<sub>4</sub>) from ruminants and nitrous oxide (N<sub>2</sub>O) from fodder production (i.e. production and spreading of fertilizers) (Carlsson-Kanyama et al., 2003).

<sup>7</sup> Based on the definition of sustainable development set out by the Brundtland Commission in 1987; “[a development] that meets the needs of the present without compromising the ability of future generations to meet their own needs” (T-L. Offergaard, personal communication, 6. October 2011; World Commission on Environment and Development, 1987).

<sup>8</sup> Mostly due to rising income levels (Steinfeld et al., 2006; WHO, 2003).

originating from the food sector, this will free up a lot of land for food production (Nellemann et al., 2009). After all, this is the only way we will be able to feed a growing human population which by 2050 is expected to reach nine billion people (Jacobsen & Lien, 2007; Kroglund & Gaupset, 2011; Randen, 2011).

The LCHF debate has largely been characterized by a focus on carbohydrates and grains as the “scapegoats” causing the worldwide disease epidemic (Bjørnstad, 2010). In his book *In Defense of Food*, Pollan (2008) introduces us to the concept of *nutritionism*. According to Pollan, we cannot isolate single nutrients, or in this case single foods, and “blame” them alone for causing diseases. In reality, we eat thousands of nutrients and non-nutrients, and dozens of different foods every day. It is obvious that other factors than grains may contribute to the illnesses we are observing; among them an industrialization and globalization of the food chain followed by an increased, and too high consumption of highly processed and easily accessible foods and drinks rich in calories, refined sugars, fat, sodium and food additives<sup>9</sup> (Cordain et al., 2005; Cordain, 2011; Ericksen, 2007; Monteiro, 2010; Prentice & Jebb, 2003; WHO, 2003), a too low intake of fruit and vegetables, and not least a sedentary lifestyle with too low levels of physical activity (Cordain, Gotshall & Eaton, 1998; Cordain et al., 2005; Cordain, 2011; Eaton et al., 2002; WHO, 2003).

Finally, LCHF can be said to be based on a positive “philosophy”, largely focusing on all the things you actually can eat following the diet; “(...) *it sounds simple, doesn't it? You can eat so much fat and proteins you want*” (Lutz et al., 2010, pp. 20 – translated from Norwegian). And there are in fact some aspects that make a LCHF diet beneficial. Firstly, it is to a small extent based on highly processed foods as those described above (i.e. soft drinks and snack products). Secondly, due to an energy-dense diet with little carbohydrates and relatively large amounts of fats and proteins, the blood sugar remains stable, hence leading to a prolonged feeling of satiety. This may again result in a generally lower food and calorie intake, and an eventual weight reduction (Cordain et al., 2005; Cordain, 2011). However, the fact that LCHF is based on a limited amount of research should make us sceptical. So far, there are no large-scale studies focusing on the long-term effects of living on a LCHF diet (Brehm & D'Alessio,

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<sup>9</sup> Monteiro (2010) classifies food items into three distinct groups based on their level of processing; *group 1* corresponds to unprocessed, fresh or minimally processed foods (e.g. parts of plants (e.g. grains) or animals), *group 2* to processed culinary or food industry ingredients (e.g. oils, sugar, flours and salt), whereas *group 3* is composed of “ultra-processed” products combining food items from group 1 and 2. Bread is categorized into group 3 together with soft drinks and snack products, among others. I will come back to this later.

2008). Until such studies are indicating that LCHF is safe and beneficial for our health, a *varied* diet rich in whole grain products<sup>10</sup>, e.g. whole grain bread, should be recommended.

## *2.2 Bread as part of the Norwegian diet – current state and future aspirations*

Despite an increased interest around LCHF in the population, and the fact that 29 percent reports that they have eaten less bread the last couple of years (Opplysningskontoret for brød og korn, 2011a), bread and cereals still consist important parts of the diet for most Norwegians. According to numbers from Statistics Norway (2010), the average consumption of bread was approximately 43 kg per capita per year in the period 2007-2009. Furthermore, the Norwegian consumption of grains has significantly increased the last decades – from approximately 70 kg per capita in 1970 to 80 kg per capita in 2010 (Helsedirektoratet, 2011).

In a recent survey (n=2009) conducted on behalf of The Norwegian Bread and Cereals Marketing Board (OBK) it was indicated that 76 and 67 percent still incorporates bread<sup>11</sup> in their breakfast and lunch meals at a regular basis, respectively. Only five percent answered that they did not eat bread at all (Opplysningskontoret for brød og korn, 2011a). Whole grain bread (50-75 percent whole grains) represented the bread most often consumed, followed by extra whole grain (75-100 percent whole grains), semi-whole grain (25-50 percent whole grains), and white bread (0-25 percent whole grains) (Opplysningskontoret for brød og korn, 2011a).

However, the consumption of whole grain products has to be increased - as set out in the official dietary guidelines (Nasjonalt råd for ernæring, 2011). Numbers indicate that whole meal flours only represent 20 percent of the total meal turnover, whereas the population's average intake of dietary fiber equivalent to 16 to 19 g is well below the recommended amount of 25 to 35 g per day (Helsedirektoratet, 2011; Nordic Council of Ministers, 2004). Due to a large body of evidence demonstrating a positive association between a regular whole grain consumption and a reduced risk of several chronic diseases (which will be presented in greater detail later), Norwegian health authorities advise a whole grain intake

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<sup>10</sup> The concept of whole grains is defined in chapter 6.1.1.

<sup>11</sup> The term “bread” covered both bread, crackers, rolls and baguettes (Opplysningskontoret for brød og korn, 2011a).

corresponding to 70 to 90 g per day (Nasjonalt råd for ernæring, 2011). What this corresponds to will be presented in a later section.

## 2.3 “*Bread-o-rama*”

In spite of an inadequate intake of whole grain products, we have during the last couple of years observed an increased health focus among the Norwegian population (Bugge et al., 2008). Many people care about the healthiness of the food they eat, and this has, among others, led to the development of a range of new, health-claiming food products for which the producers often take “premium price”. Bread and cereal products are no exception (Dewettinck et al., 2008).

Based on sales statistics from AC Nielsen, there were sold approximately 3400 different bread products from Norwegian grocery shops over a period of 52 weeks during 2010 and 2011 (K. Gartland, personal communication, 29. September 2011). In reality, only a little change in the ingredients leads to a completely new product (Nilsson, 2009). Just by adding some carrot, an ordinary oat bread can for example be sold as a carrot bread, while many so-called rye breads only contain a low percentage of rye. Several shops are also promoting their so-called “in-store baked breads”, or bake-off breads, which in reality are semi-finished breads from the producers (Nilsson, 2009). For people who bake their own breads, there are several readymade and value-added bread mixes to choose among (Bugge et al., 2008).

In this context, there are several actors (e.g. Fedon Lindberg, Birger Svihus and Ingers rugbrød) claiming that their product is the “ideal” bread (Bugge et al., 2008). However, their breads are very different, and the argumentation why they are healthy is clearly embedded in very different nutrition philosophies; i.e. low GI/low carb (Lindberg), low energy (Svihus) and high fiber (Ingers rugbrød). In other words; a more holistic view is needed in relation to what an “ideal” bread really is.

When asked where they normally obtained their bread, 19 percent of the respondents in the already mentioned OBK survey answered that they were baking their own<sup>12</sup>. However, this estimate is not exclusively as 85, 15 and 1 percent at the same time were reporting to buy it in

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<sup>12</sup> The survey is not saying anything about the amount of homebaked bread actually consumed.

the grocery store, bakery or petrol station, respectively (Opplysningskontoret for brød og korn, 2011a). This requires some facts about the industrial bread.

### 2.3.1 *The industrial bread*

Bread is among the world's oldest processed foods, which also makes bread baking a handicraft with long traditions (Frølich, 2007; Meyer, 2009; Stampfli & Nersten, 1995). A lot has, however, happened since the first bread was baked in Egypt approximately 12 000 years ago (Meyer, 2009; Mondal & Datta, 2008). From the Egyptians random experimentation with flour, water and yeast, via the small, artisan bakeries established in almost every village supplying citizens with their daily rations of bread, to present were centralization and a high-technological industrialization have taken toll on the production practice. Today, bread is produced in a large scale by a few production units and then distributed and re-distributed over large distances to wholesalers, supermarkets and in-store-bakeries (Hy, 1998; Decock & Cappelle, 2005; Mondal & Datta, 2008; Nilsson, 2009; Stampfli & Nersten, 1995; Whitley, 2009).

Currently, the bread industry is – as the food industry in general - characterized by cost-effectiveness (relatively high-quality breads to a low price) and competition (Bjørnstad, 2010; Mondal & Datta, 2008). As consumers, we are also putting our marks on the production practice. To sell, the producers have to provide breads of high quality – both when it comes to health and sensory qualities (i.e. tasteful breads with the right smell, look and texture). Additionally, the breads must remain fresh over a long period. From a production perspective, it's also beneficial that the doughs are quick and easy to handle (Mondal & Datta, 2008; Stampfli & Nersten, 1995). It is not easy to fulfil all these criteria, especially not when a “no-time dough process” characterizes the industry (Nilsson, 2009). Almost every bread baking book are mentioning *time* as the most important “ingredient” if you want to bake the “perfect” bread; *time* for kneading, *time* for fermenting and *time* for the dough to rest (Hjelme, 2004; Meyer, 2009; Whitley, 2009). So, what is actually the bread industry's “secret”?

In the 1960's, British researchers developed a bread baking method - Chorleywood Bread Process (CBP) - that contributed to reduce both the time and cost of industrial baking (but also to increase its energy expenditure) (Chamberlain et al., 1966; Nilsson, 2009; Whitley, 2009). Among the techniques incorporated in CBP are high-speed mixing (more air and water



incorporated into the dough), higher fermentation temperatures, use of large amounts of yeast (reduced fermentation time and larger loaf volume), as well as different chemical additives. It is estimated that approximately 80 percent of all industrial breads today are made using CBP (Chamberlain et al., 1966; Ledsaak & Eben, 2010; Nilsson, 2009; Whitley, 2009).

The introduction of chemical additives marked a new era of the bread industry. Today, flour treatment agents, bleaching agents, emulsifiers, anti-staling agents and preservatives are common components in the production process (Nilsson, 2009; Meyer, 2009; Whitley, 2009). While the food industry claims that prevention of food poisoning is the main reason for using these additives, Nilsson (2009) argues that preservatives and antioxidants only accounts for one percent of the additives applied, while nine out of ten additives instead are used for cosmetic purposes. Some of the different additives already mentioned will be explained in the following part.

While some bread producers still add fat<sup>13</sup> to their breads, others are replacing this with emulsifiers - both to save money, but also to please consumer demands in relation to low-fat products. Emulsifiers are fatty substances that broadly can be divided into *dough strengtheners* (e.g. soya flour) and *crumb softeners* (e.g. monoglycerides) (Stampfli & Nersten, 1995; Ulen, 1991; Whitley, 2009). In the baking process, emulsifiers have several tasks; to strengthen the dough (thus making it capable of withstanding a rough machine handling), increase the doughs water absorption, volume and oven rise (through better gas retention), soften the crumb and crust, as well as give the bread the right symmetry (Ledsaak & Eben, 2010; Mondal & Datta, 2008; Stampfli & Nersten, 1995). No emulsifier has all the mentioned properties, thus several emulsifiers are applied (Stampfli & Nersten, 1995).

Breads stale easily, leading to sensory changes like a harder crumb, less taste and crust crispness (Mondal & Datta, 2008). If the producers have to throw breads, they naturally lose money. This makes prolongations of the breads shelf life to a cheap investment (Stampfli & Nersten, 1995). A bread may in fact contain up to 16 different chemicals making it seem

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<sup>13</sup> In processed foods – including breads - oils and fats are often labelled as “vegetable oils”. This collective term may include several types of fats, e.g. palm oil. Palm oil, which is widely used by the food industry due to its low price, has recently received a lot of negative attention. First and foremost, it is stressed that palm oil production leads to deforestation of the rain forest. In addition to threatening the livelihoods of the indigenous, this destruction is estimated to account for approximately one fifth of the global emissions of greenhouse gases. Furthermore, palm oil is high in palmitic acid (45 percent) which is classified as a convincing risk factor in the etiology of cardiovascular diseases (Regnskogfondet, 2012a; WHO, 2003). According a palm oil guide developed by Green Living and the Norwegian Rainforest Foundation, some types of industrial breads may contain *moderate* amounts (i.e. up to 1 percent) of palm oil (Regnskogfondet, 2012b).

fresh, although it is not (Nilsson, 2009). Calcium propionate (E-282) is one of the preservatives most widely used (Aune, 2009), together with emulsifiers and several enzymes (e.g. Novamyl that may prolong a breads shelf life from three days up to three weeks by slowing down the staling process) (Nilsson, 2009; Stampfli & Nersten, 1995).

Finally; doughs based on high levels of whole grains often result in breads with a reduced loaf volume, a harder crust and a more compact crumb texture. To improve the sensory qualities of these breads, the bread industry often adds extra gluten<sup>14</sup> and ascorbic acid (E-300) to strenghten the gluten network (Gòmez, Ronda, Blanco, Caballero & Apesteguìa, 2003; Meyer, 2009). Some people are extra sensitive to wheat proteins. For these people, gluten-enriched breads are proposed to trigger the development of celiac disease (Whitley, 2009).

Yearly, each western consumer ingests approximately six to seven kg food additives (Nilsson, 2009), and clearly, industrial bread contributes a major part of this intake. It is important to emphasize that all food additives that are applied have received regulatory approvals from the Norwegian Food Safety Authority (Forskrift om tilsetningsstoffer, næringsmidler, 2011). At the same time, these approvals are largely based on results from animal studies which are difficult to extrapolate to humans. For example; mice live for approximately 18 months. How can we surely say something about an additives effect on the health of a human after being exposed for several decades (Nilsson, 2009)?

Epidemiological studies can say us something about how food affects our health. What makes additives difficult to study is that they are many and consumed in different combinations in every food. This makes it hard to isolate single additives (Nilsson, 2009; Whitley, 2009). It may be that some of the additives added to our food today actually are detrimental for our health (Aune, 2007). This can be illustrated by the fact that chemicals said be safe decades ago, now are banned (e.g. the oxidising substance potassium bromate which was found to be carcinogenic) (Whitley, 2009).

In addition to being a major source of food additives, it is important to stress that industrial breads also are one of our main sources of salt. According the Norwegian Directorate of Health, 22 percent of the salt in the Norwegian diet originates from cereal products (Helsedirektoratet, 2010).

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<sup>14</sup> If a wheat bread without any enrichments (e.g. seeds, nuts or milk) contains more than approximately 12 g proteins per 100 g bread (which is the protein content of whole meal wheat flour (Matportalen, 2012a)), extra gluten is probably added.

### 2.3.2 “A good bread does not need magical ingredients”<sup>15</sup>

Still the big factories dominate the bread market. Nevertheless, the picture is becoming more nuanced. During the last couple of years there has been an increased focus on local, sustainable and high quality foods (Nilsson, 2009). Farmers' markets, allotment gardens and an increased governmental investment in organic production, illustrate this (Landbruks- og matdepartementet, 2009; Nilsson, 2009). In the bread universe, small, local bakeries still exist, and are even experiencing increased popularity. *Åpent bakeri* and *Kolonihagen bakeri* located in Oslo, as well as *Bakeriet i Lom* are some examples in this context. Their focus on old baking traditions and use of natural ingredients (often organic) (Hjelme, 2004; Schakenda, 2009) makes them attractive alternatives if we want to avoid the additives present in industrial breads. At the same time, their recipes are often based on large amounts of salt (Hjelme, 2004; Schakenda, 2009). A second alternative may therefore be to bake our own bread.

## 2.4 Why should we bake our own bread?

Bread baking is a downward trend among the Norwegian population. As previously mentioned, 19 percent are reporting to obtain a large part of their bread from homebaking (Opplysningskontoret for brød og korn, 2011a). This may be viewed as a relatively high share. However, 24 percent do at the same time report to have eaten less home-baked bread the last couple of years (Opplysningskontoret for brød og korn, 2011a). In a study carried out by the National Institute for Consumer Research (SIFO) in 2008, 24 percent were answering that they were not baking bread at all, while 13 percent were baking once a week or more often (Bugge et al., 2008).

Among the respondents who were baking regularly, taste was cited as the most important reason for why they were baking - homemade bread was better tasting than industrial breads (Bugge et al., 2008). In addition to taste, there are actually several arguments for why we should bake our own bread. Under the right circumstances, bread baking may for example have multiple health benefits. Each argument is listed in table 2-2, and will then be presented in greater detail.

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<sup>15</sup> Nilsson (2009)

**Table 2-2** Why should we bake our own bread?

|                               |  |
|-------------------------------|--|
| <b>Ingredients</b>            | - Avoid food additives and excessive salt from industrial breads<br>- Being able to adjust the amount of e.g. whole grains, fat and salt<br>- Complete overview of what the bread contains |
| <b>Everyday activity</b>      | - Baking may contribute to everyday activity<br>- Baking may replace sedentary activities, e.g. watching TV  |
| <b>Empowerment</b>            | - Baking may lead to a sense of empowerment<br>- An important motivation to start making more food from scratch  |
| <b>Environmental concerns</b> | - Environmental friendly production, e.g. reduced transport costs<br>- May choose locally produced or organic ingredients  |
| <b>Household economy</b>      | - Baking may be economically beneficial compared with many of the bread alternatives in the grocery store or bakery  |

### *2.4.1 Ingredients*

As previously mentioned, Monteiro (2010) classifies bread as an “ultra-processed” food item at the same level as fast-foods like burgers and soft drinks. Group 3 foods, which Monteiro (2010) considers to be the main dietary reason for the development of the present disease epidemic, are generally characterized by their convenience (ready-to-eat), sensory appealingness, as well as appetite stimulating and addictive properties. To develop such products, refined ingredients (e.g. oils, sugars, salt and flours) and food additives are important components (Monteiro, 2010).

However, the question is whether all types of bread can be classified as ultra-processed. For example; industrial breads are as aforementioned one of the main sources of salt and food additives in the Norwegian diet (Helsedirektoratet, 2010; Nilsson, 2009). By baking ourselves, we are able to control what the bread contains, and adjust the content of e.g. whole grains, fat and salt. By adjusting the recipes amount of water, it is also possible to regulate the breads energy density (the more water, the lower energy density). In such a perspective, it becomes obvious that home-baked bread rich in whole grains and low in salt, fat and additives should be classified in another group than e.g. industrial produced white bread, and that home baking may be a more nutritional beneficial alternative than buying breads in the grocery store.

### *2.4.2 Everyday activity*

In general, our everyday life is characterized by a reduced demand for physical activity - and consequently energy expenditure. To start with, only 20 percent of the adult population fulfil

the recommendations on physical activity set out by the health authorities at 30 minutes a day (Anderssen et al., 2009). An even bigger problem, however, is that we sit “all the time” – both at work and in the leisure time in front of the TV and computer. At the same time, our daily chores are highly mechanized; for example in the kitchen where labor-saving devices like food processors and dishwashers are ubiquitous (Hill, Wyatt, Reed & Peters, 2003; Thorp, Owen, Neuhaus & Dunstan, 2011). In this context, there is a growing body of longitudinal evidences linking sedentary behaviours – independent of physical activity level – to several adverse health outcomes. In particular, there is observed convincing correlations between time spent on sedentary activities (e.g. TV-watching) and the risk of obesity, all-cause and cardiovascular-related mortality (Thorp et al., 2011; WHO, 2003).

As an everyday activity, bread baking may be a contributing factor in breaking up and substitute such sedentary behaviours, and consequently being a contributor to the overall energy expenditure. It is the kneading of the dough that may possess the true “training effect”, where both the intensity and duration may be tailored. Although bread baking only may be classified as a light-to-moderate intense activity, there are several authors suggesting that there may be the lack of engagement in such types of activities that causes the adverse health-effects observed from a sedentary lifestyle (Arrieta & Russell, 2008; Foster, Gore & West, 2006; Hill, 2005; Williams, Raynor & Ciccolo, 2008). If this is true, it *could* be that establishment of regular and frequent bread baking habits over a long-term could contribute to both weight reduction (primarily among overweight people), as well as a generally better health. An important assumption in this context is of course that the dough is kneaded manually rather than by using a food processor.

### *2.4.3 Empowerment*

During the last couple of decades we have distanced ourselves from, and developed a kind of incompetence, when it comes to cooking. Despite more spare time, we spend less time preparing foods and more time in front of the TV and computer, eat more out and consume a lot of semi-finished food products (Nestle, 2006; Pollan, 2008). To start baking bread may be a contributing factor in converting cooking from a duty to empowerment - meaning that we can create something meaningful for both ourselves and the people around us, and in this way gain a “proximity” to the bread we eat. Bread baking may also be a good starting point in generally getting engaged in cooking more food from scratch.

#### *2.4.4 Environmental concerns*

Home baking may also gain our planet. As already mentioned, the food industry is one of the most polluting sectors globally (Carlsson-Kanyama et al., 2003). Despite the fact that meat production and eating are the main contributors in this respect, bread production holds great potential to become more sustainable. In a Swedish life cycle assessment (LCA)<sup>16</sup> of breads produced on four different scales; home baking, a local bakery and two industrial bakeries with distribution areas of different sizes, it was for example demonstrated that industrial production required a lot of energy in terms of packaging and long transport distances (Andersson & Ohlsson, 1999). Home baking was also identified as quite energy demanding, especially in terms of heating of the oven and dish-washing water (Andersson & Ohlsson, 1999). However, by using the oven in an efficient way (e.g. by baking several breads at a time) and by washing the baking equipment together with other dishes, these energy requirements are reduced. In terms of total emissions related to energy use, home baking was considered to be the best alternative - mainly due to minor use of fossil fuel and packaging materials (Andersson & Ohlsson, 1999). By kneading the dough by hand – rather than using a food processor – energy can also be saved.

Another way of making the baking process more environmentally sustainable is by applying organic and/or locally produced ingredients (Bere & Brug, 2008; Nymoén et al., 2009). In the case of organic ingredients, there are in fact estimates indicating that the energy consumption of the baking process can be reduced by up to 13 percent per kg bread by replacing conventional rye with organic rye (Grönroos, Seppälä, Voutilainen, Seuri & Koikkalainen, 2006). The principles of organic production will be outlined later. When it comes to use of local ingredients, the benefits are primarily related to reduced transport emissions (due to less “food miles”), as well as value creation among local producers, e.g. farmers (Nymoén et al., 2009).

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<sup>16</sup> LCA is a standardized method used in the evaluation of a products environmental influence. Each step of the products life cycle is taken into account. In the study by Andersson & Ohlsson (1999) these steps included: production of inputs to agriculture, cultivation of wheat, milling, baking and cleaning/dish-washing, packaging systems for bread ingredients and bread, transportation, the consumer phase and waste management.

### 2.4.5 Household economy

As already mentioned, one often have to pay premium price for the healthiest bread alternatives in the grocery store (*healthy* meaning high in whole grains and low in salt) (Dewettinck et al., 2008). High-quality breads from the local bakery do often cost even more (Nilsson, 2009).

Table 2-3 presents the prices of four different breads from a regular grocery store. They are all labelled with the *Keyhole* and a full *Bread scale* (more about this later), and are therefore regarded as some of the healthiest breads on the Norwegian market. As table 2-3 illustrates, we have to pay approximately 30 Norwegian kroner (NOK) for one such bread.

**Table 2-3** Bread prices\*

| <b>Bread type</b>    | <b>Price per bread<br/>NOK</b> |
|----------------------|--------------------------------|
| Barley bread         | 31,-                           |
| Oat bread            | 29,-                           |
| Spelt bread          | 28,-                           |
| Vita hjertego'       | 33,-                           |
| <b>Average price</b> | <b>30,-</b>                    |

\*The prices are collected at a Kiwi shop in May 2012

It remains to be seen whether homemade bread can be more economically beneficial than industrially produced breads. Nevertheless, this chapter have been illustrating that bread baking may be beneficial for several reasons. Moreover, the importance of getting people engaged in baking their own bread has been emphasized. This leads us to the purposes of the present thesis.





## 3.0 PURPOSES

This thesis is part of a project with a total of four purposes. These are to:

- (1) come up with a recipe for an "ideal" bread
- (2) develop an intervention aiming at getting people to bake this bread instead of watching TV
- (3) conduct a pilot implementation study of the intervention
- (4) assess a process and outcome evaluation of the pilot implementation

The project includes two separate master theses. The present thesis is focusing on purpose 1, while the thesis of master student Line Jensen addresses purpose 2. Purpose 3 and 4 has resulted in a common article and poster (Attachment 1 and 2, respectively<sup>17</sup>). Both have contributed equally to the practical tasks of the intervention (i.e. in relation to all four purposes).

### *3.1 Specific study objective*

The more we eat of a particular food item, the more important is the fact that the food item is healthy, sustainable and tasteful. The Norwegian population's high bread consumption emphasizes the importance of eating a bread of high quality. The specific study objective of the present thesis is therefore to answer the following question:

*In a Norwegian setting, what is the recipe for the "ideal" bread?*

As we see, the study objective is placed in a Norwegian context. This delimitation is mainly explained by the fact that bread is an important dietary component for several populations, not only Norwegians. In this context, it is well-known that the definition of bread, as well as the ingredients applied, widely varies between countries and food cultures. While coarse breads primarily based on wheat (and to some extent barley, oat and rye) dominate the Norwegian bread market, bread varieties like focaccia and naan are more common in countries like Italia and India (Jaine, 1996; Treuille & Ferrigno, 1999). This underlines the need to set some limits for the present thesis. However, it should also be noted that many of the principles that will be

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<sup>17</sup> See attachment 3 and 4 for the approval from the Norwegian Social Science Services, as well as one of the questionnaires that were used during the intervention. This questionnaire includes all questions that were asked.

outlined in the following sections are common for all type of breads. To set some further limitations, gluten-free alternatives have not been included in the following review.

## 4.0 THE “IDEAL” BREAD - SOME CRITERIA

For a bread to be “ideal”, it should fulfil several criteria. In the surveys conducted by OBK and SIFO, the respondents were asked to specify their own criteria when choosing what type of bread to eat. Sensory (e.g. taste and freshness) and nutritional aspects (e.g. high in whole grains, low in sugar, salt, fats and additives) were the most commonly cited criteria, but a low price and environmental aspects (e.g. use of organic ingredients and local production) were also emphasized as important qualities (Bugge et al., 2008; Opplysningskontoret for brød og korn, 2011a). These criteria, which also are identified by others (Bakke & Vickers, 2007), represent information that is important to take into consideration when we now are to set the criteria for the “ideal” bread.

### 4.1 Health criteria

An overview of the health authorities yearly publication *Utviklingen i norsk kosthold* (Helsedirektoratet, 2011) indicates that the Norwegian diet is facing six challenges in particular. The diet is generally (1) too energy-dense, contains too much (2) sugar, (3) salt and (4) fat (especially saturated fat), as well as insufficient amounts of (5) dietary fiber and (6) antioxidants (Helsedirektoratet, 2011). The “ideal” bread should be healthy and thereby take all these challenges into account.

Firstly, the bread should contain relatively much whole grains. In addition to increase the amount of both dietary fiber and antioxidants in the diet, this will, in contrast to refined, energy-rich flours, contribute in the lowering of the energy density of the bread. If we additionally include much water, the energy density will drop further. The recipes amount of sugar, salt and fat should also be controlled and limited. In the case of fat, grains are higher in unsaturated than saturated fatty acids (Cordain, 1999). This is beneficial in the case of reducing the levels of saturated fat in the diet. However, from another point of view, grains are richer in n-6 compared to n-3 fatty acids (Cordain, 1999). According to Cordain (1999), a high n-6 to n-3 ratio is one of the main challenges of the western diet. In the case of the “ideal” bread, this issue can be solved by incorporating different seeds or nuts, which some are rich sources of n-3 (Li & Hu, 2011). Seeds and nuts are additionally important sources of different antioxidants (Blomhoff, Carlsen, Andersen & Jacobs, 2006). Still, they are among

the most common food allergy triggers identified (Cochard & Eigenmann, 2011). An “ideal” bread should be tolerated by most people - seeds and nuts seldom observed to provoke allergic reactions will therefore be preferred.

To set some exact criteria when it comes to amounts of whole grains, dietary fiber, sugar, fat and salt, the criteria of two labelling schemes - the *Keyhole* and the *Bread scale* - will be applied. They are both presented in detail below.

Finally, focus should be placed on preferring baking methods that maximize the bread’s content of nutrients (e.g. by preventing loss during the baking process), reduce the concentration of anti-nutritional components known to undermine the bread’s nutritional value (e.g. phytate known as an inhibitor of mineral absorption), as well as minimize the formation of possible harmful contaminants (e.g. acrylamide).

### 4.1.1 The Keyhole

The *Keyhole* is a voluntary labelling system common for the Nordic countries that is used to label foods from 25 different food groups, e.g. bread. In Norway, the Norwegian Directorate of Health and the Norwegian Food Safety Authority are functioning as the responsible organs for the scheme. By setting standards regarding the food products minimum content of dietary fiber (and whole grains in the case of cereal products), as well as maximum content of sugar, salt and fat, the *Keyhole* is primarily designed to make it easier for consumers to choose the healthiest food alternatives (Nasjonalt råd for ernæring, 2011).

Each food group has its own criteria to meet the requirements. For bread, the criteria are as follows (Forskrift om frivillig merking med Nøkkehullet, 2009):

|                      |                                  |
|----------------------|----------------------------------|
| <b>Whole grains</b>  | minimum 25 % of dry matter basis |
| <b>Dietary fiber</b> | minimum 5 g/100 g                |
| <b>Sugar</b>         | maximum 5 g/100 g                |
| <b>Salt (sodium)</b> | maximum 0.5 g/100 g              |
| <b>Fat</b>           | maximum 7 g/100 g                |



The “ideal” bread will be eligible for the Keyhole symbol (figure 4-1).

**Figure 4-1** The Keyhole symbol

### 4.1.2 The Bread scale

The *Bread scale* is a labelling system runned by the Federation of Norwegian Food and Drink Industry. The scheme is comprised by four labels illustrating the four groups (figure 4-2) a bread can be categorized into based on its level of whole grains, whole grain flours and bran (calculated on the basis of total flour amount) (Nasjonalt råd for ernæring, 2011; Opplysningskontoret for brød og korn, 2011b):

|                                |  |
|--------------------------------|--|
| <b>White bread</b>             | 0-25 percent whole grains, whole grain flours and bran   |
| <b>Semi whole grain bread</b>  | 25-50 percent whole grains, whole grain flours and bran  |
| <b>Whole grain bread</b>       | 50-75 percent whole grains, whole grain flours and bran  |
| <b>Extra whole grain bread</b> | 75-100 percent whole grains, whole grain flours and bran |



**Figure 4-2** The Bread scale

The scheme does not include seeds, nuts or other ingredients that might affect the nutritional value of breads (Opplysningskontoret for brød og korn, 2011b).

When the health authorities urge an increased intake of whole grain products, this will in reality mean an increased intake of e.g. breads classified as whole grain and extra whole grain – i.e. breads containing at least 50 percent whole grains. The whole grain recommendation of 70-90 g whole grains a day is equivalent to four slices of extra whole grain bread per day (Nasjonalt råd for ernæring, 2011).

A Bread scale calculator on OBK's websites (Opplysningskontoret for brød og korn, 2012a) will be used to estimate the coarseness of the final bread recipe. The "ideal" bread should fulfil at least three cakes on the Bread scale (i.e. at least constitute a whole grain bread).

## 4.2 Sensory criteria

Despite an increased consumer interest in the health aspects of food, 80 percent still emphasize taste and sensory attractiveness as the most important quality criteria of breads (Bugge et al, 2008). There is a reason why the consumption of whole meal flour is lower than recommended – products made with refined wheat taste good. In addition, people tend to prefer products which contain more salt than recommended. Often breads made to taste good are low in whole grains and high in salt, and most healthy breads do not taste that good. They may for instance be dry and with a high density (Bakke & Vickers, 2007).

These points are illustrating the importance, and challenge, of developing breads that are healthy and good tasting at the same time (Dewettinck et al., 2008; Gómez et al., 2003; Luikkonen et al., 2003). Yet, factors that affect both taste and health might alter this negative relation. Such factors may be the amount of yeast, water and added ingredients like seeds and nuts. Fermentation method and baking time may also affect both the health and taste properties of breads (Meyer, 2009).

Important sensory criteria for the “ideal” bread will be; *texture* (not too compact), *appearance* (e.g. the color; a roasty, golden color serves as an indicator of a breads wholesomeness), and not least the *taste* – the bread has to taste good.

## 4.3 Practical criteria

Several emphasize bread baking as a time-consuming activity (Bugge et al., 2008). This emphasizes the importance of developing a bread recipe that is both simple and time-efficient. Since bread baking at the same time may be considered an important contributor to everyday activity (as outlined above), focus should not be placed on shortening the time used on the kneading of the dough. Instead, it should be placed on finding practical solutions in relation to the time used on fermentation that is both convenient and time-saving.

Moreover, 23 percent states price as an important influencing factor when buying bread in the grocery store (Bugge et al., 2008). An “ideal” bread should therefore be based on relatively few ingredients that are both inexpensive and easily accessible.

## 4.4 Environmental criteria

Based on the abovementioned criteria, it is obvious that an “ideal” bread is not only as healthy as possible, but also as “perfect” as possible, meaning that the bread is healthy and good tasting at the same time - making people wanting to start baking and eating it. However, an ”ideal” bread is not only based on individual preferences. In a larger perspective, environmental considerations play an equal role. By incorporating local grains (e.g. Nordic grains like rye, barley and oat (Bere & Brug, 2008)) or organic ingredients in the recipe, this is taken into account.

Table 4-1 summarizes the abovementioned criteria.

**Table 4-1** Criteria for an ”ideal” bread

|                               |   |
|-------------------------------|---|
| <b>Health criteria</b>        | <ul style="list-style-type: none"> <li>- Rich in whole grains (dietary fiber), antioxidants and healthy fats (especially n-3)</li> <li>- Low in energy, sugar, salt and unhealthy fats (especially saturated fat)</li> <li>- Fulfil the criteria set by the <i>Keyhole</i> and achieve at least three cakes on the <i>Bread scale</i> (i.e. a whole grain bread)</li> <li>- Strive for a maximal nutritional value</li> <li>- Strive for a minimum of harmful contaminants</li> </ul> |
| <b>Sensory criteria</b>       | <ul style="list-style-type: none"> <li>- Good tasting</li> <li>- Sensory acceptable when it comes to texture and appearance (e.g. color)</li> </ul>   |
| <b>Practical criteria</b>     | <ul style="list-style-type: none"> <li>- The baking process should be time-efficient</li> <li>- The recipe should be simple</li> <li>- The recipe should be based on few, affordable and easily accessible ingredients</li> </ul>   |
| <b>Environmental criteria</b> | <ul style="list-style-type: none"> <li>- Use of local and/or organic ingredients</li> </ul>   |





## 5.0 METHODS

To identify the “ideal” bread, a literature review regarding the abovementioned criteria (table 4-1) was conducted. Additionally, bread baking books have been searched for a suitable recipe to be modified to fit with the criteria.

### *5.1 Literature review*

Two search strategies were applied to identify relevant literature for this review. In the period from June 2011 to April 2012, broad searches were conducted in Science Direct, PubMed and Wiley Online Library. Applied search words included “bread”, “bread baking”, “whole grains”, “whole grains and health effects”, “seeds and health effects”, “nuts and health effects”, “salt and bread”, “phytate”, “phytate and reduction”, “acrylamide”, “acrylamide and reduction”. The majority of the literature was, however, found when screening the reference lists of relevant publications identified through the databases.

The literature included in this review has been limited to publications in English, Norwegian, Swedish and Danish.



## 6.0 RESULTS AND DISCUSSION

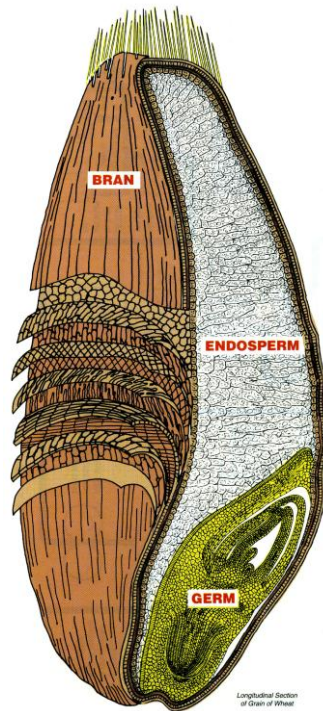
To bake a bread, you basically need flour, liquids, salt and yeast. Seeds and nuts may also be added. The baking process can be divided into three steps; (1) mixing and kneading, (2) fermentation and (3) baking. Every ingredient, and every process step, affects the bread in its own way (Dewettinck et al., 2008). The following literature review is intended to give an insight into the factors providing the best basis for developing an “ideal” bread. Additionally, the possible health effects of bread, with regard to e.g. amount of whole grains and salt, as well as fermentation and baking time, will be presented and discussed. In the last part of this chapter, a suggestion for a recipe for an “ideal” bread is proposed. Additionally, some calculations demonstrating that the proposed recipe fulfils the criteria set out by the *Keyhole* and achieves at least three cakes on the *Bread scale*, are performed.

### 6.1 Whole grains

Bread is classified as one of the most important sources of whole grains in the Norwegian diet, and is together with pasta and cereals estimated to account for approximately 50 percent of the total intake (Nasjonalt råd for ernæring, 2011). Still, and as already mentioned, the Norwegian whole grain consumption is too low and the health authorities are urging an increased intake of foods rich in whole grains, e.g. whole grain bread (Helsedirektoratet, 2010; Nasjonalt råd for ernæring, 2011). This recommendation is based upon a solid knowledge base linking whole grain consumption with a reduced risk of several diseases (Nasjonalt råd for ernæring, 2011). These associations will be outlined further, but first; what are actually whole grains?

#### 6.1.1 What are whole grains?

To understand the concept of whole grains, we have to know how a grain is constructed. Figure 6-1 illustrates the anatomical structure of a wheat grain (which also is the basic structure of all cereal grains).



**Figure 6-1** The anatomical structure of a wheat grain

As we can see, the grain is divided into three different parts; *endosperm*, *bran* and *germ* (Dewettinck et al., 2008; Slavin, Jacobs & Marquart, 2001a). The endosperm, which accounts for approximately 80 percent, makes up the core of the grain, while the bran constitutes the grain's outer layer. While the endosperm is mainly composed by starch and some proteins, the bran is rich in dietary fiber, vitamins (especially the B vitamins thiamine and folate), minerals (e.g. phosphorus, potassium<sup>18</sup>, iron, selenium, copper and zinc) and phytochemicals (e.g. antioxidants and phenolic compounds), but also anti-nutritional compounds like phytate, tannins and enzyme inhibitors. Finally, we have the germ which is the grain's fat reservoir. This part is mainly composed of lipids - especially the monounsaturated fatty acid (MUFA) oleic acid (C18:1n-9) and the polyunsaturated fatty acid (PUFA) linoleic acid (LA, C18:2n-6), as well as fat-soluble vitamins (especially vitamin E) (Bjørnstad, 2010; Dewettinck et al., 2008; Jones, 2006; Slavin, Jacobs, Marquart & Wiemer, 2001b).

During the process of milling, the bran and germ are separated from the starchy endosperm. When the endosperm is grounded, we have white flour. Whole meal flours are on the other

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<sup>18</sup> Grains are relatively high in potassium and low in sodium (Dewettinck et al., 2008). A high potassium:sodium ratio is beneficial in the case of reducing the risk of developing e.g. hypertension (Cordain, 2011). This aspect is in focus in chapter 6.4 and will therefore not be outlined further in this section.

hand made up of both the bran, germ and endosperm in a ratio corresponding to the ratio found in the original grain (Jones, 2006; Slavin et al., 2001a). Based on this, flours can be characterized by their *extraction rates*. While whole meal flours have an extraction rate corresponding to 100 percent (meaning that they contain the whole grain), white flours have a rate of 75-80 percent (meaning that 20-25 percent of the grain is removed) (Nasjonalt råd for ernæring, 2011).

Table 6-1 illustrates the differences between whole meal and white wheat flour when it comes to nutritional composition.

**Table 6-1** Nutritional composition\* (per 100 g) of wheat flours with extraction rates of 100 and 80 percent

|                                | <b>Wheat,<br/>extraction<br/>rate 100 %</b> | <b>Wheat,<br/>extraction<br/>rate 80 %</b> |
|--------------------------------|---|--|
| <b>Energy (kJ)</b>             | 1330  | 1493                                       |
| <b>Carbohydrates (g)</b>       | 54.4  | 71.6                                       |
| - <i>Starch</i>                | 52.4  | 70.7                                       |
| - <i>Mono-and disaccarides</i> | 2.0   | 0.9  |
| - <i>Dietary fiber</i>         | 11.0  | 3.4  |
| <b>Protein (g)</b>             | 12.0  | 11.4                                       |
| <b>Fat (g)</b>                 | 2.4   | 1.5  |
| - <i>Saturated</i>             | 0.3   | 0.2  |
| - <i>Monounsaturated</i>       | 0.4   | 0.2  |
| - <i>Polyunsaturated</i>       | 1.1   | 0.8  |
| <b>Vitamin A (µg)</b>          |   |  |
| - <i>β-carotene</i>            | 3.0   | 0  |
| <b>Vitamin E (mg)</b>          |   |  |
| - <i>α-tocopherol</i>          | 0.9   | 0.8  |
| <b>Vitamin B</b>               |   |  |
| - <i>Thiamine (B1) (mg)</i>    | 0.5   | 0.3  |
| - <i>Riboflavine (B2) (mg)</i> | 0.08  | 0.04                                       |
| - <i>Niacine (mg)</i>          | 6.4   | 1.5  |
| - <i>Pyridoxine (B6) (mg)</i>  | 0.2   | 0.08                                       |
| - <i>Folate (µg)</i>           | 40  | 18   |
| <b>Calcium (mg)</b>            | 30  | 18   |
| <b>Iron (mg)</b>               | 4.1   | 1.3  |
| <b>Sodium (mg)</b>             | 1   | 1  |
| <b>Potassium (mg)</b>          | 413   | 166  |
| <b>Magnesium (mg)</b>          | 116   | 34   |
| <b>Zinc (mg)</b>               | 2.7   | 0.9  |
| <b>Selenium (µg)</b>           | 10  | 5  |
| <b>Copper (mg)</b>             | 0.4   | 0.1  |
| <b>Phosphorus (mg)</b>         | 370   | 133  |

\* A selection of macro and micronutrients is chosen

Source: Matportalen (2012a)

As shown in the table, refined wheat flour contains quite low levels of dietary fiber and different vitamins and minerals, while the levels of easily absorbable carbohydrates (e.g. starch) are high. Whole meal flour, which retains the nutritious bran and germ, is on the other hand relatively high in dietary fiber, unsaturated fats and different vitamins and minerals. However, it should also be emphasized – although not illustrated in table 6-1 – that whole meal flours have a higher concentration of anti-nutritional components, e.g. phytate and tannins, which run parallel to the fiber level (Slavin et al., 2001a; Slavin et al., 2001b).

The two flours are quite similar when it comes to the amount of proteins. It should, however, be noted that their amino acid profile differs. The levels of lysine, which is the limiting amino acid in wheat, are higher in the bran and germ than in the the endosperm (Clydesdale, 1994; Dewettinck et al., 2008), meaning that refined flours also have a lower protein quality. Finally, there are estimates indicating that the antioxidant content of white flours only accounts for 23 to 54 percent of the antioxidants present in whole meal flours (Halvorsen et al., 2002).

To summarize, the concept of *whole grains* includes both intact grain kernels and processed grain products, e.g. whole meal flours, where the ratio between the three grain components (endosperm, bran and germ) corresponds to the ratio found in intact grains (Nasjonalt råd for ernæring, 2011). In Norway, a food is classified as a whole grain product if it contains at least 50 percent whole grains of total dry matter content (Nasjonalt råd for ernæring, 2011; Opplysningskontoret for brød og korn, 2011b), meaning that whole grain products may contain up to 50 percent refined flour.

### 6.1.2 *Whole grains and health effects*

The practice of grinding grains has been known since palaeolithic times when the grains were crushed between stones. With the development of the mill, grains could be even more refined (Cordain et al., 2005). The resulting increase in the intake of white flours affected our health status in different ways. For the first time, deficiency diseases like beri-beri (lack of thiamine) and pellagra (lack of niacin) were reaching epidemic proportions (Cordain, 1999). These facts are indicating that grains primarily should be eaten in their original form. At the same time, it is important to emphasize that processing of grains results in an increased bioavailability of several of the nutrients present in them, e.g. vitamins, minerals and phytochemicals, which the

body cannot digest and absorb from intact grain kernels (Dewettinck et al., 2008; Liukkonen et al., 2003; Slavin et al., 2001a).

Several large epidemiological studies (e.g. Iowa Women's Health Study and Nurses' Health Study) are linking a high consumption of whole grains with a decreased risk of different chronic diseases (e.g. cardiovascular diseases and different cancers), as well as deaths attributed to their pathology (Jacobs, Andersen & Blomhoff, 2007; Liu et al., 1999; Liu et al., 2000). Despite the facts that nutrition research is a complex field of study, and a diet rich in whole grains often are a marker of a healthy lifestyle in general (e.g. higher in physical activity, fruit and vegetables, and lower in red meat and sodium) (Jacobs et al., 2007; Lang & Jebb, 2003; Liu et al., 1999), whole grains and its components (e.g. dietary fiber and different phytochemicals) do demonstrate a convincing relationship with prevention of the aforementioned diseases. A diet rich in dietary fiber is for example showing a *probable* correlation with a decreased risk of colorectal cancer and a *possible* correlation with a decreased risk of developing overweight and obesity (Nasjonalt råd for ernæring, 2011; WCRF/AICR, 2007). There has further been observed a *probable* association between consumption of whole grains and dietary fiber, and a reduced risk of cardiovascular diseases and type 2 diabetes (Nasjonalt råd for ernæring, 2011). It is difficult to explain all the exact components and mechanisms involved in these processes (Nasjonalt råd for ernæring, 2011), but some suggestions have been proposed.

### ***Dietary fiber***

During the 1970s, the British physicians Burkitt and Trowell (1977) were observing that African populations who were consuming large quantities of whole grains and other fiber-rich foods generally were free of many of the diseases present in the western world, e.g. obesity, cardiovascular diseases, type 2 diabetes and colon cancer (Burkitt & Trowell, 1977; Mälkki, 2004). This led to the formulation of the *dietary fiber hypothesis* saying that fiber-rich foods play a protective role in relation to different chronic diseases (Burkitt & Trowel, 1977). During the last couple of decades, Burkitt and Trowell's theory has been strengthened (Kendall, Esfahani & Jenkins, 2010).

Dietary fiber has received many definitions. One of them says that dietary fiber is "(...) *carbohydrate polymers with ten or more monomeric units, which are not hydrolysed by endogenous enzymes in the small intestine of human beings (...)*" (Codex Alimentarius

Commission, 2008). Furthermore, dietary fiber has broadly been divided into *soluble* (or viscous) fibers which bind water, and *insoluble* fibers which do not. Among the *soluble fibers* we find pectins, hydrocolloids (e.g.  $\beta$ -glucans, guar gums and mucilages) and some types of hemicellulose, while the *insoluble fibers* are made up of cellulose and the remaining fractions of hemicellulose (Nordic Council of Ministers, 2004). The different types of dietary fiber mentioned here are collectively termed *non-starch polysaccharides* (NSP). Three other groups of dietary fiber are *resistant oligosaccharides*, *resistant starch* (RS) and *lignins* (Nordic Council of Ministers, 2004). This classification is summarized in table 6-2.

**Table 6-2** Classifications of dietary fiber

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|  |
|--|
| <b>Non-starch polysaccharides</b>                        |
| - <i>Soluble</i> (pectins, hydrocolloids, hemicellulose) |
| - <i>Insoluble</i> (cellulose, hemicellulose)            |
| <b>Resistant oligosaccharides</b>                        |
| <b>Resistant starch</b>                                  |
| <b>Lignins</b>   |

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Source: Nordic Council of Ministers, 2004

It is well-known that fiber-rich foods are bulky and filling. By leading to an increased and prolonged satiety, as well as a decreased food and energy intake, this characteristic may play an important role in weight-management (Kendall et al., 2010; Mälkki, 2004). However, it is the resistance of dietary fiber to hydrolysis in the small intestine that may be the main cause to the many health benefits observed from consuming whole grains (Dewettinck et al., 2008; Slavin et al., 2001b). Soluble and insoluble fibers are to some degree different in their physiological effects and these differences will now shortly be elaborated.

Due to their water-binding capacity, *soluble fibers* are able to bind and excrete bile acids with the faeces (Jones, 2006; Kendall et al., 2010; Slavin et al., 2001b). To compensate for this loss, the liver has to produce more bile on the cost of cholesterol. This results in an up-regulation of the low-density lipoprotein (LDL) receptors placed on the liver's surface and hence an increased uptake of circulating LDL cholesterol. Since high levels of LDL is recognised as a risk factor in the etiology of cardiovascular diseases, this lowering effect may play a potential disease-preventing role (Brown, Rosner, Willett & Sacks, 1999; Mälkki, 2004). An increased excretion of bile may also decrease the ability of primary bile acids to be metabolized into secondary bile acids known for their stimulatory effect on abnormal cell



proliferation and mutation formation (Jones, 2006; Slavin et al., 2001b). This is believed to be of importance in relation to the cancer preventive effects of whole grains.

Another cancer preventive factor is the fibers, both *soluble and insoluble*, ability to increase the weight, volume and moisture-content of the faeces. This results in a reduced intestinal transit time. When the transit time is reduced, faecal mutagens (e.g. from the food) have less opportunity to interact with the intestinal epithelium, thereby reducing the risk of damages to the intestinal mucosa (Cook & Sellin, 1998; Jones, 2006).

When dietary fiber reaches the colon, the fiber fractions (mainly the *soluble*) become substrates for anaerobic fermentation by the colonic microflora (Andoh, Tsujikawa & Fujiyama, 2003; Crittenden et al., 2002; Park & Floch, 2007). As the fermentation progresses, so-called short-chained fatty acids (SCFAs) (e.g. acetate, butyrate and propionate) and gases (notably hydrogen and methane), are formed. SCFAs play an important role in the maintenance of a healthy gut environment, for example by being the preferred fuel for the colonic epithelial cells, and by stimulating their growth and differentiation. The SCFAs are also, by lowering the pH in the intestinal lumen, inhibiting the conversion of the already mentioned primary bile acids to carcinogenic secondary bile acids (Cook & Sellin, 1998; Crittenden et al., 2002; Slavin et al., 2001b). Together, these effects may be part of the explanation for the observed link between a frequent whole grain consumption and a decreased risk of colorectal cancer (Andoh et al., 2003; Park & Floch, 2007). Additionally, propionate is observed to exert important cholesterol-lowering effects. In the same way as statins, the SCFA appears to influence an enzyme that controls the cholesterol-production in the liver (Cook & Sellin, 1998; Jones, 2006).

One of the attributes of whole grains that may have received most attention the last decade is, however, its effect on blood sugar and insulin responses after consumption. Compared with refined grains, whole grains lead to a slower and lower rise in both postprandial blood glucose and insulin levels (Kendall et al., 2010). GI is a relevant measure in this context as it gives us an estimate of a foods blood glucose rising potential two hours after consuming 50 g carbohydrates from the given food item. A high GI leads to a faster and higher peak in the blood glucose response compared with a low GI. While refined grains, e.g. white flour, have a relatively high GI (defined as values above 70), whole grains are classified as low-GI foods (defined as values below 55) (Aisbitt, Caswell & Lunn, 2008; Foster-Powell, Holt & Brand-Miller, 2002). This can be illustrated with table 6-3.

**Table 6-3** Glycemic index of refined versus whole grain products

| <b>Food item</b>  | <b>Glycemic index<br/>Glucose = 100</b> |
|---|---|
| White-wheat-flour bread<br>(100 % white flour)                              | 70                                      |
| Coarse wheat-kernel bread<br>(80 % whole grains,<br>20 % white wheat flour) | 52                                      |

Source: Foster-Powell et al., 2002

One of the explanations for such differences in GI response is that *soluble* fibers lead to a slower digestion by prolonging the time amino acids and fat are in contact with intestinal receptors stimulating the secretion of different appetite controlling hormones. One example is cholecystokinin - a peptide hormone which is proposed to delay stomach emptying and thereby curb the glycemic response following a meal (Mälkki, 2004).

Regardless of the mechanisms behind its effect, a stable blood sugar may be important for several reasons. Among others, there is observed a correlation between an improved blood glucose control and increased insulin sensitivity. This again results in a more efficient transportation of glucose into the cells and a limited excretion of insulin from the pancreas<sup>19</sup>. In particular, this is beneficial for people with - or at risk of developing – diabetes type 2 (Kendall et al., 2010), but also for people in general (Mälkki, 2004). Hyperinsulinemia, often observed together with hyperglycaemia, has for example been demonstrated to stimulate the lipogenesis where excessive glucose are converted and stored as fat. Additionally, insulin is known to activate a key enzyme<sup>20</sup> in the process of synthesizing cholesterol. Together, these two processes may lead to a higher share of free fatty acids and LDL cholesterol in plasma – both well-known risk factors in relation to cardiovascular diseases (Cordain, 2011; Kendall et al., 2010; Mälkki, 2004).

In this way, dietary fiber works on several levels in the protectiveness of whole grains (Kendall et al., 2010). However, studies are indicating that whole grains are more efficient in lowering blood glucose rises compared to fiber-rich bran alone. This indicates that it might be the “whole grain package” that is effective, meaning that there are other components in whole grains than dietary fiber that might be associated with the abovementioned health benefits

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<sup>19</sup> Phenolic compounds – to be presented later – have also been observed to exert such effects (Kendall et al., 2010).

<sup>20</sup> Hydroxymethylglutaryl-CoA reductase (Mälkki, 2004).

(Slavin et al., 2001a; Slavin et al., 2001b). Eventually, these compounds may work with dietary fiber in a synergistically acting manner.

### *Phytochemicals*

Despite little attention compared to that paid to fruit and vegetables, whole grains are an important dietary source of phytochemicals – partly because of our relatively high consumption of grain-based foods (Adom & Liu, 2002; Blomhoff, 2005). Phytochemicals are a group of chemical compounds generally known for their disease-preventing properties. The mechanisms are not completely understood, but antioxidant-action and hormone-mediating effects are among the suggestions. In the case of phytochemicals present in whole grains, different antioxidants, phytosterols and phenolic compounds like lignans are especially important to take into consideration (Andreasen, Kroon, Williamson & Garcia-Conesa, 2001; Piironen, Toivo & Lampi, 2002; Slavin et al., 2001b).

### *Antioxidants*

Despite the uncertainties associated with antioxidants<sup>21</sup> when it comes to e.g. bioavailability and metabolism, there are indications that antioxidants possess a potential in reducing oxidative stress<sup>22</sup> and the risk chronic degenerative diseases likely deriving from this, e.g. inflammatory diseases, ischemic diseases, cancers and neurological diseases (Blomhoff, 2005).

In the case of whole grains, there are especially tocotrienols, selenium and the “anti-nutrient” phytate that have been regarded to exert antioxidant functions. While *selenium* is a co-factor for glutathione peroxidase – an enzyme involved in the protection of cells from oxidative damages (e.g. lipid peroxidation) (Blomhoff, 2007; Jones, 2006; Slavin et al., 2001b), *tocotrienols*, which are a precursor of vitamin E, inhibit cell proliferation and the formation of carcinogens (Jones, 2006; Slavin et al., 2001b). Despite the fact that *phytate* is considered an anti-nutritional component due to its metal-chelating property, it may also, due to this feature, function as a cancer-preventing agent (Slavin et al, 2001b). By chelating metal-ions, e.g. iron, phytate inhibits their ability to catalyze redox-reactions that stimulate the formation of free radicals. Free radicals are known to react with proteins, lipids and DNA in the body, and

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<sup>21</sup> An antioxidant is defined as: “a redox active compound that limits oxidative stress by reacting nonenzymatically with a reactive oxidant” (Blomhoff, 2005).

<sup>22</sup> Oxidative stress is defined as: “a condition that is characterized by the accumulation of nonenzymatic oxidative damage to molecules that threatening the normal function of the cell or the organism” (Blomhoff, 2005).

thereby cause cell injury or cell death (Kumar, Sinha, Makkar & Becker, 2010). This will be outlined further in chapter 6.6.

#### *Plant sterols*

Another type of phytochemicals is plant sterols. Together with oils and margarines, whole grains are recognized as a significant source of this group of phytosterols (Piironen et al., 2002). Among the plant sterols identified in grains,  $\beta$ -sitosterol, campesterol and sitostanol are among the major types. Plant sterols are mainly located in the germ and have several times been demonstrated to lower both total and LDL cholesterol by interfering with the absorption of cholesterol in the intestine. They have also been observed to reduce the risk of developing colon cancer (Jones, 2006; Piironen et al., 2002).

#### *Lignans*

Finally, we have lignans which are classified as phenolic compounds and one of two major classes<sup>23</sup> of phytoestrogens. In the colon, lignans are converted by the bacterial flora to mammalian lignans, mainly *enterolactone* and *enterodiols* (Mälkki, 2004). These compounds structurally resemble the human sex hormone estrogen, and may thus interact with hormone receptors and exercise estrogenic or anti-estrogenic effects. This is believed to have a beneficial effect on different hormonally mediated conditions like osteoporosis and cancer, e.g. in the breasts, ovaries and prostate (Adlercreutz, 2007; Cornwell, Cohick & Raskin, 2004; Slavin et al., 2001b). Furthermore, it has been observed strong negative correlations between high plasma levels of enterolactone and the risk of acute coronary events and all-cause death (Mälkki, 2004).

Various studies indicate that the main percentage of whole grain phytochemicals is bound to the insoluble fraction of the bran (Adom & Liu, 2002; Andreasen et al., 2001). Although certain studies indicate that some phytochemicals are released in the upper small intestine (Andreasen et al., 2001), it is claimed that colonic fermentation and subsequent release is the most likely pathway. This means that phytochemicals present in whole grains mainly are exerting their protective effects locally in the colon, which again may be part of the explanation for whole grains beneficial effects on colorectal cancer (Adom & Liu, 2002; Andreasen et al., 2001; Mälkki, 2004).

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<sup>23</sup> The other is isoflavanoids (Adlercreutz, 2007).

## ***Fat***

Therefore; both dietary fiber and phytochemicals may explain the health benefits observed from consuming a diet rich in whole grains. Another fact is that grains in general are low in fat and mainly composed by unsaturated fatty acids in the form of MUFAs (e.g. oleic acid, C18:1n-9) and PUFAs (e.g. LA, C18:2n-6) (Dewettinck et al., 2008; Cordain, 1999). The fact that grains are low in n-3 fatty acids (e.g.  $\alpha$ -linoleic acid (ALA), C18:3n-3) is, however, a shortcoming (Cordain, 1999).

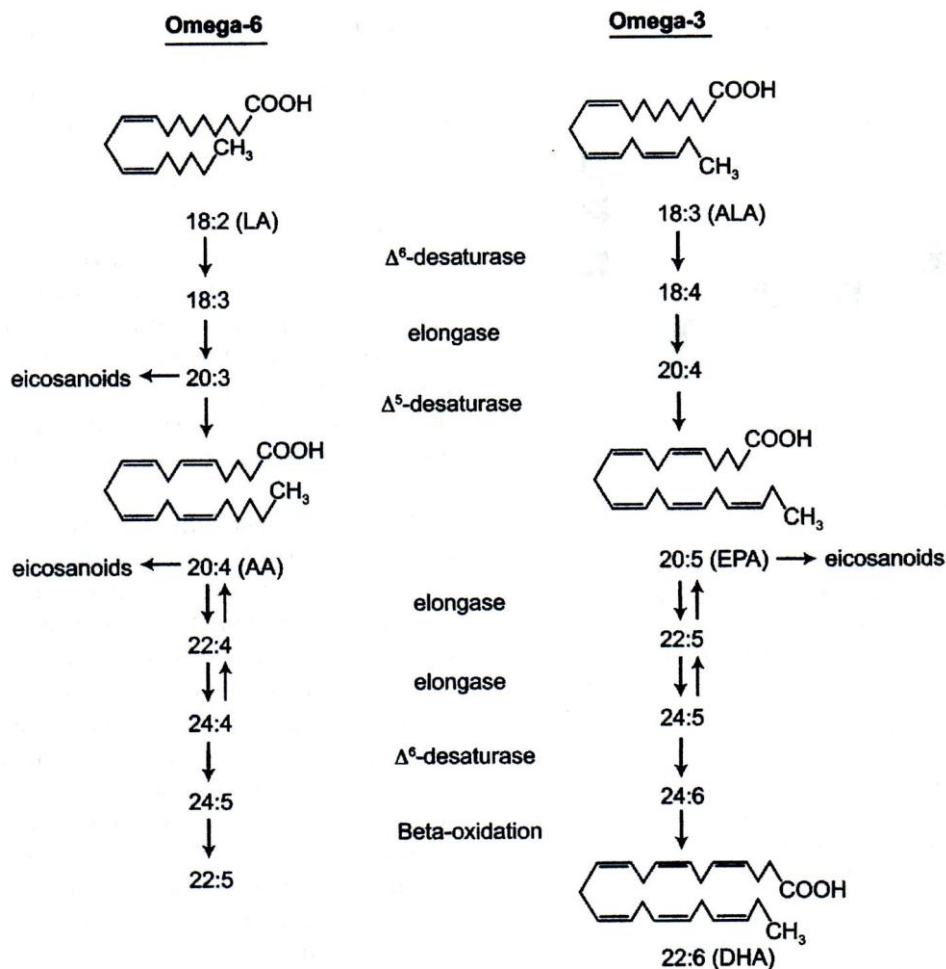
In addition to being structural fats in different membrane tissues in our body, LA and ALA are essential fatty acids that function as precursors of the longer-chained metabolites arachidonic acid (AA, C20:4n-6), eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3) which again synthesizes pro- and anti-inflammatory substances (so-called eicosanoids<sup>24</sup>), respectively (Arterburn, Hall & Oken, 2006; Barcelò-Coblijn & Murphy, 2009). There exist strong epidemiological evidences that these fatty acids, especially the long-chained n-3's, exert several beneficial effects on our health, e.g. by reducing the risk<sup>25</sup> of developing coronary heart diseases, arthritis, inflammatory and autoimmune diseases, as well as different cancers (e.g. in the prostate, lungs, colon and breasts) (Arterburn et al., 2006; Harris, Miller, Tighe, Davidson & Schaefer, 2008; Nasjonalt råd for ernæring, 2011; WHO, 2003).

The already mentioned conversion of LA and ALA to AA, EPA and DHA is a multi-step process which requires several enzymes (illustrated in figure 6-2).

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<sup>24</sup> Four “families”; prostaglandins, thromboxanes, prostacyclins and leukotrienes (Harris et al., 2008).

<sup>25</sup> Several proposed mechanisms: e.g. lipid lowering (especially serum triglycerides) and anti-inflammatory effects, improvements in vascular reactivity, as well as anti-arrhythmic and antithrombotic properties (Harris, et al., 2008).



**Figure 6-2** The multi-step process of converting n-3 and n-6 fatty acids (Harris et al., 2008)

Due to their share of enzymes, there is a competitive nature between LA and ALA in this context, with ALA having a higher affinity for the initial enzyme than LA (Harris et al., 2008). However, due to a high consumption of grains, domestic meat and vegetable oils<sup>26</sup>, and a rather low intake of oily fish and n-3 fatty acids, the western diet is today mainly dominated by n-6 fatty acids. It is estimated that the n-6 to n-3 ratio – with an estimated optimal ratio of approximately 2:1<sup>27</sup> – today is equivalent to 10:1 (Cordain et al., 2005; Cordain, 2011; Kris-Etherton et al., 2000). One of the consequences is that n-6 fatty acids are converted at the expense of n-3 fatty acids, which again results in a higher production of pro-inflammatory eicosanoids and a reduced accumulation of n-3 fatty acids in plasma (Arterburn et al., 2006; Barceló-Coblijn & Murphy, 2009; Burdge & Calder, 2006; Harris et al., 2008).

<sup>26</sup> Soybean and sunflower oil have n-6 to n-3 ratios equivalent to 7:1 and 140:1, respectively (Jahreis & Schäfer, 2011).

<sup>27</sup> In the official dietary guidelines, n-6 and n-3 are recommended to account for at least 3 and 0.5 of the total energy percent, respectively (Sosial- og helsedirektoratet, 2005).

An “ideal” bread should - as previously mentioned - strive to comply with the estimated optimal n-6 to n-3 ratio (2:1). The facts that some types of grains contain higher levels of n-3 than others (Cordain, 1999), and that several seeds and nuts are rich sources of these fatty acids (Li & Hu, 2011), are important conditions to take into consideration in the development of the recipe. This is the focus of the next two chapters and will therefore not be discussed further in this section.

### ***Summary and conclusion***

Despite beneficial components, whole grains do also have some dietary shortcomings, i.e. low levels of n-3, different vitamins and minerals (e.g. vitamin A, B<sub>12</sub>, C and D and calcium) and a reduced bioavailability of different minerals due to high concentrations of anti-nutritional components (e.g. phytate, lectins and tannins) (Cordain, 1999). Measures to reduce the levels of phytate in breads will be presented later.

This brief review is still underlining that whole grains and its components may exert several beneficial effects on our health, and yet there are components that are not identified and fully understood (Nasjonalt råd for ernæring, 2011). It is clear that an “ideal” bread should contain as much whole grains as possible. At the same time, it is well-known that whole grains are affecting the sensory characteristics of breads. This will shortly be discussed in the following section.

### ***6.1.3 Whole grains and sensory characteristics of breads***

It is a challenge to develop sensory appealing whole grain breads (Bakke & Vickers, 2007; Luikkonen et al., 2003). Generally, fiber-supplemented doughs have a higher level of water absorption<sup>28</sup> and tenacity, and a lower extensibility and gas retention compared to doughs based on refined flours. In turn, this leads to breads with pronounced decreases in quality and sensoric parameters (e.g. loaf volume, crumb and crust texture) compared to white breads (Bakke & Vickers, 2007; Gómez et al., 2003). Bitterness has also been identified as an important sensory barrier to the acceptance of whole grain breads. In some studies, the bitter taste is linked to the outer bran fraction, while others emphasize the germ, and lipid oxidation herein, to be the most likely cause (Bakke & Vickers, 2007).

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<sup>28</sup> Due to the hydroxyl groups present in the fiber fractions that allow more water to be hydrogen-bonded (Gómez et al., 2003).

To meet the whole grain criteria of the *Keyhole*, the bread has to contain at least 25 percent whole grains - meaning 25 percent intact kernels, whole grain flours and/or bran (Forskrift om frivillig merking med Nøkkehullet, 2009). However, 25 percent is quite a small share and to be classified as a whole grain bread it must contain more than 50 percent whole grains (Nasjonalt råd for ernæring, 2011). As previously mentioned, the “ideal” bread should be classified as a whole grain bread and the more whole grains the better. Still, good sensory qualities are a key priority, meaning that the bread also should be as sensory attractive as possible.

As earlier discussed, the bread industry has already identified ways to increase the consumer acceptability of whole grain breads. By adding wheat gluten and dough conditioners they counteract the deleterious effects, especially the volume reduction, of fiber-supplementation (Bakke & Vickers, 2007; Gómez et al., 2003). Added sugar may further suppress the abovementioned bitterness and provide the breads with a sweet taste (Bakke & Vickers, 2007). Sugar or additives will, however, not be alternatives in the case of the “ideal” bread. Instead, measures related to the ingredients and baking methods will be applied. For example, it is reported that fermentation methods affect the texture of breads in different ways (Katina et al., 2005). Seeds and nuts may furthermore be used to modify the bread’s taste properties, while relatively high amounts of water can be added to affect the bread’s texture (e.g. by making it seem less dry and compact). To give the bread volume and softness, some whole meal flours may, however, have to be replaced with refined flours. Additionally, it has been reported that finely grounded whole meal flours result in breads with larger loaf volumes compared with whole meal flours that are coarsely grounded (Opplysningskontoret for brød og korn, 2012b). From a health perspective, it has on the other hand been observed that coarse wheat bran delays gastric emptying and glycemc response to a larger extent than finely grounded wheat bran (Slavin, Martini, Jacobs & Marquart, 1999). Already here, we are observing the conflicts arising between the sensory and health-related aspects of an “ideal bread”.

All the aspects mentioned in this section will be outlined further. Firstly, the different types of grains and flours that can be included in the recipe will be presented.



## 6.2 Various grains and flours

Among various types of grains, wheat is – both in a Norwegian setting and globally – the grain most commonly used for bread baking. Mostly, this is due to its good baking quality. However, other grains, such as barley, oat and rye are also frequently applied – although usually in combination with wheat (Dhingra & Jood, 2004). Additionally, we have the less common flour varieties like the ancient predecessors of wheat (spelt, einkorn and emmer), as well as sorghum and maize that might be used more frequently in other parts of the world (Meyer, 2009).

With respect to the practical aspects of the “ideal” bread, easily accessible ingredients should be prioritized. Flours from einkorn, emmer, sorghum and maize might be difficult to obtain in regular grocery shops. They are therefore not included in this review. Instead, focus is placed on wheat, spelt, barley, oat and rye which are easily accessible in most Norwegian food shops. Each of them will now shortly be presented.

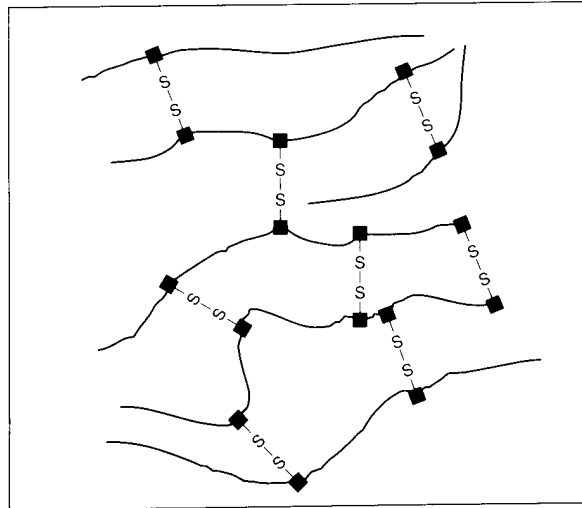
### 6.2.1 Wheat

Wheat (*Triticum aestivum* L.) is by far the grain most commonly used and consumed in the Nordic countries - third most in a globally setting (after maize and rice, respectively) (Bjørnstad, 2010; Dewettinck et al., 2008). Much of this popularity is due to the gluten-forming potential of wheat flours – an attribute which gives wheat doughs superior baking properties (Meyer, 2009; Whitley, 2009).

Shortly explained, gluten is a protein complex composed by the proteins *glutenin* and *gliadin* which are present in the wheat grains endosperm<sup>29</sup> (Meyer, 2009). When wheat flour is mixed with water and kneaded, glutenin and gliadin are absorbing the water (up to two to three times their own weight) and disulfid bonds are formed between them. Eventually, this results in gluten strands forming a three-dimensional network as illustrated in figure 6-3 (Ledsaak & Eben, 2010; Meyer, 2009; Whitley, 2009).

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<sup>29</sup> Both barley and rye contain glutenin and gliadin. However, they are not capable of forming the gluten complex in the same way as wheat, and do therefore not possess equal baking qualities (Ledsaak & Eben, 2010).



**Figure 6-3** Disulfid-bonds in a gluten network

As CO<sub>2</sub> is generated in the dough during the fermentation (as outlined in chapter 6.6), the gluten network is stretched, hence entrapping the gas in the dough. In this way, gluten is functioning as a skeleton enabling the dough to rise. When the dough is put in the oven, the heat makes the dough volume increase further due to gas-expansion. After a while, water starts to evaporate from the dough's surface and the crust is formed. The crust formation permits no further dough expansion, but results in a voluminous bread with a fine crumb texture (Ledsaak & Eben, 2010; Meyer, 2009; Ulen, 1991; Whitley, 2009).

Table 6-4 presents the nutritional composition of four of the five grains<sup>30</sup> outlined in this review. As the table demonstrates, wheat has the highest protein content with 13 g proteins per 100 g wholemeal flour. However, despite a beneficial protein composition when it comes to baking properties, the wheat grains protein quality is rather inferior. Compared to the other grains that are to be presented, wheat is for example relatively low in the essential amino acids lysine and methionine (Chavan & Kadam, 1993; Cordain, 1999). In the case of fat composition, wheat do generally have a high n-6 to n-3 ratio (15.6). On the contrary, wheat scores high – and even highest - when it comes to the content of different micronutrients, e.g. thiamine, niacine, folate, iron, potassium, zinc and selenium (table 6-4).

Wheat products that can be used in the recipe include: white wheat flour, wholemeal wheat flour (finely or coarsely grounded), intact wheat kernels, wheat germ and wheat bran (kruskakli) (Opplysningskontoret for brød og korn, 2012c).

<sup>30</sup> Due to lack of documentation, spelt is so far not included in the food composition table (Matportalen, 2011a).

**Table 6-4** Nutritional composition\* of wheat, barley, oat and rye - per 100 g wholemeal flour and oat flakes\*\*

|                                 | <b>Wheat</b> | <b>Barley</b> | <b>Oat</b> | <b>Rye</b> |
|---------------------------------|--------------|---------------|------------|------------|
| <b>Energy (kJ)</b>              | 1330         | 1279          | 1638       | 1347       |
| <b>Carbohydrates (g)</b>        | 54.4         | 60.6          | 63.1       | 57.5       |
| - <i>Starch</i>                 | 52.4         | 59.7          | 62.1       | 55.5       |
| - <i>Mono- and disaccarides</i> | 2.0          | 0.9           | 1.0        | 2.0        |
| - <i>Dietary fiber</i>          | 12.0         | 7.6           | 10.6       | 14.8       |
| <b>Proteins (g)</b>             | 13.0         | 8.6           | 11.4       | 9.6        |
| <b>Fat (g)</b>                  | 2.4          | 1.1           | 7.8        | 2.4        |
| - <i>Saturated</i>              | 0.3          | 0.2           | 1.1        | 0.3        |
| - <i>Monounsaturated</i>        | 0.4          | 0.1           | 2.7        | 0.2        |
| - <i>Polyunsaturated</i>        | 1.1          | 0.5           | 2.5        | 1.2        |
| - n-6 (C18:2)***                | 1.09         | 0.70          | 2.42       | 0.66       |
| - n-3 (C18:3)***                | 0.07         | 0.08          | 0.11       | 0.11       |
| - n-6:n-3                       | 15.6         | 8.75          | 22         | 6          |
| <b>Vitamin A</b>                |              |               |            |            |
| - <i>B-carotene (µg)</i>        | 3            | 0             | 0          | 2          |
| <b>Vitamin E</b>                |              |               |            |            |
| - <i>α-tocopherol (mg)</i>      | 0.9          | 0.7           | 0.9        | 1.0        |
| <b>Vitamin B</b>                |              |               |            |            |
| - <i>Thiamine (B1) (mg)</i>     | 0.5          | 0.3           | 0.4        | 0.5        |
| - <i>Riboflavine (B2) (mg)</i>  | 0.08         | 0.1           | 0.08       | 0.2        |
| - <i>Niacine (mg)</i>           | 6.4          | 4.5           | 0.7        | 0.7        |
| - <i>Pyridoxine (B6) (mg)</i>   | 0.2          | 0.3           | 0.2        | 0.2        |
| - <i>Folate (µg)</i>            | 40           | 20            | 32         | 31         |
| <b>Calcium (mg)</b>             | 31           | 28            | 40         | 24         |
| <b>Iron (mg)</b>                | 4.1          | 2.2           | 3.7        | 2.8        |
| <b>Sodium (mg)</b>              | 2            | 2             | 1          | 1          |
| <b>Potassium (mg)</b>           | 414          | 315           | 382        | 370        |
| <b>Magnesium (mg)</b>           | 116          | 60            | 118        | 79         |
| <b>Zinc (mg)</b>                | 2.7          | 1.5           | 2.5        | 2.2        |
| <b>Selenium (µg)</b>            | 10           | 3             | 1          | 6          |
| <b>Copper (mg)</b>              | 0.4          | 0.6           | 0.4        | 0.3        |
| <b>Phosphorus (mg)</b>          | 370          | 250           | 516        | 325        |

\* A selection of macro and micronutrients is chosen

\*\* Matportalen (2012a)

\*\*\* USDA (2012)

### 6.2.2 Spelt

Spelt (*Triticum spelta* L.) has during the last decade gone from being a niche product to become a grain easily accessible in most grocery stores (Bugge et al., 2008; Sæland, 2006). As a precursor of the modern wheat grain, spelt possesses several of the wheat's properties, e.g. a high level of the gluten-forming proteins, and thereby relatively good baking properties.

However, experiences indicate that the gluten structure of spelt is somewhat weaker than the modern wheat gluten (Meyer, 2009; Whitley, 2009). While some suggest that this is caused by a significant higher gliadin/glutenin<sup>31</sup> ratio in spelt (Kohajdová & Karovičová, 2008), others are emphasizing the intensive breeding and fertilization of modern wheat to produce higher levels of gluten proteins (Whitley, 2009). One of the consequences is, however, that spelt flour may behave slightly different from modern wheat flour in the baking process, e.g. by absorbing less water. If spelt is used to replace wheat flour in a recipe, it results in a stickier and less elastic dough, as well as a bread with a decreased loaf volume. A rule of thumb when baking with spelt is therefore to reduce the amount of water, eventually increase the amount of flour (Meyer, 2009; Sæland, 2006).

Spelt has been found to possess several beneficial effects. For example, it should be emphasized that spelt – compared to modern wheat – supplies the bread with a milder and nuttier taste (Kohajdová & Karovičová, 2008; Meyer, 2009; Sæland, 2006). When it comes to its nutritional composition, it has several times been reported that spelt – compared with modern wheat – contains a higher level of essential amino acids (e.g. lysine), MUFAs (up to twice as much), different vitamins (e.g. niacin and  $\beta$ -carotene) and minerals (e.g. iron, zinc, copper, magnesium, potassium and phosphorus), as well as a lower level of phytate. On the contrary, modern wheat has been found to be richer in the B-vitamins thiamine and riboflavin (Kohajdová & Karovičová, 2008; Whitley, 2009).

Much of the popularity linked to spelt can also be attributed to its many claimed health effects. Among them; a more functional digestibility and a lower incidence of allergic reactions following consumption compared to the effects following consumption of modern wheat (Whitley, 2009). Due to insufficient amounts of evidence, it is, however, too early to draw conclusions when it comes to the nutritional and health-related effects of spelt consumption (Matportalen, 2011a). What we do know is that spelt is a low-input plant that requires marginal areas of cultivation. Furthermore, the cultivation is carried out without the use of pesticides (Kohajdová & Karovičová, 2008). In contrast to modern wheat, spelt has remained unchanged since ancient times, and while the modern wheat grain is designed to provide as high yields as possible (as cheaply as possible), spelt results in smaller yields per area<sup>32</sup> (Opplysningskontoret for brød og korn, 2012d; Whitley, 2009). One of the

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<sup>31</sup> Which in the wheat grain is approximately 1:1 (Chavan & Kadam, 1993).

<sup>32</sup> Approximately three to four times less grains per acre compared to modern wheat (Opplysningskontoret for brød og korn, 2012d).

consequences is that spelt products are in the highest price range among the grains presented in this section (see table 6-5).

**Table 6-5** Flour prices\*

| <b>Flours**</b> | <b>Price (NOK)<br/>per kg</b> |
|-----------------|-------------------------------|
| Wheat           | 13,-                          |
| Spelt           | 35,-                          |
| Barley          | 11,-                          |
| Oat flakes      | 11,-                          |
| Rye             | 13,-                          |

\* The prices are collected at a Kiwi shop in May 2012

\*\* Coarse variants

Spelt products that can be used in the recipe include: white spelt flour, wholemeal spelt, intact spelt kernels, spelt bran and spelt flakes (Opplysningskontoret for brød og korn, 2012d). It should be noticed that some types of spelt flours are mixed with regular wheat flour (Sæland, 2006).

### 6.2.3 Barley

Barley (*Hordeum vulgare L.*) is the oldest and most extensively cultivated grain in the Nordic region. It has been grown here for more than 10 000 years and has therefore constituted an important part of the Norwegian diet in former years. However, since modern wheat is considered to provide products of higher sensory quality, barley is currently mainly used as feed for animals or in brewing (Baik & Ullrich, 2008; Bere & Brug, 2008; Bjørnstad, 2010; Statens landbruksforvaltning, 2011a). At the same time, barley consumption has during the recent years been associated with several health benefits. This indicates that barley may hold great potential in relation to increase the nutritional value of our diet (Baik & Ullrich, 2008; Brennan & Cleary, 2005).

As table 6-4 emphasizes, barley is not – compared to the other grains - especially abundant in any of the nutrients presented. On the other hand, barley is identified as an especially rich source of soluble fibers - particularly  $\beta$ -glucans which are found to constitute approximately 5-11 percent of the grain (versus 1 percent in wheat) (Brennan & Cleary, 2005). As already mentioned, soluble fibers are documented to exert several health benefits, e.g. in relation to

lower both blood cholesterol, glucose and insulin levels (Baik & Ullrich, 2008). Furthermore, barley contains antioxidants in a much greater amount (1.0 mmol/100g) than found in both oat (0.59 mmol/100g), rye (0.47 mmol/100g) and wheat (0.33 mmol/100g) (Carlsen et al., 2010; Halvorsen et al., 2002). As shown in table 6-4, barley is also quite low in fat and possesses the second lowest n-6 to n-3 ratio (8.75) amongst this selection of grains.

However, despite its beneficial nutritional composition, barley is considered as demanding in a baking context. Dhingra & Jood (2004) examined the effects of incorporating barley into wheat breads at four different substitution levels (5, 10, 15 and 20 percent). The results indicated that barley addition led to linearly increases and decreases in the loaf weight and loaf volume, respectively. These effects can mainly be explained by the facts that barley (due to its high concentration of soluble fibers) increases the dough's water retention, while it decreases the dough's retention of gas (due to its lack of gluten-forming potential). As a consequence, the Danish chef and author of the bread baking book *Meyers bageri* (Meyer, 2009), Claus Meyer, is emphasizing that barley should not constitute more than 20 percent of the total amount of flour in a wheat bread. By keeping this level low, it is possible to retain the breads sensory acceptability (e.g. in relation to crumb texture and loaf volume) (Meyer, 2009). Due to a higher level of water absorption, more water should also be added when barley is used (Dhingra & Jood, 2004; Meyer, 2009).

Barley products that can be used in the recipe include: barley flour and barley grains (Opplýsningskontoret for brød og korn, 2012e).

#### 6.2.4 Oat

From being treated as a weed, oat (*Avena sativa L.*) is today our third most cultivated grain, and also considered by many as the healthiest (Bjørnstad, 2010; Frølich, 2007; Statens landbruksforvaltning, 2011b). However, this is not reflected in the grain consumption statistics that estimate that only two percent of all domestically cultivated oat is used for human consumption. The rest is used as animal feed (Opplýsningskontoret for brød og korn, 2012f). Oat thrives in the Nordic climate. In fact, it is observed that oat cultivated in the Nordic countries contains significantly higher concentrations of different health-promoting nutrients compared with the concentrations present in oat cultivated in warmer climates (Bere & Brug, 2008; Meyer, 2009).

Oat contains several components which make it a healthy grain. As barley, oat is for example a valuable source of  $\beta$ -glucans (approximately 3-7 percent of the grain) and antioxidants (0.59 mmol/100g) (Brennan & Cleary, 2005; Halvorsen et al., 2002). Furthermore, oat is reported to have a favourable protein composition and is containing several essential amino acids (e.g. relatively high levels of lysine) (Cordain, 1999; Meyer, 2009). Oat is on the other hand high in energy and is actually containing seven times as much fat as barley, and three times as much fat as rye and wheat (table 6-4). The main proportion of this fat consists of healthy MUFAs (e.g. oleic acid) and PUFAs. However, oat does also have the highest n-6 to n-3 ratio (22) among the grains presented in this section (table 6-4). Additionally, oat is reported to contain more phytate than both wheat, barley and rye<sup>33</sup> (Kumar et al., 2010), and is also the only grain that does not contain phytate-degrading enzymes (Ulen, 1991).

Due to lack of gluten-forming proteins, oat does not contribute to increase the breads loaf volume (Hjelme, 2004; Whitley, 2009). On the contrary, oat absorbs a lot of water (due to high levels of soluble fibers), and is therefore producing breads with high moisture-levels. The high fat content is further reported to have a softening effect on the crumb (Meyer, 2009; Whitley, 2009). Consequently, it has been emphasized that oat may be added in wheat doughs in a 1:1 ratio and still produce breads of high quality (Meyer, 2009).

Oat products that can be used in the recipe include: oat flakes, oat flour and oat bran (Opplýsningskontoret for brød og korn, 2012f).

### 6.2.5 Rye

As in the case of barley and oat, rye (*Secale cereale L.*) is well adapted to the Nordic climate (Bere & Brug, 2008). However, in contrast to the other Nordic countries, the Norwegian production and consumption of rye is relatively low (deMello et al., 2011; Sahlstrøm & Knutsen, 2010; Statens landbruksforvaltning, 2011a).

There have several times been established a link between frequent rye consumption and different beneficial health effects. In a Danish cohort study, where the consumption of Nordic food items (e.g. rye bread, berries, cabbages and fish) were related to all-cause mortality, whole grain rye bread was demonstrated to be the factor most consistently associated with

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<sup>33</sup> 8.4-12.1 mg/g versus 1.9-4.3 mg/g in rye and 3.2-7.3 mg/g in wheat. The levels in barley are not reported (Kumar et al., 2010).

lower mortality rates among men (Olsen et al., 2011). The fact that whole grain rye might possess a greater disease-preventing potential compared to the other types of whole grain cereals (the so-called “rye-factor”), has also been demonstrated in other studies. Some studies are for example proposing that rye might play an inhibitory role in the tumor development of prostate cancer (Bylund et al., 2003; Wikstrøm et al., 2005), while others have identified that consumption of rye – to a larger extent than wheat and oat - might have a lowering effect on the postprandial insulin-responses (the postprandial glucose response remains, however, unchanged). This effect is thought to play an important role in improving the endothelial dysfunctions and inflammations involved in the etiology of type 2 diabetes and cardiovascular diseases (deMello et al., 2011; Kallio et al., 2008).

There may be several factors involved in these disease-preventive effects. For example, rye is containing twice as much fiber as barley (table 6-4), e.g. in the form of soluble fibers (Whitley, 2009), as well as high concentrations of lignans (Bylund et al., 2003). When it comes to fat, and especially saturated fat and MUFAs, the lipid profile of rye is quite the same as that of wheat. On the other hand, rye is lower in n-6 and higher in n-3, and has the lowest n-6 to n-3 ratio (6) among the grains presented in this review (table 6-4) (Dewettinck et al., 2008; Eliasson & Larsson, 1993; Matportalen, 2012a). Furthermore, rye has been observed to exert a greater phytate-degrading activity than both wheat, barley and oat, respectively (Greiner & Konietzny, 2006).

However, rye does not only contain beneficial components. Cordain (1999) is especially emphasizing the grain’s high concentration of alkylresorcinols. This is phenolic lipids (van Dam & Hu, 2008) which in animal studies have been demonstrated to cause both red-cell blood hemolysis, permeability changes of the erythrocytes and liposomes, as well as hepatocyte and renal degradation. In vitro human studies have also indicated that alkylresorcinols may stimulate the formation of the pro-inflammatory component thromboxane (TXA<sub>2</sub>) (Cordain, 1999). On the other hand, there is implemented few in vivo human studies on alkylresorcinols, meaning that the effects of these compounds on human health are rather uncertain. In this context, it is also important to stress that alkylresorcinols also have been demonstrated to exert antimutagenic, as well as antioxidant activity (Cordain, 1999).

Rye contains both glutenin and gliadin, but instead of forming the gluten complex, rye flour is creating a water-film when mixed with water. This film may trap the CO<sub>2</sub> in the dough, but is



not as strong as the gluten network present in a wheat dough. Pure rye breads will therefore not rise as much as wheat breads (Ledsaak & Eben, 2010; Ulen, 1991; Whitley, 2009). Consequently, and as in the case of barley, Meyer (2009) recommends that rye only should account for 20 percent of a bread's total flour amount. In general, rye has a full-bodied flavour and a high content of water-absorbing fibers that make rye breads succulent and long-lasting (Chavan & Kadam, 1993; Opplysningskontoret for brød og korn, 2012g).

Rye products that can be used in the recipe include: white rye flour and whole grain rye flour (finely and coarsely grounded) (Opplysningskontoret for brød og korn, 2012g).

### *6.2.6 What to choose?*

Flours of high quality are one of the prerequisites for an "ideal" bread. But what defines a flour's qualities? It's baking properties and ability to produce large, airy and tasty breads, or its nutritional composition and health-related value? In this thesis, where the "ideal" bread is to be identified, both health-related and sensory qualities should be taken into account. However, sustainability and environmental considerations will also be in focus. Aspects related to health and nutrition will be presented first, followed by the environmental and sensory considerations, respectively.

#### ***Nutritional and health-related aspects***

Worldwide, there is estimated to be more than 80 000 edible plant species. 30 000 of them can be cultivated and about 7 000 have been cultivated. Today, fewer than 150 are commercially cultivated, and only 30 of them (including corn, rice and wheat) represent 95 percent of all plant food provided globally (Mouillè, Charrondièrè & Burlingame, 2010). In Norway, it has been calculated that wheat alone accounts for 20 percent of our total energy intake (Bere & Brug, 2008), and a little more than 85 percent of all grains consumed (Statens landbruksforvaltning, 2011b). These estimates indicate that our grain consumption is relatively unvaried, and that grains like barley, oat and rye can be considered under-utilized in the Norwegian diet.

The intrinsic health potential of local foods and ingredients has been emphasized by several investigators worldwide. One of the most well-known examples is Ancel Keys' observations from the Seven Countries Study where Southern Europeans living on a local diet mainly composed of ingredients from the Mediterranean area (e.g. olive oil, fruits, vegetables,

legumes, grains and fish), had a significantly lower risk of coronary death compared to people living in Northern Europe and the United States eating a western diet (Keys, 1980). In the aforementioned cohort study by Olsen et al. (2011), similar results, just in a Nordic context, were found. A high consumption of traditional Nordic food items (e.g. fish, cabbages, rye bread, oatmeal, apples, pears and root vegetables) correlated with significantly lower mortality rates among Danish men.

Drawing a conclusion from these studies, it would be that our global eating pattern to a larger extent should be tailored to the Nordic context. In the case of grains, this implicates a larger dietary inclusion of Nordic grains like barley, oat and rye, as well as a lower consumption of wheat (Bere & Brug, 2008). From a nutritional point of view, this will lead to higher intakes of several health-promoting substances that to a lower degree are present in wheat. Relevant examples in this context are essential amino acids (e.g. lysine), soluble fibers (e.g.  $\beta$ -glucans) and antioxidants (Baik & Ullrich, 2008; Bere & Brug, 2008). Barley, oat and rye are also higher in n-3 fatty acids, and barley and rye have more beneficial (i.e. lower) n-6 to n-3 ratios than wheat (as shown in table 6-4).

According to Park & Floch (2007), it has been observed that a combination of different types of dietary fiber (i.e. a mixture of insoluble and soluble fibers) exerts more optimal health effects compared to one type of fiber alone. Since barley and oat contain insoluble and soluble fibers in a ratio of 1:1, while insoluble fibers make up 90 percent of the wheat grain, it may seem like barley and oat also have a more beneficial fiber-composition (Park & Floch, 2007). In a study by Cavallero, Empilli, Brighenti & Stanca (2002), this was partly demonstrated. After consumption of wheat breads enriched with different levels of  $\beta$ -glucans (present in barley and oat), it was observed that the post-prandial blood glucose response decreased in a dose-dependent manner with increasing levels of substitution. These results may indicate that we are able to lower the bread's GI by replace some of the wheat with barley and/or oat (Brennan & Cleary, 2005).

Much of the controversy around the modern wheat grain is due to its cultivation practice. The intensive breeding of the grain to produce higher levels of the gluten-forming proteins (glutenin and gliadin) are for example suggested to come at the price of reductions in its nutritional quality. Despite limited research and knowledge about the health-related value of spelt, it is proposed that this ancient wheat grain has higher levels of different nutrients; e.g. twice as much iron and zinc as found in modern wheat (Whitley, 2009). Due to exceptional

high levels of glutenin and gliadin, modern wheat is furthermore suggested to be more inclined to provoke wheat allergy and celiac disease among people most susceptible to this (Whitley, 2009). From a health perspective, there are therefore arguments for choosing spelt at the expense of wheat.

### ***Sustainability and environmental aspects***

At the same time as a more frequent consumption of barley, oat and rye is emphasized as important for dietary diversity (Bere & Brug, 2008), it has been suggested that these grains also are essential in relation to sustain diversity in the agricultural sector. Due to high yields, wheat is considered as a cost-efficient and highly profitable grain. Globally, this has resulted in an agricultural specialization where wheat is cultivated at the expense of grains like barley, oat and rye. As well as contributing to declines in the number of crop varieties, as well as formation of wheat monocultures, this practice has been claimed to result in loss of agricultural biodiversity<sup>34</sup> (Jacobsen & Lien, 2007; Torjusen & Vittersø, 1998). Shortly explained, biodiversity is stressed as essential for the maintenance of a highly productive and adaptable agriculture, meaning that it also is one of the most important factors in relation to create a sustainable cultivation potential for future generations (FAO, 2008; Statens landbruksforvaltning, 2012).

According to Coff (2005), *self-sufficiency* is a crucial factor for obtaining diversity in the food cultivation sector. With this, Coff believes that our current and highly efficient food system, mainly based on import and export, is one of the main reasons for the observed decreases in agricultural biodiversity globally. In a self-sufficiency situation, Coff claims that a country would not have been “rewarded” if its production volume was greater than its consumption, meaning that the focus instead would be placed on a deliberate and diversified production practice.

In Norway, we are approximately 30-40 percent self-sufficient in grains (Helsedirektoratet, 2011). A closer look at crop statistics compiled by the Norwegian Agricultural Authority for 2010 discloses that 100 percent of all barley and oat used for human consumption was

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<sup>34</sup> Defined by Food and Agricultural Organization (FAO) as: "The variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries. It comprises the diversity of genetic resources (varieties, breeds) and species used for food, fodder, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators), and those in the wider environment that support agro-ecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agro-ecosystems" (FAO, 1999).

domestically produced (Statens landbruksforvaltning, 2011b). The corresponding share for wheat was only 36 percent, while domestically produced rye, due to a low total production, accounted for 46 percent (Statens landbruksforvaltning, 2011b). In this context, it is important to notice that in Norway, larger cultivation areas are used for barley, oat and rye in total, than for wheat (Statens landbruksforvaltning, 2011a). Despite the fact that this may reflect a generally varied cultivation practice, it should at the same time be emphasized that the main fraction of grains produced domestically (mainly barley and oat) is used as animal feed (Bere & Brug, 2008; Sahlstrøm & Knutsen, 2010).

One thing that becomes clear from these estimates is that a shift in the grain consumption pattern towards a higher dietary inclusion of barley and oat (at the expense of wheat), would have resulted in a greater level of grain self-sufficiency (i.e. a higher consumption of grains produced domestically). In addition to agricultural biodiversity, there are several other reasons why such a scenario would have been beneficial. Self-sufficiency is for example identified as an important contributor in the creation and maintenance of global food security. Globally, we are - through climate changes, degradation of natural resources, rises in raw material prices and not least population growth - experiencing significant pressure on the food resources (Meld. St. 9 (2011-2012), 2011). By 2050, it is estimated that the global food production will have to be increased by 70 percent to feed a population of nine billion people (FAO, 2009a). In this context, it is calculated that the annual cereal production will need to increase with almost 1 billion tons (FAO, 2009a). In such a situation, it appears important that every country should be able to provide for themselves as far as possible.

Another point is that local foods are important components in a sustainable diet. By eating foods that are produced domestically, we are for example reducing the greenhouse gas emissions related to food transport. This is mainly due to reduced transport distances (“food miles”) between the producers and the consumers (Bere & Brug, 2008; Fogelberg, 2008; Nymoen et al., 2009). To sum up, both barley and oat do therefore point out as environmentally beneficial grain alternatives for an “ideal” bread.

In the case of wheat versus spelt, no cultivation statistics on spelt was found during the literature searches. However, it is well-known that the old wheat varieties generally are portrayed as more environmentally friendly than modern wheat. This is mainly due to the fact that they are low-input plants and their cultivated is based upon organic principles (more about organic production in the next section) (Kohajdová & Karovičová, 2008). At the same

time, it is important to emphasize that spelt yields per area is much smaller than the yields arising from modern wheat (Whitley, 2009). This again, may not be compatible with the aim of an increased food production. All in all, more research is needed in this area.

### ***Sensory aspects***

Based on the two aspects presented so far, barley, oat and rye overall appear as the most optimal grain alternatives for an “ideal” bread. However, it is important not to forget the breads sensory qualities (e.g. its loaf volume). As already mentioned, a flour's baking properties largely depends on its ability to form gluten of high quality (Meyer, 2009). In this context, wheat, and to some extent spelt, are superior. As emphasized by Meyer (2009), a wheat bread should not contain more than 20 percent barley or rye, or more than 50 percent oat. If these limits are exceeded, it does among others result in significant decreases in the breads loaf volume. It is, however, important not to forget that sensory qualities also include aspects related to the bread's taste. In this context, both barley, oat and rye are considered as more tasteful than wheat (Hjelme, 2004; Meyer, 2009).

### ***Summing up***

A large percentage of the food we eat (e.g. bread and semi-finished food products) contains wheat. Some of the responsibility for this may be ascribed to the food industry which applies cheap wheat to produce food products of high sensory quality. One of the benefits related to bread baking is that we are able to choose what kind of grains (and ingredients in general) that is incorporated into the bread. As consumers, our choices are furthermore affecting what kind of grains that is produced and distributed (Nymoene et al., 2009).

In the case of the “ideal” bread, it is difficult to rank some of the grains presented in this section as better than the others. Basically, they are all quite similar. At the same time, they have their own positive qualities, either in relation to health and environmental sustainability, or in relation to sensory properties. However, to draw some conclusions; due to the fact that wheat consist an important component of the diet of most Norwegians, it is reasonable to believe that some expectations are to be met when it comes to e.g. sensory attributes of breads. Put in other words, wheat should make up a relatively high percentage of the flour amount of the “ideal” bread. At the same time, it will be pursued that barley, oat and/or rye account for a percentage as high as possible without destroying the breads sensory qualities.

### 6.2.7 Organic flour

In the introduction of this thesis, much focus was placed on meat and the energy required for its production. In the case of conventional grain cultivation it has been estimated that the major burdens in relation to energy use and climate-related emissions (which is much lower than in the case of meat (Carlsson-Kanyama et al., 2003)) are related to the production of mineral fertilizers<sup>35</sup> and synthetic pesticides. This does not apply to organic grain cultivation, and was also reflected in the aforementioned estimates demonstrating that bread baking with organic rye is 13 percent less energy-demanding (per kg bread) than baking with conventional rye (Grönroos et al., 2006). Other estimates are indicating that organic grain production may require 35-50 percent less energy inputs than conventional production systems (Fogelberg, 2008; Scialabba & Müller-Pedersen, 2010). Abstention from mineral fertilizers has furthermore been estimated to possess a reduction potential equivalent to 20 percent of the world's current annual agricultural greenhouse gas emissions (Scialabba & Müller-Lindenlauf, 2010). Further research is, however, required to consolidate these estimates.

Shortly explained, organic production is a natural production method where the use of synthetic fertilizers, pesticides and genetically modified organisms (GMOs), are banned. Additionally, there exist strict restrictions in relation to the use of concentrates. The production process is in general varied, which in the case of grain cultivation can be illustrated with the use of crop rotations (Scialabba & Müller-Lindenlauf, 2010). In addition to a less energy-demanding cultivation practice, there are several environmental benefits of organic production. Due to versatile crop rotations and prohibition of chemical fertilizers, soil degradation is for example to a large extent prevented. This results in a soil with a higher carbon sequestration capacity and hence reduced CO<sub>2</sub> emissions. By avoiding nitrogenous fertilizers, N<sub>2</sub>O emissions are also to a large extent prevented. Finally, organic production is highlighted for its stimulating effects on biodiversity (Nymoen et al., 2009; Pimentel, Hepperly, Hanson, Douds & Seidel, 2005; Scialabba & Müller-Lindenlauf, 2010).

There have been put forward many claims about the health benefits of eating organic food. Yet, few well-controlled studies have been performed to date (Dangour et al., 2009). The data that exists do, however, indicate some trends. In the case of carbohydrate-rich foods, e.g. grains, it has for example been observed that organic variants tend to contain less proteins and free amino acids, but a higher proportion of essential amino acids (i.e. a higher protein

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<sup>35</sup> To produce one kg nitrogen for mineral fertilizers, the energy of one kg oil is required (Nymoen et al., 2009).

quality), compared to conventional variants (Magkos, Arvaniti & Zampelas, 2003; Dangour et al., 2009). It is believed that conventional plants have a higher protein content due to a higher access to nitrogen from nitrogen-containing fertilizers (Magkos et al., 2003). Furthermore, it has been indicated that organic plant foods, which are not sprayed with pesticides, produce more antioxidants (Dangour et al., 2009).

One of the main motivations for eating organically produced foods may, however, be their low concentrations of foreign substances (e.g. pesticide residues) (Holmboe-Ottesen, 2004). In the case of grain cultivation, it has furthermore been observed that organic crops contain significantly lower levels of mycotoxins (Bernhoft, Clasen, Kristoffersen & Torp, 2010). Mycotoxins are, as the name indicates, toxic metabolites that are produced by moulds (e.g. *Fusarium*) infecting the grains. It is believed that a conventional cultivation practice, with its use of mineral fertilizers and high-density cropping systems, stimulate this infestation (Bernhoft et al., 2010). It is, however, important to emphasize that the levels of mycotoxins in Norwegian conventional grains are found to be rather low (Aune, 2007).

Therefore; should an “ideal” bread be based on organic flours? Despite the facts that organic crops, compared to conventional crops, in general have lower yields (Fogelberg, 2008), and that some in this context claim that organic food not is able to feed the worlds population (FAO, 2009b), it is from an environmental point of view emphasized that this production practice, by being based on the precautionary principle, is essential in terms of long-term sustainability in the agricultural sector (Pimentel et al., 2005). Organic food is therefore often highlighted as an important component of a sustainable diet (Nymoene et al., 2009; Holmboe-Ottesen, 2004).

Even though organic flours have a lower protein content compared to conventional flours, the western diet is generally high in proteins (Cordain, 1999), meaning that this difference is not crucial for our health status. The higher concentrations of antioxidants, as well as the absence of contaminants and secondary substances, may on the other hand be important qualities of organic flours (Holmboe-Ottesen, 2004).

A last aspect is related to the costs and availability of organic flours. Despite the fact that organically grown food is high on the political agenda<sup>36</sup>, organic flours (and organic food in

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<sup>36</sup> By 2020, it is a goal that 15 percent of the Norwegian food production and consumption is to be organic (Landbruks- og matdepartementet, 2009).

general) are more expensive than corresponding conventional flours. This can be illustrated with the price differences between organic (26,- per kg) versus conventional (11,- per kg) oat flakes<sup>37</sup>. Additionally, most organic producers (e.g. Holli Mølle) are only distributing their products to a selection of grocery stores, meaning that organic flours are less readily available. All in all; if organic flours are affordable and easily available, they should be preferred over the conventional variants.

## 6.3 *Nuts and seeds*

To satisfy an increasingly health-conscious population, many bread producers are now focusing on maximizing the nutritional value of their breads, e.g. by the use of enrichments. So far, this practice is more common abroad, where breads are enriched with both vitamins and minerals (Young, 2001). Among the Norwegian examples we do, however, find breads enriched with n-3 fatty acids. In these breads, which are promoted as “Omega-3 breads”, canola or fish oil are added. One example is ”Sunt & Grovt Kornbrød med Omega-3” (Din Baker) which contains 0.16 g n-3 fatty acids per 100 g bread, of which 0.13 g consists of EPA/DHA (Din baker, 2012).

Instead of adding oils, the focus of this thesis, in the context of the “ideal” bread, will be on the potential of different nuts and seeds. One reason is that these foods are rich in several health-promoting substances – not only healthy fatty acids. This will shortly be outlined below and is followed by a review on a selection of different nuts and seeds. Nuts and seeds that are frequently applied and recommended in the context of bread baking are included (Finngaard, 2006; Frølich, 1999; Hjelme, 2004).

### 6.3.1 *The health potential of nuts and seeds*

In several large epidemiological studies, e.g. Iowa Women’s Health Study, Nurses’ Health Study and Physicians’ Health Study, frequent nut consumption has been observed to correlate with a generally better health, i.e. a prolonged longevity and a reduced risk of coronary heart diseases (both fatal and non-fatal) and all-cause death (Albert, Gaziano, Willett & Manson, 2002; Ellsworth, Kushi & Folsom, 2001; Hu et al., 1998; Mente, de Koning, Shannon & Anand, 2009). It is believed that these favourable effects are mediated by several components

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<sup>37</sup> The prices are collected at a Kiwi shop in May 2012.



and mechanisms. Due to their beneficial composition, seeds and nuts are in fact regarded as some of our most nutritionally concentrated and disease-preventing foods (Blomhoff et al., 2006).

As well as being relatively low in sodium, nuts and seeds are rich in several essential and disease-preventing micronutrients (e.g. folate, vitamin K, magnesium, calcium, potassium, phosphorus, iron, zinc and copper) (Rodushkin, Baxter & Engström, 2011; Segura, Javierre, Lizarraga & Ros, 2006). Furthermore, many nuts and seeds have been identified as rich sources of phytochemicals - ranging from different antioxidant vitamins (e.g. vitamin E) and provitamins (e.g. carotenoids), to minerals (like selenium), phytosterols (mainly  $\beta$ -sitosterol) and phenolic compounds (like flavonoids and lignans) (Blomhoff et al., 2006; Carlsen, Halvorsen & Blomhoff, 2011; Segura et al., 2006; Maguire, O'Sullivan, Galvin, O'Connor & O'Brien, 2004). Moreover, most seeds and nuts are rich in fat. In some cases, unsaturated fatty acids may account for as much as 75 percent of the total fat content. The ratio between PUFAs and MUFAs varies between different varieties, but many seeds and nuts are rich sources of the aforementioned essential PUFAs (LA and ALA) (Li & Hu, 2011; Maguire et al., 2004).

Due to their high fat content, especially nuts are regarded as energy-rich foods. One g nut can provide up to 30 kJ (Lee, Lavie, O'Keefe & Milani, 2011). Even though current data does not indicate a correlation between frequent nut consumption and a high body weight (Banel & Hu, 2009; Sabatè, 2003), nut intake should be limited. This statement is also supported by the fact that some seeds and nuts contain significant amounts of trace elements that may accumulate in the body's fat tissues and become toxic in cases with excessive ingestion. Relevant examples in this context are cadmium, arsenic, lead and mercury (Aune, 2007; Rodushkin et al., 2011). It is also important not to forget that nut and seed allergies are among the food-related allergies most often observed in populations of industrialized countries (Cochard & Eigenmann, 2011; Gangur, Kelly & Navuluri, 2005). Despite their observed health-benefits, these points are therefore emphasizing that one also should be cautious with regard to seed and nut intake. The official dietary guidelines recommend a daily intake of unsalted nuts corresponding to a small handful (equivalent to 20 g per day) (Nasjonalt råd for ernæring, 2011).

### 6.3.2 Hazelnuts

Hazelnuts (*Corylus avellana L.*) contain significant amounts of different phytochemicals (about 0.5-1.0 mmol/100g). Among the phytochemicals most present are *antioxidants* (e.g.  $\alpha$ -tocopherol and selenium), *phenolic compounds* (e.g. tannins), and *phytoestrogens* (Carlsen et al., 2011; Contini, Frangipane & Massantini, 2011; Ramalhosa, Delgado, Estevinho & Pereira, 2011). Additionally, hazelnuts are rich in *phytosterols*.  $\beta$ -sitosterol, which seems to be the most active among the phytosterols identified, has been observed to account for as much as 1 mg per g hazelnut (Contini et al., 2011; Maguire et al., 2004).

Furthermore, hazelnuts are rich in fat which accounts for approximately 60 percent of the nut. Of this, 80 percent is comprised by MUFAs (especially oleic acid (C18:1), followed by LA (C18:2n-6) (Contini et al., 2011; Maguire et al., 2004; Ramalhosa et al., 2011). Moreover, hazelnuts are high in dietary fiber (about 10 percent of the nut), essential amino acids (e.g. arginine and leucine), B- and C-vitamins and minerals like potassium, phosphorus, calcium and magnesium. Especially favourable is a high potassium to sodium ratio which is identified as a protective factor in the development of hypertension (Contini et al., 2011; Ramalhosa et al., 2011).

In a study with hazelnut supplementations, Durak et al. (1999) demonstrated that an intake equivalent to 1g/kg body weight/day over a period of 30 days was able to lower both total and LDL cholesterol among a group of healthy subjects. Furthermore, elevations in the high density lipoprotein (HDL) cholesterol were observed, which again led to a more optimal LDL to HDL ratio. The hazelnuts were also found to increase the antioxidant potential in plasma.

At the same time, hazelnuts are identified as one of the most common allergy triggers in the diet. Together with peanuts, hazelnuts actually account for approximately 90 percent of all fatalities associated with food allergies (Cochard & Eigenmann, 2011; Contini et al. 2011).

### 6.3.3 Walnuts

Walnuts (*Juglans regia*), compared to other nuts, stand out due to their fat composition. While other nuts primarily contain MUFAs, walnuts are high in PUFAs which account for approximately 70 percent of the total fat content (mostly LA (57 percent of total fat content), but also relatively high amounts of ALA (12 percent of total fat content)) (Lee et al., 2011; Li

& Hu, 2011; Maguire et al., 2004; Mukuddem-Petersen, Oosthuizen & Jerling, 2005; Stonehouse, 2011).

Moreover, walnuts are the richest source of antioxidants among the nuts. According to Carlsen et al. (2010), walnuts contain approximately 22 mmol antioxidants per 100 g, and are thereby ranging over well-known, but also more energy-poor, antioxidant-sources like blueberries (8.2 mmol/100g) and blackberries (6.1 mmol/100g) (Halvorsen et al., 2002). The antioxidants present in walnuts are mainly located in the pellicle (the thin outer layer of the nut) and consist of a composition of both polyphenols and tocopherols (mainly  $\gamma$ -tocopherol which is suggested to have a higher antioxidant capacity than  $\alpha$ -tocopherol found in most other nuts and seeds) (Blomhoff et al., 2006; Carlsen et al., 2010; Carlsen et al., 2011; Maguire et al., 2004; Stonehouse, 2011). Walnuts are also rich in  $\beta$ -sitosterol and contain more than 1 mg  $\beta$ -sitosterol per g nut (Maguire et al., 2004).

Various randomized controlled trials have been focusing on the health effects of incorporating walnuts into the diet<sup>38</sup> over periods from four to six weeks. When compared with control diets, it has been observed that walnuts may reduce the levels of both total and LDL cholesterol, as well as the LDL to HDL cholesterol ratio (Banel & Hu, 2009; Iwamoto et al., 2002; Zambòn et al., 2000). It has also been observed higher plasma concentrations of ALA, as well as improvements in the vascular endothelial function (Banel & Hu, 2009; Ros et al., 2004). There may be several explanations for such beneficial effects, e.g. the walnuts fatty acid profile (relatively high in ALA), plant sterols, dietary fiber or antioxidant content - or a combination of these (Blomhoff et al., 2006; Iwamoto et al., 2002; Ros et al., 2004; Zambòn et al., 2000).

It is, however, also important to mention that walnuts are a common dietary allergy trigger (Cochard & Eigenmann, 2011).

#### 6.3.4 Flax seeds

Flax seeds (*Linum usitatissimum* – meaning “very useful”, and also called linseeds (Singh, Mridula, Rehal & Barnwal, 2011)), differ from other seeds by being the plant source most abundant in n-3 fatty acids (see table 6-6). ALA accounts for more than 50 percent of the

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<sup>38</sup> Replacing 32 (Ros et al., 2004) and 35 percent (Zambòn et al., 2000) of the energy obtained from MUFA, or 12.5 percent of total energy (Iwamoto et al., 2002).

seeds total fat content which constitute 35-45 percent of the seed (Singh et al., 2011; Verghese, Boateng & Walker, 2011).

**Table 6-6** ALA-content of oils from a selection of vegetables, seeds and nuts

| <b>Food sources</b> | <b>ALA,<br/>g/5 ml</b> |
|---------------------|------------------------|
| Olive oil           | 0.1                    |
| Soybean oil         | 0.9                    |
| Canola oil          | 1.3                    |
| Walnut oil          | 1.4                    |
| Flax seed oil       | 8.5                    |

Adopted from Verghese et al. (2011, pp. 489)

Moreover, flax seeds are rich in dietary fiber (both soluble and insoluble) which accounts for approximately 28 percent of the seeds' weight (Singh et al., 2011; Verghese et al., 2011). In the case of proteins, flax seeds have been reported to possess a high protein quality with an estimated biological value equal to 77 percent (Singh et al., 2011). Additionally, the seeds are rich in phytochemicals, e.g. antioxidants (0.5-1.0 mmol/100g) (Carlsen et al., 2011) and lignans (Singh et al., 2011). In fact, in addition to their superiority when it comes to ALA, flax seeds are also regarded as the plant source most abundant in lignans (Adlercreutz, 2007; Cornwell et al., 2004; Singh et al., 2011). According to Tolkachev & Zhuchenko (2000), the amount of lignans present in flax seeds are hundred times larger than the amounts identified in most other plant seeds. Lignans are therefore proposed as one of the substances most likely involved in the diseases-preventing effects observed from flax seed consumption - e.g. suppression of atherosclerosis (Prasad, 2009).

Flax seeds do also contain anti-nutritional components, e.g. in the form of phytate and oxalates. The levels of these components are, however, rather low (approximately 2-3 percent of the seed) (Prasad, 2009; Singh et al., 2011; Verghese et al., 2011). Moreover, flax seeds may contain some compounds named *cyanogenic glycosides*. These compounds are known to release hydrogen cyanide (HCN) which, among others, are observed to inhibit the mitochondrial respiration pathway. This causes a reduced utilization of oxygen in the tissues and a shift from aerobic to anaerobic metabolism (Ballhorn, 2011). For an adult, a toxic dose of HCN is approximately 50-250 mg. It is estimated that the levels of HCN released from cyanogenic compounds present in one to two tablespoons of flax seed meal correspond to 5-10 mg. A low to normal intake of flax seeds does therefore not involve any hazard as HCN

is easily metabolized by the body (approximately 30-100 mg/day) (Ballhorn, 2011; Prasad, 2009; Singh et al., 2011; Verghese et al., 2011).

Few allergic reactions are reported following flax seed consumption (Verghese et al., 2011).

### 6.3.5 *Pumpkin seeds*

There exists little research on the health effects of pumpkin seeds (*Cucurbita pepo L.*). Some studies do, however, indicate that these seeds exert a beneficial effect on prostate health. For example, it has been found that intake of pumpkin seed oil may lead to significant improvements in the symptoms related to benign prostatic hyperplasia (Hong, Kim & Maeng, 2009). There may be several explanations for these protective effects. For example, it is known that fat comprises approximately 50 percent of the pumpkin seed (Murkovic, Hillebrand, Winkler & Leitner, 1996). The fat present does mainly consist of saturated fatty acids like palmitic acid and stearic acid, as well as the MUFA oleic acid and the PUFA LA. These four fatty acids account for approximately 98 percent of the pumpkin seeds total fat content (Murkovic et al., 1996).

Furthermore, pumpkin seeds are rich in different essential micronutrients like selenium, vitamin E, zinc, magnesium and different phytochemicals (Krimer-Malesevic, Madarev-Popovic, Vastag, Radulovic & Pericin, 2011; Murkovic et al., 1996; Rodushkin et al., 2011). A high level of anti-nutrients (e.g. oxalates and tannins) does, however, limit the nutritional value of the seeds (Krimer-Malesevic et al., 2011). Pumpkin seed consumption is rarely observed to evoke any allergic reactions (Krimer-Malesevic et al., 2011).

### 6.3.6 *Sesame seeds*

Sesame seeds (*Sesamum indicum L.*) contain approximately 55 percent fat, of which 35-50 percent is made up of LA. ALA constitutes less than 1 percent of the total fat amount. Other substances present in the seeds are dietary fiber, proteins (about 20 percent) and micronutrients like minerals, lignans (e.g. sesamin and sesamol), tocopherols (especially  $\gamma$ -tocopherol) and phytosterols (e.g. sitosterol) (Adlercreutz, 2007; Chen et al., 2005; Cochard & Eigenmann, 2011; Elleuch, Bedigian & Zitoun, 2011; Hsu, Chu & Liu, 2011).

Consumption of sesame seeds has several times been observed to cause elevations in the tocopherol and vitamin E activity of plasma (Cooney, Custer, Okinaka & Franke, 2001). Vitamin E is believed to prevent against different cancers and heart diseases (Cooney et al., 2001; Elleuch et al., 2011). In a study by Chen et al. (2005), it was further demonstrated that dietary supplementation with 40 g sesame seeds over a period of four weeks led to significant decreases in both total and LDL cholesterol, as well an improved plasma antioxidant activity among patients with hypercholesterolemia. These effects were abolished after cessation of the treatment.

At the same time, sesame allergy is - of unknown reasons - emerging as one of the food allergies most often observed in the developed world (Cochard & Eigenmann, 2011; Gangur et al., 2005).

### 6.3.7 Sunflower seeds

Sunflower seeds (*Helianthus annuus L.*) are high in unsaturated fats (mainly MUFAs and n-6 fatty acids), dietary fiber, vitamins (especially B and E), magnesium, copper, selenium, phosphorus and folate (Pal, 2011). The seeds are also a rich source of antioxidants and contain approximately 5-6 mmol/100g (Blomhoff, 2005; Carlsen et al., 2011; Halvorsen et al. 2002).

Due to low concentrations of toxic substances, seeds and nuts are normally regarded as safe foods that do not provoke any adverse health effects when ingested (except for an increased energy intake) (Rodushkin et al., 2011). However, in case of sunflower seeds some precautions should be taken as these seeds are reported to be relatively high in cadmium (up to 2.5 µg/g) (Andersen & Hansen, 1984; Reeves & Vanderpool, 1997). Cadmium is a heavy metal and defined as a carcinogenic compound by the International Agency for Research on Cancer (IARC) (Aune, 2007; IARC, 1997). Cadmium has a long biological half-life (up to 30 years) and may thus accumulate in the body (mainly in the kidneys and liver), leading to toxic effects on kidneys and demineralization of the bones (Aune, 2007; Reeves & Vanderpool, 1997; Rhoduskin et al., 2011).

The European Food Safety Authority (EFSA) has established a tolerable weekly intake (TWI) for cadmium at 2.5 µg/kg body weight (EFSA, 2011). Estimates indicate that this limit may be exceeded with a daily intake of 30 g sunflower seeds. Although these estimates are based on the highest levels of cadmium observed in sunflower seeds (Rhoduskin et al., 2011), also

Norwegian health authorities are recommending a limited intake of these seeds (Mattilsynet, 2011).

### 6.3.8 What to choose?

Despite certain differences in composition when it comes to e.g. micronutrients and phytochemicals, seeds and nuts are generally regarded as nutritious and health-promoting foods. Thus, it may, as in the case of grains, be difficult to designate one as being “superior” to the others. However, there are some factors that may be relevant to take into consideration; for example fat composition, content of anti-nutritional compounds, and price. Firstly, a comparison of the fat compositions will be made.

Table 6-7 presents the n-6 and n-3 content of the presented selection of nuts and seeds. As the table illustrates, flax seeds and walnuts are the most optimal alternatives when it comes to high levels of n-3 fatty acids. Both are quite rich in ALA and appear as good vegetarian alternatives to the marine sources of n-3 fatty acids (Barceló-Coblijn & Murphy, 2009; Kris-Etherton et al., 2000; Rodriguez-Leyva, Bassett, McCullough & Pierce, 2010).

**Table 6-7** n-6 and n-3 composition, as well as the n-6 to n-3 ratio, of the presented nuts and seeds, g per 100 g whole nut/ intact seed kernel

|                        | <b>n-6 (18:2)</b> | <b>n-3 (18:2)</b> | <b>n-6:n-3</b> |
|------------------------|-------------------|-------------------|----------------|
| <b>Hazelnuts</b>       | 7.8               | 0.1               | 87             |
| <b>Walnuts</b>         | 38.1              | 9.1               | 4              |
| <b>Flax seeds</b>      | 5.9               | 22.8              | 0.3            |
| <b>Pumpkin seeds</b>   | 20.7              | 0.1               | 173            |
| <b>Sesame seeds</b>    | 21.4              | 0.4               | 56             |
| <b>Sunflower seeds</b> | 23.1              | 0.1               | 384            |

Source: USDA (2012)

With a n-6 to n-3 ratio equivalent to 1:4 (Jahreis & Schäfer, 2011), flax seed consumption has several times been reported to decrease the n-6 to n-3 ratio by raising the levels of circulating ALA and n-3 PUFAs (especially EPA) (Austria et al., 2008; Cunnane et al., 1993; Mantzioris, James, Gibson & Cleland, 1994; Verghese et al., 2011). This may be advantageous in case of reducing the risk of several chronic diseases caused by an unfavourable fatty acid profile (e.g. cardiovascular diseases) (Prasad, 2009).

However, it is worth emphasizing that the health-related value of ALA from flax seeds or walnuts, compared to fish and EPA/DHA, is debated (Arterburn et al., 2006; Burdge & Calder, 2006; Rodriguez-Leyva et al., 2010). According to Rodriguez-Leyva et al. (2010), 4 g of ALA are required to replace 0.3 g EPA/DHA. Moreover, several studies are indicating that the conversion of ALA to EPA and DHA is quite limited (Arterburn et al., 2006; Barceló-Coblijn & Murphy, 2009; Burdge & Calder, 2006; Cordain, 1999). According to Singh et al. (2011), only 5 to 10 percent of the ALA we ingest is converted to EPA and DHA. At the same time, ALA has been observed to possess disease-preventing properties comparable to those originating from EPA and DHA (deLorgeril et al., 1999). By replacing and decreasing the elongation of n-6 PUFAs, ALA is for example increasing the concentration of n-3 PUFAs in plasma, thereby having a beneficial effect on a range of cardiovascular risk factors (e.g. high blood cholesterol, high triglycerides, elevated levels of lipoprotein (a), hypertension and high levels of C-reactive protein (CRP)) (Barceló-Coblijn & Murphy, 2009; Burdge & Calder, 2006; Rodriguez-Leyva et al., 2010).

In the Lyon Diet Heart Study it was demonstrated that a diet rich in ALA was able to significantly lower the risk of recurrent fatal and non-fatal myocardial infarctions. Compared with the control group, it was in the experimental group furthermore observed a 73 percent reduction in the risk of primary end points (i.e. cardiac mortality and morbidity) (de Lorgeril et al., 1999). These results indicate that ALA might be an important component in terms of long-term health benefits (Rodriguez-Leyva et al., 2010).

The anti-nutritional characteristics of seeds and nuts have been in focus in many studies. In a study by Reeves & Vanderpool (1997), a high intake of sunflower seeds was not observed to cause any significant changes in the cadmium concentrations of the whole blood or in the red blood cells. Despite such findings, and as long as the long-term health effects of a habitual intake of sunflower seeds still are quite unclear, it may be advisable to follow the health authorities' advices and substitute sunflower seeds with other alternatives (Mattilsynet, 2011). In the case of flax seeds, the main concern is related to the cyanogenic compounds and their production and release of HCN. In various studies, these compounds are, however, not detected after cooking or baking of the seeds (Cunnane et al., 1993; Prasad, 2009) - thus making this issue irrelevant in the context of bread baking. As already mentioned, pumpkin seeds are rich in oxalates and tannins. These compounds reduce the seeds nutritional value by inhibiting the absorption of nutrients from the intestine (Krimer-Malesevic et al., 2011).



Based on the presented literature review, both flax seeds and walnuts point out as potential ingredients to be added in an "ideal" bread. If price is taken into consideration, seeds are, however, generally less expensive compared to nuts. Table 6-8 presents a price comparison of the selected nuts and seeds, and flax seeds are shown to be slightly cheaper than both pumpkin, sesame and sunflower seeds. The fact that consumers prefer foods low in energy further emphasizes flax seeds as a beneficial alternative, as walnuts have a high energy-density (table 6-8).

**Table 6-8** Energy content (kJ/100g) and price (per kg) of the selected seeds and nuts

|                        | <b>kJ/100 g*</b> | <b>Price (NOK)<br/>per kg**</b> |
|------------------------|------------------|---------------------------------|
| <b>Hazelnuts</b>       | 2762             | 117,-                           |
| <b>Walnuts</b>         | 2888             | 151,-                           |
| <b>Flax seeds</b>      | 1842             | 34,-                            |
| <b>Pumpkin seeds</b>   | 2315             | 121,-                           |
| <b>Sesame seeds</b>    | 2440             | 62,-                            |
| <b>Sunflower seeds</b> | 2386             | 62,-                            |

\* Source: Matportalen (2012a)

\*\* The prices are collected at a Kiwi shop in May 2012

Due to their high concentrations of mucilages, flax seeds have also been reported to function as a water-binding agent (Pohjanheimo, Hakala, Tahvonen, Salminen & Kallio, 2006). By maintaining the moisture content and retard the staling process, this attribute may be advantageous for the sensory qualities of the "ideal" bread (e.g. in relation to its softness and freshness) (Pohjanheimo et al., 2006). As mentioned, flax seed consumption is furthermore rarely reported to cause any allergic reactions. This makes the seeds to a beneficial alternative for most people (Verghese et al., 2011).

On the other hand, the bioavailability from whole flax seeds has been both discussed and studied (Austria et al., 2008; Kuijsten, Arts, van't Veer & Hollman, 2005). Several results indicate that milling and oil extraction enhance the bioavailability of both ALA and lignans from the seeds (Austria et al., 2008; Kuijsten et al., 2005; Rodriguez-Leyva et al., 2010). Kuijsten et al. (2005) studied the bioavailability of lignans from whole, grounded and crushed flax seeds and found that whole seeds had a lignan bioavailability of 28 percent compared with grounded seeds. The corresponding percentage found for crushed flax seeds was 43 percent. Austria et al. (2008) found that ingestion of flax oil or milled flax seeds over a 12-week period led to significantly increases in the concentration of ALA in plasma, while

ingestion of whole flax seeds increased the concentration to some degree, but not significantly.

These results may indicate that the bioavailability of flax seeds will be enhanced if whole seeds are replaced by crushed or grounded seeds (flax seed oil does not contain lignans, fiber, etc.) (Austria et al., 2008; Kuijsten et al., 2005). At the same time, it is observed that this practice may lead to slightly decreases in the levels of ALA when the seeds are heat-treated (Singh et al., 2011). This was demonstrated by Chen, Ratnayake & Cunnane (1994) who observed a four percent decrease in the levels of ALA in grounded flax seeds after heating at 178°C for 1.5 hours. Furthermore, whole seeds have a higher oxidative stability compared to crushed or grounded seeds (Chen et al., 1994). This means that crushed or grounded seeds (compared with intact seeds) are more susceptible to rancidity which again may lead to unwanted sensory effects (Chen et al., 1994). Oxidised lipids are also thought to be involved in several disease-promoting processes in the body, e.g. oxidative stress and atherosclerosis (Blomhoff, 2005). All in all, intact flax seeds will be preferred for the “ideal” bread.

## 6.4 Salt

In chemical terms, common salt is sodium chloride (NaCl). As a simple rule one can say that 1 g salt is equivalent to 0.4 g sodium (Nasjonalt råd for ernæring, 2011; Nordic Council of Ministers, 2004). Both sodium and chloride are essential micronutrients for our body. While chloride is an important component in the maintenance of the metabolism and acid-base-balance, sodium ions are involved in the regulation of nerve functions, blood volume, hormone excretion, transport mechanisms for glucose and amino acids, the acid-base-balance, as well as the osmotic pressure in the extracellular fluids (Nasjonalt råd for ernæring, 2011; Nordic Council of Ministers, 2004).

However, too much sodium is not beneficial and salt is perceived as such an important cause of the world-wide disease burden (e.g. of cancer and coronary heart diseases), that a reduction in the intake is pointed out by the United Nations (UN) as one of the main priorities in relation to reduction of these diseases (UN, 2011). For example, there is identified a *convincing* relationship between a high consumption of sodium and an increased risk of high blood pressure, which again relates to cardiovascular diseases - especially cerebral stroke and myocardial infarction (Nasjonalt råd for ernæring, 2011). Moreover, there is a *probable*

connection between total salt consumption and the risk of stomach cancer (WCRF/AICR, 2007).

As presented in chapter 4, the Norwegian diet contains too high levels of salt. It is estimated that approximately 10 g per person per day is ingested – an amount that are more than twice the recommended amount (3 to 4 g per day, maximum 5 g per day) (Helsedirektoratet, 2011; Nasjonalt råd for ernæring, 2011). About 70-80 percent of the salt intake originates from industrially processed foods, of which bread is a leading source. This can be illustrated by the fact that bread and cereal products contributed around 22 percent of the overall sodium intake from the Norwegian household diet in the period from 2007 to 2009 (Helsedirektoratet, 2010).

However, it is important to remember that this high share also is due a generally high consumption of bread. Moreover, it means that a reduction in the salt content of breads may have a significant effect on lowering the population's overall salt consumption. This in turn, may hold great potential in relation to decrease the long-term incidence of the abovementioned health complications associated with a high intake (Bolhuis et al., 2011). According to Selmer et al. (2000), a reduction in the daily salt intake by 6 g per person in the Norwegian population, would have led to an average decrease of 2.2 mm Hg systolic blood pressure in normotensive, and even more in hypertensive. Furthermore, this would have caused an overall risk reduction of 4.2 percent for stroke and 3.8 percent for myocardial infarction, as well as a cut in the total mortality rates by approximately one to two percent. By reducing the number of people in need for medical treatment (e.g. antihypertensive drugs), health-care (e.g. hospitalization) and sick leave, it was further estimated that 801 million US \$ would have been saved within a 25-year period (Selmer et al., 2000). A reduction in the overall salt intake would in other words benefited individuals just as much as the society as a whole.

#### *6.4.1 Salt in breads*

In the case of breads, salt has three important tasks; (1) to improve the bread's flavour and sensory qualities, (2) to strengthen the gluten network and thereby the dough's elasticity and handling characteristics, as well as the bread's loaf volume, and (3) to extend the bread's shelf-life by preventing microbial growth (by binding water) (Hjelme, 2004; Linko, Härkönen & Linko, 1984; Salovaara, 2009; Whitley, 2009). At the same time, too high levels of salt are known to retard the fermentation process (Linko et al., 1984; Meyer, 2009). In a study by

Salovaara (2009), it was for example indicated that a 2 percent salt addition (based on total flour weight) reduced the CO<sub>2</sub>-formation by approximately 20 percent compared to a 0.5 percent addition level.

Most bakers are, however, focusing on the beneficial effects salt exerts on the taste and handling characteristics of bread, and are therefore emphasizing the importance of large amounts of salt for obtaining optimal baking results. In several bread baking books, it is furthermore highlighted that extensive use of salt in breads should be prioritized at the expense of using salt in other types of food (Hjelme, 2004; Schakenda, 2009). As a basic rule, Meyer (2009) suggests 35 g sea salt per l of liquid - i.e. 1.52 g salt per 100 g bread (for calculations, see attachment 5). According to Nasjonalt råd for ernæring (2011), a food is classified as high in salt if it contains more than 1.25 g salt per 100 g. If the salt level is below 0.3 g per 100 g, the food is on the other hand considered as a low-salt product.

At the same time as bakers and bread producers are emphasizing the important role of salt in breads, several studies have demonstrated that gradual reductions in breads salt level may be possible without causing any reductions in their sensory and palatable characteristics. In a six-week study conducted by Girgis et al. (2003), it was for example demonstrated that small, cumulative decreases in the salt content until a one-quarter reduction (from 2 g salt per 100 g flour to 1.5 g salt per 100 g flour) was reached, could be made without significantly affecting the participants' perceptions and liking of the bread. In a study by Rodgers & Neal (1999), 60 subjects were asked to rank three types of bread with different salt content (standard (3.1 g salt per 750 g), 10 and 20 percent salt-reduced) on a liking-scale from zero to ten, where ten being the best liked. Additionally, they were asked to guess to which group each of the three breads belonged. The results revealed that only 63 out of 180 guesses were correct, whereas the taste-ranking gave the following scores: 4.4 (standard), 4.3 (10 percent reduction) and 4.6 (20 percent reduction) – although not significant.

However, the largest salt reductions were obtained in a study by Bolhuis et al. (2011). During a four-week period, 116 participants were randomised to either a control group or one of two experimental groups. One of the experimental groups was receiving bread in which the salt content was decreasing each week – from standard bread (1.8 g salt per 100 g flour), to a 31 percent reduction (1.25 g salt per 100 g flour), 52 percent reduction (0.87 g salt per 100 g flour) and finally a 67 percent reduction (0.60 g salt per 100 g flour). In the other experimental group, salt was gradually replaced by flavour compensations in the form of

potassium chloride (KCl) and yeast extracts. To evaluate the experimental effect, the subject's bread consumption pattern was monitored. The final results from the salt-reduced group indicated that the salt levels could be reduced up to 52 percent without affecting the overall bread consumption. When the salt reduction reached 67 percent, the bread consumption went significantly down. In the flavour-compensated group, a 67 percent salt-reduction did not affect the consumption patterns (Bolhuis et al., 2011).

#### *6.4.2 Potassium chloride – an alternative approach?*

Bolhuis et al. (2011) focused on reducing some sodium with potassium. Other studies have also focused on this alternative approach. Salovaara (1982) conducted a sensory evaluation of four different breads where 5, 10, 20 or 40 percent of the sodium chloride (2 percent of total flour weight) was substituted with potassium chloride. The results indicated that the lowest levels of replacement (5, 10 and 20 percent) could be applied without significantly affecting the breads flavour. However, unlike the results from Bolhuis et al. (2011), a bitter and undesirable taste was reported at a 40 percent replacement level. Similar results were found by Braschi, Gill & Naismith (2009). At a 50 percent replacement level, the breads were judged to be overall acceptable with regard to e.g. appearance, odour and texture, but the flavour was rather poor.

To avoid any adverse sensory effects, these results indicate that only approximately 20 percent sodium chloride can be substituted with potassium chloride. However, even this level might possess an important health-promoting potential. The industrialization of the food chain, which was described in the introduction, has resulted in a diet that is quite low in potassium compared to the levels found in the Paleolithic diet (which also was higher in fruits and vegetables rich in potassium). At the same time, the levels of sodium have risen linearly (Cordain, 2011). From a Paleolithic diet containing approximately ten times more potassium than sodium, the picture is now reversed with an American diet that is containing approximately five times as much sodium as potassium (Cordain et al., 2005; Cordain, 2011; Demigné, Sabboh, Rèmèsy & Meneton, 2004; Morris, Schmidlin, Frassetto & Sebastian, 2006).

As outlined above, these changes can be of great importance in relation to our health status. In contrast to sodium, it is for example well-known that potassium plays an important role in the

protectiveness against hypertension and stroke<sup>39</sup> (Demigné et al., 2004; He & MacGregor, 2001). According to Morris et al. (2006), potassium may even counteract and attenuate the blood pressure-rising effects of sodium. The mechanisms are not completely identified, but potassium is known to be natriuretic – meaning that it stimulates the excretion of sodium in the urine. As the sodium-levels in the blood drops, water is excreted together with sodium due to osmotic pressure. This leads to a reduced extracellular volume and blood volume, which again possesses the antihypertensive effect.

Given a salt level of 2 percent of total flour weight, a 20 percent substitution of sodium chloride with potassium chloride, would have led to a decrease in the ratio of sodium to potassium from about 8:1 to 2:1 (Salovaara, 1982). Despite the fact that the “ideal” bread will not contain so high levels of salt (see next paragraph), it is clear that replacement of sodium chloride with potassium chloride (e.g. Seltin) holds a health promoting potential.

To conclude, the salt levels of breads should be reduced. In the case of the “ideal” bread it should be prioritized that the salt level stays within the limits set by the *Keyhole* scheme, i.e. no more than 0.5 g salt per 100 g bread (Forskrift om frivillig merking med Nøkkehullet, 2009). Furthermore, it is a possibility to substitute some sodium chloride with potassium chloride. Seltin, which contains 50 percent sodium chloride, 40 percent potassium chloride and 10 percent magnesium chloride, can be an optimal salt substitution in this context.

## 6.5 *Liquid ingredients*

Only in Norway, it is estimated that more than 300 000 tons of usable foods are wasted each year. This is equivalent to more than 50 kg food per person per year, and approximately 25 percent of the yearly food turnover (Sundt, 2010). Based on estimates from the food manufacturing industry, wholesalers, the grocery sector and consumer studies, it can be concluded that bakery products are among the foods most often wasted. In the grocery sector, it was in 2009 estimated that more than six percent of the total bakery turnover was thrown. This corresponds to 244 tons of edible bakery products worth more than 5.3 million NOK (Hanssen & Schakenda, 2011). In Britain, it is calculated that the greenhouse gas emissions deriving from avoidable food wastes correspond to 25 percent of the emissions from the

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<sup>39</sup> Also established a relation between a high consumption of potassium and a reduced risk of cardiac dysfunctions, renal damage, kidney stones, hypercalciuria and osteoporosis (Demigné et al., 2004; He & MacGregor, 2001).

countries fleet vehicle (Sundt, 2010). Food wastes are in other words a major obstacle for the efforts towards a more sustainable food consumption pattern. Moreover, it is an unethical practice in a world in which one billion people are suffering from hunger (Kroglund & Gaupset, 2011; Sundt, 2010).

In the grocery sector, breads are thrown if they're not sold within a day. In the case of consumers, exceedings of the expiry date, as well as loss of quality (staling) are ranged as the most frequent reasons for throwing bakery products (Hanssen & Schakenda, 2011). Despite the fact that changes in both awareness and attitudes are required to reduce the amounts of avoidable food waste (Hanssen & Schakenda, 2011; Sundt, 2010), there are also some factors in the bread baking process that might be relevant in the case of extending the breads shelf life. One factor is salt which, as described above, extends the bread's shelf-life by preventing microbial growth (Salovaara, 2009). Another factor is the choice of fermentation method (Meyer, 2009) which will be outlined in the following chapter. A last crucial factor is the amount of liquids added (Meyer, 2009).

Industrial breads are in general based on relatively low amounts of liquids. There may be several reasons for this. One reason might be that drier doughs are easier and more time-efficient to handle as they are less sticky and generally require less kneading, as well as shorter fermentation and baking times, compared to moister doughs (Meyer, 2009). Another reason might be that the industry is taking advantage of the fact that lower moisture contents contribute to increase the breads dry matter content. By reducing the doughs amount of liquids, the breads' relative amount of e.g. dietary fiber is increasing, which again makes it easier to fulfil the criteria set out by the *Keyhole*. This will be discussed further in chapter 6.8.

As a contrast, Meyer (2009) is recommending that bread doughs should have a soup-like consistency at the start of the kneading. During the kneading, the dough is thickening due to the flours water absorption<sup>40</sup>. It is well-known that doughs that are based on relatively high moisture levels and long kneading periods<sup>41</sup> are softer and with a larger potential for the gluten network to develop and expand. In turn, this leads to breads with a more humid, airy and tasty texture, as well as a crispier crust compared to breads based on drier doughs and shorter kneading times. It is also observed that moist breads remain fresh over a longer period

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<sup>40</sup> Whole grains have a larger absorption potential than refined flour. More liquids should therefore be added when using whole grain flours (Meyer, 2009).

<sup>41</sup> Meyer (2009) recommends that bread doughs should be kneaded for 20 to 30 minutes – preferably divided into three to four intervals.

(Dewettinck et al., 2008; Hjelme, 2004; Meyer, 2009; Stampfli & Nersten, 1995; Whitley, 2009). As we may remember from earlier, these qualities are also stressed in different consumer studies on bread preferences (Bugge et al., 2008; Opplysningskontoret for brød og korn, 2011a). Furthermore, it is observed that a high moisture level may have an impact on different nutritional qualities of the bread, e.g. by stimulating phytate-degradation and reducing the levels of acrylamide-formation (Greiner & Konietzny, 2006; Lingnert et al., 2002). This will be outlined in the following two chapters. Last but not least, breads based on high levels of liquids are more filling.

When it comes to what kind of liquids that should be added, there are a range of possibilities. Water, dairy products (e.g. different types of milk and yoghurt), fruit and vegetable juices, fats (e.g. oils, margarine and butter) and even syrup, vinegar and beer, are among alternatives proposed in different bread baking books (Meyer, 2009; Sæland, 2006; Whitley, 2009). In the case of the “ideal” bread, there are some alternatives that might be more suitable than others. As mentioned in chapter 4, it is for example a criterion that the energy-density of the bread should be kept as low as possible, e.g. by not including energy-dense and unneeded ingredients like fat. In this context, it is important to emphasize that it is possible to make breads of high quality without adding fats (Whitley, 2009). Ingredients like syrup, vinegar and beer may also be considered as unneeded. Based on this, water, dairy products and juices are the most relevant liquid candidates for an “ideal” bread.

### *6.5.1 Water*

Water is the most obvious liquid alternative to be used in an “ideal” bread. In addition to being essential for the formation of the gluten complex (Eliasson & Larsson, 1993), water can be considered a “universal” ingredient; it is tolerated by everyone, it does not affect the taste of the bread and it is free of charge. Furthermore, water does not contain any nutritional energy and is therefore contributing in the lowering of the bread’s energy-density.

### *6.5.2 Dairy products*

As mentioned in the introduction, grains are low in essential amino acids like lysine. As a consequence, grains are generally regarded to have a low protein quality (Cordain, 1999). Animal products, e.g. dairy, are on the other hand considered to have a high protein quality



due to their high levels of essential amino acids (Cordain, 1999). Therefore, it is often emphasized that the protein quality of bread meals can be improved by for example drinking milk. In a bread baking context, milk can also be added to the dough. In the case of fermented milk products, e.g. yoghurt, it is well-known that they are supplying the bread with lactic acid bacteria (LAB) and organic acids that are beneficial for both the taste and shelf-life of the bread (Corsetti & Settanni, 2007). Furthermore, these microorganisms are affecting the nutritional quality of the bread, for example by lowering its GI and stimulate phytate-degradation (Meyer, 2009). This will be the main focus of the next chapter.

Dairy products are also rich in calcium. As mentioned in the introduction, lack of calcium is one of the shortcomings of grains (Cordain, 1999). On the contrary, calcium is observed to inhibit the absorption of other minerals, e.g. iron, from the diet. In a study by Hallberg, Brune, Erlandsson, Sandberg & Rossander-Hultèn (1991), it was observed that as little as 40 mg added calcium (corresponding to 0.4 decilitre (dl) of milk) could reduce the amount of iron absorbed from the bread with 40 percent. At the same time, it was observed that the breads added with calcium contained significantly higher levels of phytate compared to the levels present in the control breads. Similar results were found by Türk & Sandberg (1992). It is believed that calcium inhibits the degradation of phytate by forming insoluble calcium-phytate-complexes (Hallberg et al., 1991; Lopez, Leenhardt, Coudray & Remesy, 2002). As outlined in the following chapter, it should be an overarching goal to optimize the nutritional availability of an “ideal” bread. Consequently, calcium addition should be kept at a minimum. It is also important to remember that dairy products frequently are reported to cause allergic reactions (Strobel & Ferguson, 2005), thereby constituting an unacceptable alternative for many.

### *6.5.3 Juice*

While dairy products and calcium are reported to lower the degradation of phytate, different acids, e.g. ascorbic acid (vitamin C) and citric acid, are observed to reverse the inhibitory effects of phytate on iron absorption (Bohn et al., 2008). In a study by Porres, Etcheverry, Miller & Lei (2001), it was found that addition of 6.25 g citric acid per kg flour increased the phytate-degradation from 42 to 69 percent (significant at  $p < 0.05$ ). This was followed by a 12-fold increase in the iron availability. There are several explanations for this effect. Firstly, acids are pH-lowering agents, meaning that they promote an acidic environment which, as

will be outlined in the next chapter, favours phytate-degradation (Bohn, Meyer & Rasmussen, 2008; Porres et al., 2001). Furthermore, a low pH is beneficial in the case of reducing non-haeme iron (ferric iron,  $\text{Fe}^{3+}$ ) found in grains, to haeme-iron (ferrous iron,  $\text{Fe}^{2+}$ ) which is absorbed to a much larger extent in the intestine (Bohn et al., 2008).

While grains are the only plant source not containing vitamin C, fruit and vegetables are rich sources of this vitamin. Based on the abovementioned aspects, fruit and vegetable juices may be viewed as beneficial alternative ingredients for an “ideal” bread. However, in order to keep the recipe as simple as possible, water will be preferred as the “ideal” liquid.

## 6.6 Fermentation

The fermentation process is essential for several reasons. First and foremost, it is important for obtaining a gaseous dough and thereby a voluminous bread. This happens when the yeast – either naturally present in the flour or added – by enzymatic activity splits glucose (released from the starch complexes in the flour) into  $\text{CO}_2$ , water and ethanol. While the water and ethanol are evaporating, the  $\text{CO}_2$  makes the gluten network stretch (Ledsaak & Eben, 2010; Mondal & Datta, 2008). Moreover, it is well-known that the fermentation affects the flavour-development of the bread. Both the amount of yeast and the fermentation time are crucial factors in this context (Meyer, 2009). Finally, the fermentation is considered to affect the bread’s nutritional value. For example, it is observed that some fermentation methods increase the levels of different health-promoting substances (e.g. vitamins) and lower the concentration of anti-nutritional components like phytate (Meyer, 2009). This will be elaborated later in this chapter.

The practice of yeast-leavening has been known since the ancient Egyptians discovered that yeasts (*Saccharomyces cerevisiae*) used in the brewing of beer also exerted beneficial effects when added in bread doughs. For example, it was observed that the doughs started fermenting more rapidly (Meyer, 2009). In much of the literature, sourdough fermentation is, however, presented as the most ideal fermentation method – especially in terms of the nutritional value and aromatic characteristics of the fermented product. Sourdough fermentation, which is the oldest cereal fermentation method in the world, is in its simplest form based on a mix of flour

and water<sup>42</sup> that is put in box with a lid and set to ferment in a warm place (approximately 30°C) over a period from several hours to several days<sup>43</sup> (Decock & Cappelle, 2005; Meyer, 2009; Whitley, 2009). In technical terms, this mix is called a “starter culture” which can be refreshed in several rounds by adding more flour and water. In the end, when the mix is kneaded into the final dough, it serves as the dough’s leavening agent (Whitley, 2009).

LAB<sup>44</sup> and yeasts<sup>45</sup> are substances that are naturally present in flours. What makes sourdoughs special is their ability to stimulate the formation of these microorganisms – mainly by facilitating their optimal growth conditions (i.e. a long fermentation period at a relatively high temperature). As a result, sourdoughs have a unique microflora that can be viewed as one of the main reasons for the many benefits observed from sourdough fermentation. While the yeast is responsible for the fermentation of the dough by forming CO<sub>2</sub> and ethanol as described above, LAB is identified to produce organic acids (e.g. lactic and acetic acid) which among others lead to an acidification of the dough (Corsetti & Settanni, 2007). The beneficial effects of this will be outlined later.

In the identification of the optimal fermentation method (yeast-leavening versus sourdough fermentation), optimization of the bread’s nutritional composition (i.e. maximize beneficial compounds, minimizing anti-nutritional compounds, and preventing loss of nutrients during processing), taste and convenience will be the most important aspects to take into account. But first; phytate has briefly been mentioned several times in this thesis – mainly as an anti-nutritional component. At the same time, there are studies that indicate that phytate also may exert beneficial effects on our health (Konietzny, Jany & Greiner, 2006). This requires a brief introduction on phytate.

### 6.6.1 Phytate – an adverse or beneficial food component?

Shortly explained, phytate, or *myo-inositol hexaphosphate*, is a natural food component present in most cereals, legumes, nuts and oil seeds. Phytate consists of an inositol-ring with – as the name indicates – six reactive phosphate-groups attached to it (figure 6-4) (Bohn et al., 2008).

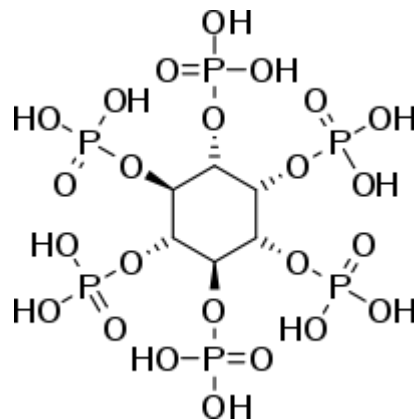
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<sup>42</sup> Small amounts of e.g. baker’s yeast, buttermilk, yoghurt or honey can also be added (Meyer, 2009).

<sup>43</sup> Depending on the firmness of the dough – a firmer dough requires a longer fermentation time (Meyer, 2009).

<sup>44</sup> Approximately 50 different species are identified in sourdoughs. *Lactobacillus* strains are among the bacterias most frequently observed (Corsetti & Settanni, 2007).

<sup>45</sup> More than 20 species are identified (Corsetti & Settanni, 2007).



**Figure 6-4** The structure of phytate

In addition to being the major storage compounds of phosphorous in plants (up to 90 percent of total phosphorous), the phosphate-groups are negatively charged (Greiner & Konietzny, 2006). Consequently, phytate is well-known for its chelating and inhibiting effect on the digestion and absorption of several minerals (especially iron, zinc and calcium, but also heavy metals like cadmium and lead) (Kumar et al., 2010). It is further observed, mainly in animal and in vitro studies, that phytate may form insoluble complexes with proteins, carbohydrates and lipids, and affect their structure and function (e.g. the enzymatic activity of proteins) (Greiner & Konietzny, 2006; Konietzny et al., 2006; Minihane & Rimbach, 2002). By complexing calcium ions, which are essential for the activity of several digestive enzymes (e.g. trypsin and  $\alpha$ -amylase), phytate may also seem to affect the overall digestibility and utilisation of free macronutrients (Greiner & Konietzny, 2006; Kumar et al., 2010).

On the other hand, there are studies that have focused on the beneficial health effects of phytate, although this documentation so far is relatively scarce and largely based on animal and in vitro studies. As mentioned in chapter 6.1.2, phytate may for example, due to its metal-binding capacity, function as an antioxidant (Kumar et al., 2010). Iron interacts in the Fenton reaction<sup>46</sup> that catalyzes the generation of free hydroxyl radicals. These radicals are known to stimulate oxidative processes that are believed to be involved in the development of several conditions, e.g. cancers, inflammatory and neurological diseases (Blomhoff, 2005; Bohn et al., 2008). In 1987, Graf et al. (1987) demonstrated that the Fenton reaction could be almost

<sup>46</sup> When  $\text{Fe}^{2+}$  reacts with  $\text{H}_2\text{O}_2$  or peroxides and are oxidized into  $\text{Fe}^{3+}$  (Bohn et al., 2008).

completely blocked by the addition of phytate. In their conclusion, phytate was presented as the most effective and non-toxic food antioxidant that until then was studied.

In the case of cancer it has also more recently been demonstrated that intake of phytate may inhibit or limit the proliferation of different cancer cell lines (e.g. in the colon, pancreas, liver, breasts, cervix and prostate) (Konietzny et al., 2006; Kumar et al., 2010). Furthermore, there have in animal and in vitro studies been observed a connection between consumption of phytate and a decreased risk of cardiovascular diseases, type 2 diabetes and renal stones (Bohn et al., 2008; Konietzny et al., 2006; Kumar et al., 2010).

There are three types of enzymes that can hydrolyse<sup>47</sup> the phytate complex; i.e. mucosal phytases in the upper small intestine (little activity in man despite this is where the main mineral absorption takes place), phytases in the bacterial flora of the colon (mostly calcium is released and absorbed here), as well as dietary phytases present in plants (e.g. grains) and microorganisms (e.g. yeast) (the most efficient way to decrease the levels of phytate in foods) (Bohn et al., 2008; Greiner & Konietzny, 2006; Kumar et al., 2010). Dietary phytases are in focus in the rest of this chapter.

As previously emphasized, the “ideal” bread should strive for a maximal nutritional composition. To increase the mineral bioavailability by reducing the levels of phytate will be an essential measure in this respect. However, based on the abovementioned studies, phytate may seem to be just as much a beneficial as an adverse food component. Still, this depends upon the population of interest. With regard to men and post-menopausal women, phytate may be considered beneficial due to its disease-preventing properties. On the contrary, phytate may exert adverse effects on the iron status of groups with particularly high needs for iron (e.g. children and adolescents in growth and pubertal development, pre-menopausal women and elderly with a reduced food intake) (Sharp, 2005). Despite the prevalence of anaemia among Norwegian women<sup>48</sup> and adolescents<sup>49</sup> may seem relatively low (Borch-Iohnsen, Sandstad & Åsberg, 2005; Eskeland & Hunnskaar, 1999), estimates from the national nutrition surveys *Norkost 1997* and *Ungkost 2000* indicated that the intake of iron was below

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<sup>47</sup> Phosphate-groups are removed from the inositol-ring (dephosphorylation) one by one, hence leading to intermediate myo-inositol phosphate-complexes that are less negatively charged and thereby less chelating (Greiner & Konietzny, 2006; Minihane & Rimbach, 2002).

<sup>48</sup> 4.7 percent (based on estimates from the Nord-Trøndelag Health Study) (Borch-Iohnsen et al., 2005).

<sup>49</sup> Four and eight percent for girls and boys, respectively (Eskeland & Hunnskaar, 1999).

recommended amount in both groups (Johansson & Solvoll, 1999; Øverby & Andersen, 2002).

In this context, it is also important to stress that bread is one of the major sources of iron in the Norwegian diet. Estimates indicate that 31 percent of total dietary iron is provided from cereals (Helsedirektoratet, 2010). However, this estimate does not say anything about the amount of iron actually absorbed from the intestinal tract (which probably is much lower). In a Danish study (Bach Kristensen et al., 2005), the effects of long-term consumption of the recommended amount of whole-grains (based on the official Danish dietary guidelines) on iron stores, were studied. A total of 41 young women with adequate iron stores (serum ferritin >20µg/L and haemoglobin >120 g/L) were provided a daily ration of 300 g fiber-rich wheat bread for a period of 16 weeks. The final results revealed that both serum ferritin and haemoglobin had decreased significantly during the study period (serum ferritin with 27 percent and haemoglobin with 1.5 percent) (Bach Kristensen et al., 2005).

In this respect, it is also important to remember that the iron present in grains exclusively is in the non-haeme form. As we may remember from the previous chapter, non-haeme iron has a much lower bioavailability than haeme iron originating from meat and meat products - partly because of phytate (Minihane & Rimbach, 2002). This is exemplified by the fact that haeme iron may account for only 10 to 20 percent of total dietary iron, but up to 50 percent of the iron actually absorbed in the intestine (Bohn et al., 2008). It may, however, seem like the absorption of non-haeme iron is up-regulated in people with low body iron stores. However, such an up-regulation is also dependent upon low levels of inhibiting factors like phytate (Hunt, 2003).

### *6.6.2 Identifying the optimal fermentation conditions*

It is important to remember – especially in the case of iron – that a degradation of phytate will lead to an improved, rather than a complete absorption (Bohn et al., 2008; Türk, Carlsson & Sandberg, 1996). Greiner & Konietzny (2006) are also emphasizing that phytate must be reduced to very low levels to strongly increase the mineral absorption rate. The food industry has devoted a lot of resources to identify ways to do this - for example by adding exogenous phytases (Greiner & Konietzny, 2006; Kumar et al., 2010). In the case of bread baking, there are several factors that can be optimized to enhance the activity of the endogenous phytases present in the yeast (3-phytase) and flour (6-phytase) (Bohn et al., 2008; Brune, Rossander-

Hultèn, Hallberg, Gleerup & Sandberg, 1992; Harinder, Tiwana & Kaur, 1998; Türk et al., 1996). It should be noted that these kinds of measures not are observed to exert any adverse effects on associated food components (e.g. dietary fiber). In fact, they are rather identified to cause additional benefits - both in relation to nutritional factors and sensory qualities of the bread (Greiner & Konietzny, 2006). This will be elaborated in the following section.

### ***(1) Choice of cereal and flour extraction rate***

As mentioned in chapter 6.2.5, rye has been observed to exert the greatest phytate-degrading activity among the cereals, followed by wheat, barley and oat, respectively (Greiner & Konietzny, 2006). In a study by Fretzdorff & Brümmer (1992), the phytase activity of rye was actually found to be almost three times the activity in wheat.

Furthermore, phytate has been observed to be more easily degraded in finely, compared to coarsely grounded whole meal flours (Fretzdorff & Brümmer, 1992). It is believed that the grinding allows a better contact between phytate and phytase (Fredlund, Asp, Larsson, Marklinder & Sandberg, 1997). On the contrary, a substitution of coarsely grounded flours is in conflict with their observed health benefits (as outlined in chapter 6.1.3) (Slavin et al., 1999).

### ***(2) Conditions during the fermentation***

#### ***Baker's yeast***

Yeast can be added to the dough in the form of baker's yeast, but are also naturally present in flours. As previously mentioned, yeast contains phytase in the form of 3-phytase. Studies are, however, not so convincing when it comes to the effectiveness of this enzyme (Greiner & Konietzny, 2006). Harland & Harland (1980) examined the phytate-degrading effect of doubling the dough's amount of baker's yeast. A greater phytate-hydrolysis was observed, but only 27 percent of the initial phytate was degraded after eight hours of fermentation. Türk et al. (1996) examined the phytate-degradation rate in breads with and without added yeast. They observed a significantly higher degradation in the latter, but the difference between them was rather small (65 versus 58 percent reduction). Based on these results, it may be reasonable to assume that the phytate-degrading contribution of yeast phytases is relatively small compared with endogenous flour phytase (i.e. 6-phytase) (Lopez et al., 2001).

### *pH of the dough*

Optimal pH for 3-phytase and 6-phytase is estimated to be 3.5 and 5.1, respectively (Türk et al., 1996). In this situation three outcomes exist; (1) that none of the phytases are stimulated by an optimal pH, (2) that one of the phytases is predominating, or (3) that both 3-phytase and 6-phytase are stimulated (Türk et al., 1996). While doughs based on baker's yeast are reported to have pH values of approximately 6.3-6.1, the pH of sourdoughs is estimated to be approximately 5.6-5.4 – i.e. more optimal in relation to the functional rate of 6-phytase (i.e. outcome 2) (Bohn et al., 2008; Leenhardt, Levrat-Verny, Chanliaud & Rèmèsy, 2005). The fact that sourdoughs are more efficient than yeast-fermentation in reducing the phytate-concentration of breads has also been demonstrated in several studies. As an example, Lopez et al. (2001) found that sourdoughs could reduce the levels of phytate by 62 percent, while the corresponding reduction in a yeast-fermented dough only reached 38 percent. This difference is mainly explained by the pH-lowering effect of the organic acid production of the sourdough microflora (i.e. LABs) (Leenhardt et al., 2005).

Nevertheless, the highest phytate-reductions have been observed to occur at pH values around 4.5 – i.e. outcome 3 (Fretzdorff & Brümmer, 1992; Larsson & Sandberg, 1991; Türk et al., 1996). Türk et al. (1996) demonstrated this by adjusting the pH of doughs with acetic acid. When the pH reached approximately 4.5, it was observed that as much as 96 percent of the phytate had been hydrolysed after 2 hours of fermentation (compared to only 36 percent reduction in the control bread (pH 5.3-5.8)). This is in agreement with the findings of Larsson & Sandberg (1991). It is believed that phytate-reductions of this magnitude lead to significant increases in the bioavailability of minerals (Larsson & Sandberg, 1991). At the same time, it is important to emphasize that this pH range is not obtainable in doughs unless acidic ingredients (e.g. juices) are added.

### *Fermentation time*

Despite the fact that the rate of phytate-hydrolysis seems to be highest at the start of the fermentation period (Larsson & Sandberg, 1991), long fermentations are observed to maximize the amount of phytate degraded. In a study by Nävert, Sandström & Cederblad (1985), the effect of fermentation time on phytate reduction and zinc absorption from breads, was examined. From containing 1370 µmol phytate after 15 minutes of fermentation, it was observed that the levels had been reduced to 520 µmol after 16 hours. In the case of zinc



absorption, a doubling was observed after 16 hours versus 45 minutes of fermentation. This may favour sourdoughs with long fermentation periods.

### *Temperature*

Optimal temperature for 3-phytase and 6-phytase is estimated to be 30°C and from 50 to 55°C, respectively (Fretzdorff & Brümmer, 1992; Türk et al., 1996).

### *Water level*

Phytate is a water-soluble compound which has been observed to be hydrolysed to a greater extent in dough systems than in flours alone (Fretzdorff & Brümmer, 1992). It is believed that water stimulates the phytase activity. According to Lopez et al. (2002), phytate-hydrolysis may furthermore seem to rise with increasing amounts of water. This corresponds to the benefits of high moisture breads reported in chapter 6.5.

### ***Summary and conclusion***

Due to their acidity, sourdoughs have several times been observed to possess health benefits beyond their stimulating effect on phytate-degradation. Their acidic environment is, for example, found to reduce the activity of several digestive enzymes - especially  $\alpha$ -amylase which is responsible for starch degradation (Katina et al., 2005). Scazzina, Rio, Pellegrini & Brighenti (2009) were in this context evaluating the influence of sourdough fermented breads on postprandial glycaemic response and found significantly lower increments compared to the increments following consumption of yeast-fermented breads. Probably, some of this effect may also be ascribed to the organic acids (e.g. lactic or acetic acid) which are observed to play a direct role in blood glucose reduction (Liljeberg, Lönner & Björck, 1995; Östman et al., 2002).

Sourdoughs have also been reported to stabilise or increase the levels of various bioactive compounds (e.g. folate and different phenolic compounds) (Kariluoto et al., 2004; Luukkonen et al., 2003), but also to decrease the levels of tocopherol, tocotrienol and thiamine – tocopherol and tocotrienols with as much as 20 to 60 percent (Katina et al., 2005; Luukkonen et al., 2003; Wennermark & Jägerstad, 1992). Finally, sourdough products are observed to have an extended shelf-life compared to yeast-leavened products. It is believed that the organic acids generate antibiotic compounds and promote a microbial stability that is essential in the prevention of microbial growth (e.g. fungal spoilage) (Corsetti & Settanni, 2007). The benefits of products with an extended shelf-life were elaborated in chapter 6.5. These products

do not only satisfy consumer demands, but also the ethical concerns attached to food consumption.

Based on the abovementioned aspects, it may seem evident that sourdough fermentation is the most beneficial fermentation method in the case of increasing the nutritional value of the bread, as well as its sensory qualities and shelf life. However, in light of the practical aspects, the method is not so favourable. By being divided into several steps it may for example take up to ten days from the dough is set to the bread is finished (Whitley, 2009). Additionally, it may be a difficult and challenging fermentation technique – especially for beginners. One of the criteria for an “ideal” bread is that the baking process is so convenient that people want to start baking on their own. In other words; is it possible to transfer the beneficial properties of sourdough fermentation into a simpler fermentation method?

In the second section of this thesis, the industrial bread was in focus. The bread industry’s widespread use of yeast to shorten down the fermentation time is often criticized. A baker may use as much as 100 g baker’s yeast per l water (Meyer, 2009). According to Meyer (2009), this amount of yeast does not only give the bread a “yeasty” taste, but may also make it seem drier and thereby affect its shelf life. Instead of minimalizing the fermentation time by scaling up the amount of yeast, Meyer (2009) and Hjelme (2004) are focusing on extending it. In their bread recipes it is stressed that yeast-doughs should be fermented up to 24 hours, and that the amount of baker’s yeast should be limited to 10 g per l water. Due to such a long fermentation<sup>50</sup> time it is also recommended that the doughs are placed in a cool place, e.g. a refrigerator.

Although a cool temperature is not facilitating optimal conditions for the phytases (as described above), a long fermentation period gives the dough time to stimulate phytate-degradation. Moreover, and perhaps most important of all, prolonged fermentation periods are observed to stimulate the growth and formation of LAB and its fermentation products (e.g. lactic and acetic acid) in the same way as sourdoughs (Meyer, 2009). This may also be one of the reasons why long-leavened breads are observed to have a longer shelf life compared to breads based on a short fermentation periods and large amounts of added yeast (Meyer, 2009).

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<sup>50</sup> Long and warm fermentation generates a degradation of the gluten network and hence a reduced loaf volume (Meyer, 2009).

In different studies it has also been observed that yeast-fermentation over relatively long periods are beneficial in the case of increasing the bread's level of different bioactive compounds. For example, it may seem like the yeast contains and stimulates the synthesis of both riboflavin (up to 30 percent increase) and folate (up to 65 percent increase) (Batifoulier, Verny, Chanliaud, Rèmèsy & Demigné, 2005; Kariluoto et al., 2004), while it retains thiamine, pyridoxine (B<sub>6</sub>), carotenoids and vitamin E which under short fermentation periods to a large extent are observed to get lost (Batifoulier et al., 2005; Leenhardt et al., 2006).

Based on this review, it seem like fermentation methods initially selected due to their phytate-degrading capacity, may produce breads with several other qualities. When small amounts of yeast, as well as long fermentation periods are applied, the breads are for example obtaining a good taste, a longer shelf life, as well as many nutritional benefits, e.g. a reduced GI and a higher level of several micronutrients. Last but not least, this is a simple and time-saving fermentation method. After the kneading, the dough is placed in the refrigerator. The next day, the dough is transferred into baking tins which are placed directly into the oven. In this way, you do not have to heat up water and wait for the dough to ferment.

## 6.7 Baking

So, the ingredients are identified, mixed, kneaded and fermented, and the final step of the bread making process can start – the baking. When the bread is put in the oven there are a range of physical, chemical and biochemical processes that are taking place; the dough is expanding due to an increased temperature and yeast activity (the “oven spring”), water evaporates from the dough's surface and forms the crust, starch is gelatinized, proteins are coagulated and enzymes are inactivated (Eliasson & Larsson, 1993; Ledsaak & Eben, 2010; Mondal & Datta, 2008). Moreover, the heat stimulates a non-enzymatic reaction between reducing sugars (sugars with free carbonyl groups, i.e. all mono- and disaccharides except for sucrose) and the free amino acid asparagine – the so-called *Maillard reaction* (MR) (Claus, Carle & Schieber, 2008a; Lignert et al., 2002; Stadler & Scholz, 2004).

The MR results in the formation of a wide range of brown melanoidins (i.e. polymers of high molecular weight) - also known as Maillard reaction products (MRPs). Some MRPs are desirable components that are essential for the roasty flavour and colour development of the bread (Claus et al., 2008a; Stadler & Scholz, 2004; Taeymans et al., 2004). Furthermore,

some MRPs are found to exert anti-oxidative effects (e.g. by scavenging oxygen radicals and chelate metal-ions). In a study by Nicoli, Anese, Parpinel, Franceschi & Lericci (1997), it was in fact indicated that the antioxidant activity of food products (tomatoes and coffee) could be maintained and even enhanced by the development of MRPs – despite significant losses of natural occurring antioxidants during the thermal treatment. However, some MRPs are also found to be unfavourable. One of these compounds is acrylamide (Claus et al., 2008a).

### *6.7.1 Acrylamide*

Easily explained, acrylamide is a reactive compound that is observed to exert toxicological actions in animals and humans (Aune, 2007). After being absorbed from the intestine, acrylamide is readily incorporated and distributed in the body where it in the liver is metabolized into glycidamide via a cytochrome P-450-enzyme or conjugated to glutathione<sup>51</sup>. Both acrylamide and its metabolites are found to interact and bond with different macromolecules, e.g. haemoglobin, enzymes and DNA. This has been observed to cause mutations and cancers, as well as neurological and reproductive damages in various experimental mammalian in vivo and in vitro studies (Aune, 2007; Claus et al., 2008a; Lingnert et al., 2002).

It is important to keep in mind that the findings regarding acrylamide's neurotoxic and reproductive-damaging effects only are observed at very high dosages, i.e. 0.5 mg/kg body weight and day (Claus et al., 2008a). Such amounts are not obtainable via food products. In a Swedish study, it was for example estimated that the daily dietary intake of acrylamide in the adult population “only” accounted to 35 µg per day, meaning approximately 0.5 µg/kg body weight/day in a person weighing 70 kg (Svensson et al., 2003). The conclusion is also supported by the fact that acrylamide has a relatively short half-life (approximately ten days), meaning that it does not accumulate in the body to toxic levels (Aune, 2007).

In the case of cancers, acrylamide was already in 1994 defined as “probably carcinogenic to humans” (Group 2A)<sup>52</sup> by IARC (IARC, 1994). This conclusion was mainly based on results from animal studies. Since then, much effort has been (and still is being) put into elaborating the relationship between intake of acrylamide and cancers in humans. Some studies are

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<sup>51</sup> An important compound in the body's antioxidant defence (Thommessen & von Krogh, 2001).

<sup>52</sup> Meaning that there is “sufficient evidence of carcinogenicity” in relation to animals, but “limited evidence of carcinogenicity” in relation to humans (Aune, 2007).

indicating a connection. In a prospective study with women, it was for example found an increased risk of postmenopausal endometrial and ovarian cancer with increasing acrylamide consumption (Hogervorst, Schouten, Konings, Goldbohm & van den Brandt, 2007). Olesen et al. (2008) found a significant correlation between the risk of breast cancer and the levels of acrylamide-haemoglobin adducts in the red blood cells<sup>53</sup>. On the contrary, there are studies that have not been able to find any clear correlation (Mucci, Dickman, Steineck, Adami & Augustsson, 2003; Mucci et al., 2005; Pelucchi et al., 2006).

In Norway, it was in 2002 estimated that the intake of acrylamide yearly contributes to approximately 40 cases of cancer (i.e. one percent of all food-related cancers) (Mattilsynet, 2012). Table 6-9 presents the acrylamide levels in a selection of foodstuffs. It is well-established that heat-treated carbohydrate-rich foods, especially potato products, contain the highest levels of acrylamide (e.g. potato crisps: 1360 µg/kg) (Svensson et al., 2003). However, based on actual consumption, bread and coffee should be considered as the food categories most responsible for the dietary intake – although their acrylamide levels are at the lower end of the range. Bread is for example estimated to have an average acrylamide content of 50 µg/kg (Dybing et al., 2005; Svensson et al., 2003).

**Table 6-9** Acrylamide levels in various food items

| <b>Food product</b>      | <b>Acrylamide level<br/>(µg/kg)</b> |
|--------------------------|-------------------------------------|
| Potato crisps            | 1360                                |
| Crisp bread (unleavened) | 300                                 |
| Bread                    | 50                                  |
| Coffee                   | 25                                  |

Adopted from Svensson et al. (2003)

### *6.7.2 How to reduce the bread's concentration of acrylamide?*

Despite the fact that available data are too limited to draw any conclusions regarding the health risks associated with acrylamide consumption, it is clear that an "ideal" bread should contain as small amounts of this component as possible (Claus et al., 2008a). In the same way as phytate-degradation is modified by influencing the main variables affecting the fermentation process, the generation of acrylamide may be reduced by adjusting factors involved in the baking process. First and foremost, acrylamide formation is closely linked to

<sup>53</sup> A biomarker for acrylamide exposure (Olesen et al., 2008).

the concentration of acrylamide-precursors in the raw material, i.e. the flours concentrations of asparagine and reducing sugars (Claus et al., 2006; Dybing et al., 2005). The dough's pH, salt and water content, as well as the fermentation method, baking time and temperature used are also identified as important adjustable parameters (Keramat, LeBail, Prost & Jafari, 2011; Lingnert et al., 2002; Taeymans et al., 2004).

However, the formation of acrylamide is also closely linked to the formation of the other MRPs described above. This can be illustrated by the fact that approximately 99 percent of the acrylamide found in breads is located in the crust and strongly correlating with components essential for the organoleptic properties of the bread (e.g. flavour, colour and texture) (Ahrnè, Andersson, Floberg, Rosèn & Lingnert, 2007; Keramat et al., 2011; Taeymans et al., 2004). So, when speaking about measures related to acrylamide-reduction, it should be taken into account that some of these measures are prone to affect the formation of beneficial MRPs. This will be described in a later section.

### ***The flours concentration of asparagine and reducing sugars***

First and foremost, it is important to remember that the flour's concentrations of asparagine and reducing sugars greatly vary depending on factors like type of cultivar, seasonal variations, fertilization, harvesting and storing conditions (Claus et al., 2006). For a consumer, these kinds of variations are unavoidable. However, there are some tendencies that seem consistent and that should be taken into account. They will now shortly be outlined.

In several studies on breads, asparagine is found to be the limiting substrate in the formation of acrylamide (Amrein, Schönbacher, Escher & Amadò, 2004; Claus et al., 2006; Surdyk, Rosèn, Andersson & Åman, 2004). As an example, it was in a study by Mustafa, Andersson, Rosèn, Kamal-Eldin & Åman (2005) observed that addition of asparagine led to proportional and significant elevations in the levels of acrylamide - regardless of the fructose level (i.e. the reducing sugar). Similar observations were reported by Surdyk, Rosèn, Andersson & Åman (2004). This may indicate that a lower concentration of asparagine in the dough may lead to a lower rate of acrylamide formation, and that focus should be placed on prioritizing ingredients with low levels of asparagine.

In this respect, it is observed that wheat flours contain significantly less asparagine than flours from barley, oat and rye (Claus et al., 2006; Fredriksson, Tallving, Rosèn & Åman, 2004; Taeymans et al., 2004). In chapter 6.2, it was concluded that wheat should account for the

largest share of flours in the recipe, mainly due to the sensory qualities of wheat flour. However, in this context it may seem like wheat is a good alternative also in the case of reducing the formation of acrylamide. Simultaneously, and as mentioned in chapter 6.2.6, it is found that N-fertilization of grains improves their nitrogen utilization and thereby formation of proteins and amino acids (including asparagine) (Claus et al., 2006). Sprouting has furthermore been observed to increase the enzyme activity (especially of proteases) in grains. Again, this leads to elevated levels of free amino acids in the flour (Claus et al., 2006). Based on these observations, organic flour may point out as more beneficial than conventional flour, as organic production prohibits the use of these substances (Scialabba & Müller-Lindenlauf, 2010).

Glucose and fructose are observed as the sugars most often present in the MR (Claus et al., 2008a; Taeymans et al., 2004). In addition to being involved in the formation of acrylamide, reducing sugars have the greatest impact on the colour development of the crust (Lingnert et al., 2002). As mentioned earlier, sugar, or sugar-containing ingredients (e.g. syrup and beer) will not be added to the recipe. It should, however, be noted that mono- and disaccharides are naturally present in flours, and to a larger extent in flours with higher extraction rates (as showed in table 6-2). This is also the case for asparagine. Mainly, this is due a higher concentration of proteins and amino acids in the outer bran (Claus et al., 2008a; Keramat et al., 2011), but also a higher level of proteases and amylases which increase the hydrolysatation of proteins and carbohydrates to free amino acids and mono- and disaccharides (Claus et al., 2006). However, based on the health-effects of whole grain consumption, it is probably not an option to substitute whole grain flours with refined flours to reduce the formation of acrylamide. On the contrary, it is in fact indicated that water-binding compounds, e.g. whole grains, may inhibit the reactions involved in the formation of acrylamide (Rydberg et al., 2003). This leads to the next parameter; the dough's moisture level.

### ***Water amount***

Acrylamide is highly soluble in water. The dough's moisture level may therefore play an inhibitory role in its formation by functioning as a solvent agent (Lingnert et al., 2002). In a study with biscuits, it was demonstrated that the dough's moisture level significantly affected the biscuits' final concentration of acrylamide. At a 10 percent moisture level, no acrylamide was detected. However, with descending moisture levels, increasing concentrations of acrylamide were observed (Taeymans et al., 2004).

In addition to being a solvent agent, it is proposed that water may exert a cooling effect. Many studies are focusing on the oven temperature when observing acrylamide formation. However, since acrylamide mainly is located in bread's crust, it is the temperature of the bread's surface that should be of importance for its formation (Ahrnè et al., 2007; Claus et al., 2008a). The crust is formed when the surface temperature increases and water starts to evaporate. When the surface dries out and the water-activity drops, the MR is stimulated (Claus et al., 2008a; Keramat et al., 2011). Taeymans et al. (2004) demonstrated that evaporating water may have a cooling effect on the crust; even with an oven temperature of 220°C, the effective temperature of the crust never reached 120°C. In another study on acrylamide formation in breads, Ahrnè et al. (2007) determined the effect of crust temperature and water content. The results showed that lower levels of water led to increased crust temperatures and an increased formation of acrylamide. A relatively high moisture level, as proposed in chapter 6.5 for an "ideal" bread, may therefore be beneficial. On the contrary, moist breads require a longer baking time (see below).

### ***Fermentation***

In the case of fermentation, there are studies that have found that the choice of fermentation method may affect the dough's level of asparagine. Fredriksson et al. (2004) examined the effect of both yeast and sourdough fermentation, as well as short (15+15 minutes) and long (180+180 minutes) fermentation periods. When comparing yeast versus sourdough fermentation, it was demonstrated that the use of added yeast was most efficient in reducing asparagine. After two hours of fermentation, nearly all the asparagine (92 percent) was utilized by the yeast. In the case of sourdough fermentation, it was after 72 hours of leavening also found lower levels of asparagine (from 1.0 g/kg to 0.7 g/kg). However, after refreshing the dough, the levels were again rising (to 1.2 g/kg). It is believed that this difference mainly is due to the yeast's ability to metabolize amino acids (including asparagine) as a source of nitrogen for its growth (Fredriksson et al., 2004). LABs, as found in sourdoughs and to some extent in long-fermented doughs, are on the other hand observed to inhibit this metabolism (Claus et al., 2008a).

In the case of fermentation time, it was observed that the long fermentation period was most efficient in reducing the levels of acrylamide in the final bread (Fredriksson et al., 2004). Compared with the short fermentation period, it reduced the levels of acrylamide in a whole grain wheat bread with 87 percent (24 µg acrylamide/kg versus 180 µg acrylamide/kg,



respectively). The corresponding reduction in rye breads was 77 percent. It is believed that longer fermentation periods allow more asparagine to be utilized by the yeast (Fredriksson et al., 2004). Based on these findings, which also are supported by others (Claus, Mongili, Weisz, Schieber & Carle, 2008b), it may seem like an extensive fermentation with added yeast (which also was the conclusion in chapter 6.6) may be the most efficient fermentation method when it comes to reducing the dough's levels of asparagine and probably also acrylamide.

### ***pH and salt level***

pH values around 8 are identified as optimal with regard to the MR (Rydberg et al., 2003). A low pH may consequently be favourable in the case of reducing the generation of acrylamide - just as a low pH was concluded to promote an optimal phytate-degradation. In addition to slow down the generation of acrylamide, it is proposed that an acidic environment leads to a more rapid degradation of acrylamide that is already present (Rydberg et al., 2003). By adding e.g. ascorbic acid as described in a previous chapter, it is for example observed that the levels of acrylamide may decrease almost linearly (Keramat et al., 2011). Amrein et al. (2004) observed an almost four-fold reduction in the levels of acrylamide after adding citric acid. However, when speaking about slowing down the MR, it is also important to remember that at more moderate MR decreases the formation of organoleptic MRPs (Claus et al., 2008a). For example, it is observed that the colour development of breads increases with increasing pH (Lingnert et al., 2002).

In the case of salt, there are studies that indicate that NaCl - to a certain level - may lower the formation of acrylamide. Kolek (2006) found that 1 percent NaCl could reduce the formation with 40 percent, while Claus et al. (2008b) reported a significant reduction up to 2 percent NaCl addition, while higher levels were stimulating an increased formation. It is believed that lower levels of salt may inhibit the amylase activity, and thereby reducing the release of reducing sugars, while a higher salt level is preventing the yeast's amino acid metabolism (Claus et al., 2008b). A low salt addition, as proposed in chapter 6.4, may therefore be beneficial in the case of reducing the bread's final concentration of acrylamide.

### ***Baking time and temperature***

Finally, both baking time and temperature are essential parameters influencing the MR and acrylamide formation. In a study by Bråthen & Knutsen (2005), it was observed that the

amount of acrylamide present in bread crusts strongly correlated with increasing baking time and temperatures. In another study it was demonstrated a 30 percent reduction in the levels of acrylamide when the baking temperature was lowered (from 210°C to 180°C) and the baking time prolonged (from 52 minutes to 80 minutes) (Haase, Matthäus & Vosmann, 2003). These results may indicate that the baking temperature is a stronger influencing factor in the MR than the baking time.

As mentioned above, it is the crust's temperature which is of importance when studying acrylamide-formation. Acrylamide is not detected unless this temperature rises above 120°C, and this happens as soon as the crust dries out (Ahrnè et al., 2007; Aune, 2007; Keramat et al., 2011). As stated above, water may play an important inhibitory role in acrylamide-generation by lowering the surface temperature of the crust. Moreover, there are several studies that have focused on the possibility of adjusting the baking temperature. In some studies it is found that a reduction in the temperature at the end of the baking period may lower the levels of acrylamide in the final product. In one study it was demonstrated that a reduction from 220-230°C at the start, to 190°C at the end of the baking period, could reduce the acrylamide-generation with 60 percent (Claus et al., 2008a). This can be explained by the fact that the MR is more intense at the end of the baking period (Keramat et al., 2011). However, such strategies are also observed to impair the sensory qualities of the bread, e.g. by providing less flavour and aroma due to a lighter crust (Ahrnè et al., 2007; Keramat et al., 2011). Two additional measures that should be mentioned in this context are the ability to cover the breads with baker paper during the baking (and hence lower the formation of MRPs), as well as the possibility of baking breads with thinner crusts (e.g. by baking the breads in a roasting pan). It is reasonable to believe that these measures will result in breads with lower acrylamide concentrations.

Based on this review, it becomes clear that there are a lot of dilemmas in deciding the optimal baking conditions. The main focus should be placed on minimizing the formation of harmful components like acrylamide. As outlined above, most of the factors involved in acrylamide-reduction are in accordance with the conclusions from the previous chapters, i.e. prioritizing wheat flour, a high moisture level and a prolonged fermentation, as well as low pH and salt levels. In relation to baking time and temperature, an intermediate alternative should be proposed (i.e. 200-220°C for approximately an hour). At this baking temperature, the

formation of acrylamide will be reduced (compared to baking temperatures at e.g. 250°C) at the same time as the breads sensory qualities will be addressed.

## 6.8 The "ideal" bread

### 6.8.1 The intervention bread

In relation to the bread baking intervention, that is part of this project (see attachment 1 for article), a bread recipe was developed. The recipe was formulated before the preceding literature review was conducted. Therefore, at this point, the bread only had four main criterias to fulfil, i.e. (1) to meet the criteria set out by the Keyhole scheme, (2) to achieve four cakes on the Bread scale, (3) to be well-tasting, and (4) that the recipe should be simple and time-efficient.

Bread baking books were used to look up a suitable and modifiable recipe. In Claus Meyers' book "Meyers bageri" (Meyer, 2009), simple recipes based on long fermentation at a low temperature (i.e. up to 24 hours fermentation at 4°C), were identified. By basing the recipe on the given amounts of water and yeast, different combinations of salt, flours and seeds were tested out. Table 6-10 presents the recipe for the intervention bread.

**Table 6-10** The intervention bread

| Ingredients (2 breads)  | Procedures   |
|---|--|
| <ul style="list-style-type: none"> <li>• 1 l cold water</li> <li>• 12.5 g yeast*</li> <li>• 10 g salt (1 teaspoon)</li> <li>• 2 dl flax seeds</li> <li>• 4 dl oat flakes</li> <li>• 3 dl white wheat flour</li> <li>• 4 dl whole meal wheat flour</li> <li>• 4 dl whole meal rye flour</li> </ul> | <p><b>Day 1</b></p> <ul style="list-style-type: none"> <li>• Mix the yeast with the water and add in rest of the ingredients.</li> <li>• Knead the dough thoroughly for minimum 20 minutes – preferably with some short breaks.</li> <li>• Put the dough in the refrigerator for 24 hours.</li> </ul> <p><b>Day 2</b></p> <ul style="list-style-type: none"> <li>• Divide the dough into to two baking tins.</li> <li>• Bake the breads in the oven at 200°C for approximately one hour and fifteen to thirty minutes.</li> <li>• Let the breads cool on a rack.</li> <li>• The breads should be kept in a towel after they have cooled down.</li> </ul> |

\* ¼ package of yeast

To confirm that the final recipe achieved a full *Bread scale*, the Bread scale calculator on the OBK websites (Opplysningskontoret for brød og korn, 2012a), was applied. Moreover, calculations in relation to the amount of whole grains, dietary fiber and salt, as well as nutrient calculations in relation to amount of sugar and fat were carried out to control that the bread fulfilled the *Keyhole* criteria. All calculations are given in attachment 6. Table 6-11 presents the results of the calculations.

**Table 6-11** Keyhole criteria and comparable numbers for the intervention bread

|                      | <b>Keyhole criteria*</b>   | <b>Intervention bread**</b> |
|----------------------|----------------------------|-----------------------------|
| <b>Whole grains</b>  | ≥ 25 % of dry matter basis | 78 % of dry matter basis    |
| <b>Dietary fiber</b> | ≥ 5 g/100 g bread          | 7.6 g/100 g bread           |
| <b>Sugar</b>         | ≤ 5 g/100 g bread          | 0 g/100 g bread             |
| <b>Salt (sodium)</b> | ≤ 0.5 g/100 g bread        | 0.22 g/100 g bread          |
| <b>Fat</b>           | ≤ 7 g/100 g bread          | 3.5 g/100 g bread           |

\* Source: Forskrift om frivillig merking med Nøkkehullet (2009)

\*\* For calculations, see attachment 5

As table 6-11 illustrates, the intervention bread fulfilled all *Keyhole* criteria. Compared with the quantity of whole grains (78 percent), the amount of dietary fiber (7.6g/100g) may, however, seem quite low. The main reason for this is the recipe's high moisture level. When this level is increased, the bread's relative share of dry matter basis, e.g. dietary fiber, is decreasing. At the same time, the bread's weight is increasing, making it more difficult to stay within the limits in relation to sugar, salt and fat. However, the bread is also well within these three limits. This can probably be ascribed to the fact that the bread is not containing any added sugars or fat. In relation to the salt level (0.22g Na/100g), this is also quite low. As a comparison, industrial *Keyhole* labelled breads contain on average 0.47 g Na/100g (own calculations). In addition to being relatively close up to the *Keyhole* limit of 0.5 g Na/100g bread, this corresponds to a difference of 0.25 g Na/100g compared to the intervention bread. The fact that this difference is quite large can be illustrated with the following example: If you yearly eat approximately four slices of bread per day (each slice weighing approximately 30 g), you ingest approximately 206 g salt from industrial breads, whereas the corresponding intake from the intervention bread is 96 g – meaning a difference of 110 g salt per year (for calculations, see attachment 7).

Compared with equivalent industrial breads (e.g. Vita hjertego'), the intervention bread is also quite low in energy (231 kcal/100g versus 173 kcal/100g (see attachment 6), respectively - i.e.

25 percent less energy. This difference can mainly be explained by the lower moisture levels present in industrial produced breads. By adding relatively low amounts of dietary fiber, and high amounts of salt (to stimulate the sensory attributes of the bread), the breads may still fulfil the *Keyhole* criteria as long as their water concentration is kept low (as indicated above). Considering the fact that a high water content is essential in the case of lowering a bread's energy density, as well as that the criteria set in relation to whole grains and salt are relatively low and high, respectively, it may be reasonable to modify some of the existing *Keyhole* criteria. Moreover, the present calculations contribute to underline the benefits of baking our own bread, e.g. in relation to keep control of what the bread contains.

In the attached article to this thesis it is shown that the intervention bread was well-liked by the intervention participants. Based on general feedbacks, the bread was, however, by some judged to be too moist. In relation to the practicability of the baking process, the recipe was appreciated for being simple and time-efficient. Altogether, all four criterias in relation to the intervention bread were therefore fulfilled.

### 6.8.2 *The "ideal" bread*

Table 6-12 presents a summary of the preceding literature review.

**Table 6-12** Summary of the literature review

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## **Health criteria**

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### **Low energy-density**

- Whole meal flours rather than refined flours
- Seeds rather than nuts
- High levels of water

### **High coarseness**

- Fulfil at least  $\frac{3}{4}$  on the Bread scale
- Whole meal flours rather than refined flours
- Coarsely rather than finely grounded whole meal flours
- Add seeds and nuts

### **Small amounts of salt/sugar/fat**

- Fulfil the Keyhole criteria
- Substitute sodium chloride with potassium chloride (e.g. Seltin)

### **Beneficial fat composition (high in n-3 fatty acids)**

- Barley and rye → low n-6 to n-3 ratio
- Walnuts and flax seeds → rich in n-3 fatty acids

### **Rich in antioxidants**

- Whole meal flours rather than refined flours
- Barley → high in antioxidants
- Organic flours → higher in antioxidants than conventional flours
- Walnuts → high in antioxidants

### **Avoid common allergy triggers**

- (Spelt rather than wheat) – limited data
- Avoid hazelnuts, walnuts and sesame seeds
- Flax seeds → seldom reported to cause allergic reactions
- Water instead of e.g. dairy products

### **Maximal nutritional value**

- Whole meal flours rather than refined flours
- Substitute wheat with barley, oat and rye
- (Spelt rather than wheat) – limited data
- Add seeds and nuts
- Stimulate phytate-degradation → add juice, long fermentation period, high moisture-level
- Dairy products → complement the bread's amino acid profile

### **Minimum of harmful contaminants**

- Organic flours → lower concentrations of mycotoxins
  - Avoid sunflower seeds → high in cadmium
  - Reduce acrylamide formation → wheat and organic flours, high moisture-level, long fermentation period with added yeast, low baking temperatures and prolonged baking
-

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## Sensory criteria

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### Appealing texture

- Refined flour → greater loaf volume and softness
- Finely rather than coarsely grounded whole meal flours → increased loaf volume
- Wheat → increased loaf volume
- Oat flakes → softness
- Long fermentation period → affects the breads texture
- High water level → prevents dry and compact breads

### Appealing appearance

- Refined flour → loaf volume
- Wheat flour → loaf volume
- High baking temperatures → golden crust

### Well tasting

- Refined wheat flour
- Barley, oat and rye → tasteful grains
- High water levels → moist breads
- Add seeds and nuts
- Salt addition
- Dairy products → richer taste
- Sourdough fermentation → richer taste
- Long fermentation period
- Small amounts of yeast
- High baking temperatures → roasty flavour

---

## Practical criteria

---

### Time-efficient

- Long and cold fermentation (up to 24 hours at 4°C)
- Few ingredients, simple recipe

### Cheap ingredients

- Conventional rather than organic flours
- Wheat rather than spelt
- Seeds rather than nuts
- Flax seeds rather than other seeds
- Water → free of charge

### Accessible ingredients

- Conventional rather than organic flours

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## Environmental criteria

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### Local ingredients

- Barley and oat → 100 percent domestically cultivated → less “food miles”
- Barley, oat and rye → increased agricultural biodiversity

### Organic ingredients

- Spelt rather than wheat → environmentally friendly production
-

As recognized from table 6.12, the intervention bread is fulfilling many of criteria that were set for an “ideal” bread. When the final bread recipe now is to be identified, it will therefore not result in any significant changes. Instead, it will be set out suggestions for how the intervention recipe can be modified.

### ***Health criteria***

The criteria in relation to high coarseness, low energy density, as well as low amounts of salt and sugar are all fulfilled by the intervention bread and will therefore not be changed or outlined any further. The same applies to the avoidance of allergy triggers, maximization and minimization of nutritional composition and harmful components, respectively.

In relation to the intervention bread’s fat composition, it is in attachment 8 carried out some calculations. As emphasized, an ”ideal” bread should strive for an optimal n-6 to n-3 ratio (i.e. 2:1). As the calculations illustrate, the intervention bread has a ratio of 0.5. This ratio is actually lower than recommended. In this context, there are, however, some aspects that should be taken into account. Firstly, and as outlined in chapter 6.3, the n-3 bioavailability from whole flax seeds are disputed. As suggested by Kuijsten et al. (2005), the bioavailability is only 28 percent. From another point of view, our diet is already quite high in n-6 fatty acids. A low n-6 to n-3 ratio may therefore be rather beneficial. The given amount of flax seeds will therefore be transferred to the “ideal” bread.

With regard to the bread’s antioxidant-level, this can to some extent be increased by substituting e.g. rye with barley flour.

### ***Sensory criteria***

The sensory qualities of the intervention bread were overall judged as good. While a long fermentation period (with low amounts of added yeast) gives the bread a good taste, the high moisture level contributes in making the bread’s high coarseness sensory acceptable. These parameters will therefore be transferred to the “ideal” bread.

### ***Practical criteria***

The intervention recipe was considered as simple and time-efficient by the intervention participants. In the case of price, it was in table 2-3 calculated that an industrially produced bread labelled with the *Keyhole* and a full *Bread scale* costs approximately 30 NOK. Table



6-13 illustrates the costs of the intervention bread. With total costs of approximately 14 NOK per bread (and a difference of 16 NOK compared to the industrial breads), it is confirmed that homebaked bread may be an economically beneficial alternative.

**Table 6-13** Costs (NOK) of the intervention bread (one bread)\*

| <b>Ingredients</b> | <b>Costs NOK</b> |
|--------------------|------------------|
| Flours             | 6.5,-            |
| Oat flakes         | 2.0,-            |
| Yeast              | 0.25,-           |
| Flax seeds         | 2.0,-            |
| Electricity**      | 3.0,-            |
| <b>SUM</b>         | <b>13.75,-</b>   |

\* Based on the prices presented in previous sections

\*\* 1.5 hours of baking<sup>54</sup>

### *Environmental criteria*

From an environmental point of view, it is reasonable to argue that an “ideal” bread should contain domestically produced barley rather than imported rye. This has also been tested. When the rye present in the intervention bread was substituted with barley, this resulted in breads with a more compact structure and a drier crumb. These breads may not be as sensory acceptable as the intervention bread. Another way of making the bread more environmentally friendly is by substituting the wheat with spelt. This will, however, increase the costs of the bread.

All in all, since the intervention bread was well-liked by the intervention participants, and that it already contains relatively high levels of oat (which is domestically produced), no changes in the flour composition will be made.

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<sup>54</sup> Electricity (1.5 hour of baking): Electricity price: 0.81 øre/kWh (Hafslund, March 2012)

Energy use (oven): 3 kW/hour

Time: 1.25 hour

Electricity price \* kW \* hours

= 0.81 \* (3 \* 1.25)

= 3.0 NOK

Table 6-14 presents the “ideal” recipe resulting from the literature review.

**Table 6-14** The “ideal” bread

---

|                             |
|-----------------------------|
| 1 l cold water              |
| 12.5 g yeast                |
| 10 g salt (1 teaspoon)      |
| 2 dl flax seeds             |
| 4 dl oat flakes             |
| 3 dl white wheat flour      |
| 4 dl whole meal wheat flour |
| 4 dl whole meal rye flour   |

---

When the ”ideal” bread now is identified, it is important to underline that this recipe takes all the four aspects outlined in this thesis (i.e. health, environment, sensory qualities and practical considerations), into account. Which aspects that are prioritized do, however, depend upon on individual preferences. For some, sensory attributes outweigh the health-related aspects. For a person normally preferring semi whole grain bread, extra whole grain bread (as the “ideal” bread) may for example not be viewed as sensory acceptable. From a health-perspective, it should, however, be a goal that this person starts to eat at least whole grain bread. In this situation, the recipe presented in table 6-14 may not be the most “ideal”, and it should therefore be modified – for example by substituting some whole grain flours with refined flours. In this way, table 6-12 can be used as a tool to modify the “ideal” recipe to fit with individual criterias. Table 6-15 is additionally listing some suggestions for alternative ingredients that may be included in the recipe to create some variation.

**Table 6-15** Alternative ingredients to be added to the "ideal" bread

| <b>Ingredients</b> | <b>Alternatives</b>   | <b>Properties</b>   |
|--------------------|---|---|
| <b>Liquids</b>     | Dairy products (e.g. milk, yoghurt)   | Increase the bread's protein quality. Yoghurt adds LABs. Provides a richer taste.                     |
|                    | Fruit and vegetable juices  | Increase the bioavailability of iron by stimulating phytate-degradation. Lowers acrylamide formation. |
|                    | Oils, syrup, vinegar, beer and eggs   | Affect taste and texture  |
| <b>Flours</b>      | Vary with different grains (for example by substituting rye with barley, wheat with spelt and oat flakes with different types of cereals (e.g. 4-korn)) | Create dietary variation  |
|                    | More flour can be added   | Provides a less moist bread (but increases the energy density of the bread)                           |
| <b>Salt</b>        | Seltin  | Higher in potassium   |
|                    | Sea salt  |   |
| <b>Seeds/nuts</b>  | All types of seeds and nuts can be added (sunflower seeds should be limited due to high cadmium levels)   | Creates dietary and taste variation   |
| <b>Others</b>      | Herbs and spices (e.g. allspice, coriander, basil, cinnamon) can be added   | Taste variation. Many types are high in antioxidants (Carlsen et al., 2010)                           |
|                    | Other ingredients, e.g. rasped carrot or swede  | Taste variation   |



## 7.0 CONCLUDING REMARKS

Even in periods when the nutritional value of breads is thoroughly discussed and debated, it is reasonable to believe that most Norwegians will continue to incorporate bread in their diet. This underlines the importance of eating a bread that is as ideal as possible. One fact that becomes obvious from this literature review is, however, that there is no single “ideal” bread. On the other hand, there may be several variations of ideal breads.

One of the main challenges of this process has been to draw some clear conclusions since the healthiest alternatives not always are the most optimal alternatives from a sensory point of view (e.g. in relation to whole meal versus refined flours), or that the most beneficial environmental alternative is the most practical one (e.g. organic versus conventional flour). At the same time, the recipe resulting from this work is aimed at being as close to an “ideal” bread as possible – both in relation to health, sensory qualities, environmental aspects, and practical concerns.



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# ATTACHMENT 1

*- Article*



# **Outcome and Process Evaluation of a Bread Baking Intervention - A Pilot Study**

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## **Keywords:**

Bread baking

Television viewing

Rothschild's Framework

Intervention Mapping

Intervention study

**Short title:** Evaluation of a bread baking intervention

## **Abstract**

**Objective:** To determine the outcome and process evaluation of a bread baking intervention aiming at getting people to start baking their own bread in order to; (1) eat a healthier bread, and (2) reduce their sedentary behaviours (i.e. TV watching).

**Design:** A bread baking intervention was developed and tested in a pilot study with a pre-post design (no control group). The intervention consisted of a two-day baking course and a commitment period in which the participants committed themselves to bake bread at least four times over a period of two weeks after the course. Baking habits (times per last 14 days) and TV/DVD/PC habits (minutes/weekdays, weekends, and yesterday) were measured by a questionnaire on three occasions – at baseline, two weeks (follow-up 1) and two-three months after the course (follow-up 2). Wilcoxon Signed Ranks Test was used to assess the impact of the intervention on baking and TV/DVD/PC habits.

**Setting:** Norway.

**Subjects:** Of a total of 51 participants (both men and women), 46 completed all three questionnaires. They constitute the study sample of the present paper.

**Results:** A statistical significant increase in the baking frequency was observed; from 0.2 times/last 14 days at baseline to 2.7 times/last 14 days at follow-up 1 ( $p < 0.001$ ), and 1.2 times/last 14 days at follow-up 2 ( $p < 0.001$ ). Furthermore, a non-significant decrease in the prevalence of TV watching was indicated; from 97 minutes/day at baseline, to 81 minutes/day at follow-up 1 ( $p = 0.31$ ), and 82 minutes/day at follow-up 2 ( $p = 0.23$ ).

**Conclusions:** The bread baking intervention was effective in increasing bread baking frequency, also beyond the 14 days of commitment time. Whether increased bread baking results in a lower frequency of TV watching needs further investigation.

## Introduction

Despite frequent discussions in the media about the health benefits of carbohydrates in general and bread in particular, bread still is an important part of the diet for most Norwegians. In a survey recently conducted on behalf of The Norwegian Bread and Cereals Marketing Board, it was for example indicated that 76 and 67 percent still incorporates bread (i.e. bread, crackers, rolls and baguettes) in their breakfast and lunch meals at a regular basis, respectively. Only five percent answered that they did not eat bread at all <sup>(1)</sup>.

However, the survey did also indicate that bread baking is a downward trend among the Norwegian population. When asked where they normally obtained their bread, 19 percent of the respondents stated that they were baking their own, however, not exclusively as 85, 15 and 1 percent were reporting to buy it in the grocery store, bakery or petrol station, respectively. Despite the fact that 19 percent is relatively high, 24 percent of the respondents did at the same time report to have eaten less home-baked bread the last couple of years <sup>(1)</sup>.

There are several arguments for why we should bake our own bread. Some of them are related to factors like nutrition and everyday activity. In relation to the nutritional aspects, it is for example well-known that most industrial breads are high in both salt and food additives <sup>(2)</sup>. By baking ourselves we are able to control what the bread contains and adjust the content of e.g. whole grains, fat, salt and water (the more water, the less energy). As an everyday activity, bread baking may furthermore be a contributing factor in breaking up and substitute sedentary behaviours (for example TV watching). Although baking only may be classified as a light-to-moderate intense activity, there are several authors suggesting that there may be the lack of engagement in such type of activities that causes the adverse health-effects observed from a sedentary lifestyle <sup>(3,4,5)</sup> (i.e. weight gain and all-cause mortality) <sup>(6,7)</sup>.

The present study assess the outcome and process evaluation of an intervention developed to get people to start baking their own bread in order to; eat healthier bread and reduce their sedentary behaviours (i.e. TV-watching).

## Experimental methods

### *Theoretical framework*

The present bread baking intervention was a pilot study with a pre-experimental design (i.e. a one-group sample in which before-and-after measurements were performed). The intervention was developed with inspiration from *Intervention Mapping*<sup>(8)</sup>, and based on *Rothschild's Framework*<sup>(9)</sup> of determinants affecting health behaviour change. From now only referred to as *Rothschild's Framework*.

### Intervention Mapping

*Intervention Mapping* is a technique used in the planning and development of interventions and can be drawn as a cycle<sup>(8)</sup>. The cycle starts with a planning process consisting of a needs assessment, establishment of objectives, selection of methods and production of program components. The planning process is followed by implementation and monitoring, before the cycle ends with a process evaluation. Based on scientific evidence and theories it guides how health behavior change should be induced<sup>(8)</sup>.

### Rothschild's Framework

It is well-known that we have to change the determinants of a behaviour in order to change the behaviour itself<sup>(10)</sup>. Based on different health communication theories (e.g. Theory of Planned Behaviour, Protection Motivation Theory and Social Cognitive Theory), four groups of factors that influence health behaviour have been identified; i.e. attitudes, self-identity, self-efficacy and social influence<sup>(10)</sup>. In *Rothschild's Framework*, as described by Brug<sup>(10)</sup>, these factors are represented by *motivation*, *ability* and *opportunity*. In the present intervention, these three determinants were further operationalized into four influencing factors, i.e. *attitude* (motivation), *knowledge* and *skills* (ability) and *time* (opportunity). Based on these factors, five change objectives were created, i.e. (1) get positive to bake bread (attitude), (2) learn what a healthy bread is (knowledge), (3) learn to bake bread (skills), (4) adopt a less time-consuming bread recipe (time), and (5) adjust bread baking to the timetable (time). These five change objectives formed the basis for the development of the intervention. The operationalization is further described by Jensen<sup>(11)</sup>.

## ***Intervention programme***

### **Baking course and commitment period**

The intervention programme consisted of a two-day baking course (both practical and theoretical) and a commitment period in which the participants committed themselves to bake bread at home for a minimum of four times over the following two weeks after the course. A total of six baking courses were carried out during October/November 2011. The courses were held in the school kitchens at the University College of Oslo and Akershus and Vestbygda Elementary School (Drammen municipality). LJ and KL were responsible for the course implementation.

At the first course day (lasting for approximately 45 minutes), the participants were shortly introduced to the intervention. Afterwards they were guided through a bread recipe developed especially for the course (see next section) and taught to make their own bread dough. The recipe was based on long and cold fermentation, and after the kneading the dough's were therefore put to storage in refrigerators until the next day (course day two). At course day two (lasting for approximately 90 minutes), a 45 minutes lecture was held while the breads were baking. The main focus of the lecture was placed on emphasizing the benefits connected to home-baked bread in relation to; health (e.g. the ability to adjust the breads coarseness, salt and water level), everyday activity (e.g. that baking may replace sedentary activities), the environment (e.g. reduced transport costs compared to industrially produced breads), economy (more economically beneficial compared to breads from the grocery shop or bakery), as well as taste. It was emphasized that the lecture should be understandable and easy to follow, e.g. by basing it on a low literacy level and with a frequent use of illustrations.

The intention with the commitment period was to give the participants some time to establish a baking habit. For this period, they were given all necessary ingredients and equipment, as well as a printed recipe booklet with pictures illustrating the baking process step by step.

### **The bread recipe**

The bread recipe was developed based on a literature review <sup>(12)</sup> and practical testing. First and foremost, it was emphasized that the recipe should be healthy, well tasting, timesaving and convenient. In relation to the health aspect, focus was primarily placed on the recipe to have a high coarseness and relatively low amounts of salt. To set some exact criteria in this

context, it was decided that the intervention bread should achieve the criteria set out by the *Keyhole* and achieve a full *Bread scale*. These are food-labelling schemes applied in Norway to identify the healthiness of food products in general (the *Keyhole*), and bread in particular (the *Bread scale*)<sup>(13, 14)</sup>.

To achieve the *Keyhole*, the bread had to fulfil the following criteria: minimum 25 percent whole grains of total dry matter basis, minimum 5 gram dietary fiber per 100 gram bread and maximum 5 gram sugar, 0.5 gram salt (sodium) and 7 gram fat per 100 g bread<sup>(13)</sup>. To achieve a full *Bread scale*, whole grains (i.e. whole grains, whole grain flours and bran) should constitute at least 75 percent of total flour amount<sup>(14)</sup>. This resulted in a recipe (see table 1) with a high coarseness (78 percent), relatively much dietary fiber (7.6g/100g), low amounts of salt (0.2g/100g) and fat (3.5g/100g), and no added sugar. Due to a high water content, the bread also had a relatively low energy-density (173 kcal/100g).

As the fermentation process often is divided into several steps, many claim bread baking as a time-consuming activity<sup>(15)</sup>. This fact emphasizes the importance of a time-efficient fermentation technique. The recipe of the intervention bread was therefore based on a method where the dough is fermented at a low temperature (approximately 4°C) over a period of 24 hours. In this way, the workload related to the baking process is spread over two days. In total, the intervention bread requires approximately 20 to 30 minutes of mixing ingredients and kneading (day one), and one and a half hour baking in the oven (day two). It is also worth mentioning that a long fermentation time is found to increase the bioavailability, as well as the amount of several nutrients present in the bread (e.g. iron, zinc and different B-vitamins)<sup>(16, 17)</sup>.

Thus, the bread baking intervention set out to try to influence the participant's bread baking habits through the four determinants, i.e. *attitude* (by including a motivation lecture), *skills* and *knowledge* (by including an educational lecture, as well as a practical baking session), and *time* (by including an easy, timesaving and convenient bread recipe).



## ***Pilot study***

### **Study sample**

The majority of the participants were recruited among the employees at the University College of Oslo and Akershus, Vestbygda Elementary School and Fredholdt Nursing Home, as well as among parents at Karihaugen Kindergarden and users of Akropolis Training Center in Drammen. These arenas were mainly chosen based on their proximity to the kitchen facilities. Furthermore, a part of the study sample was recruited by the “snowball-method”, i.e. from the social networks of the people already included in the study.

Telephone and e-mail contact was made with the concerned places and people. Furthermore, an information letter, describing the aim of the intervention and participant requirements (i.e. answering three questionnaires and bake at least four times during the two-week commitment period), was sent out. The ones interested were asked to take contact with the study coordinators by mail or telephone. People with celiac disease, people who were part of weight reduction programs and/or people who baked bread regularly, were excluded.

As an initial goal, a study sample of 50 participants was planned. This number was mainly based on practical aspects (e.g. time, facilities and economy), but also the fact that this only was a pilot study, meaning that a large study sample was not required.

A total of 51 respondents (88 percent women) agreed to take part in the study. The sample had a median age of 48 years, and 72 percent had higher education (i.e. at least three years at university college/university).

Research clearance was obtained from the Norwegian Social Science Services (NSD). Written informed consent was obtained from each participant before joining the study. All participation was voluntary.

### **Study design and instruments**

To evaluate the intervention, an outcome and process evaluation was conducted. A total of three semi-structured questionnaires were developed. The first questionnaire was filled out at the first course day (baseline), while the second and third questionnaires were filled out two weeks (follow-up 1) and two months (follow-up 2), respectively, after attending the course. Due to the Christmas holidays, and the fact that most people make some changes in their

eating and cooking habits during these days, some of the participants had a longer period between questionnaire two and three (up to three months). All participants (a total of 51) filled out the questionnaire at baseline, and 49 and 46 completed the questionnaires at follow-up 1 and follow-up 2, respectively. Only the participants returning all three questionnaires (a total of 46) are included in the statistical analysis of the present study.

Information concerning their completion was given at the front page of each questionnaire. Furthermore, there was stressed that there were no right or wrong answers and that all information was made unidentifiable by the use of ID-numbers. The questionnaires were delivered and collected at the workplaces of the participants or by ordinary mail. If the questionnaire was sent by post, a prepaid return envelope was sent along. E-mails and text messages were sent out to remind the participants of filling out and delivering the questionnaires.

The three questionnaires were identical, while questionnaire two also included questions related to the process evaluation of the intervention. Each questionnaire started by asking for general information, i.e. age, highest completed education and weekday. Furthermore, the questionnaires included questions related to bread and baking habits and determinants of baking (i.e. knowledge, attitude, skills and perceived time to bake) and TV/DVD/PC habits.

### **Bread and baking habits**

To assess baking frequency, the participants were asked to state the number of times they had been baking the last 14 days. Bread consumption was assessed by asking for the normal intake of slices of bread per day, as well as the intake yesterday. Type of bread eaten was assessed by ticking of one of the following alternatives: “white” (a coarseness of 0-25 percent), “semi-whole grain” (a coarseness of 25-50 percent), “whole grain” (a coarseness of 50-75 percent) and “extra whole grain” (a coarseness of 75-100 percent) bread. The answers were later recoded into coarseness percentage (12.5, 37.5, 62.5 and 87.5 percent, respectively). Bread origin was examined by asking the participants where they normally obtained their bread. Following answer options were given: “grocery store”, “bakery”, “home-baked” or “other”. Before the statistical analysis, these answer options were sorted and recoded as home-baked (1) or not (0).

### **Determinants of baking habits**

Bread knowledge was measured by asking the participants to describe in their own words the concepts of the *Keyhole* and the *Bread scale*. The answers were assessed by the authors as right or wrong and coded into 1 and 0, respectively. Moreover, the respondents were asked to rate their knowledge about bread and health on a five-level scale (“very good”, “good”, “neither good or insufficient”, “insufficient”, “very insufficient”). These answer options were later recoded from -2 to 2, with 2 being the highest score (i.e. “very good”).

The rest of the baking determinants (i.e. attitude, skills and time) were respectively operationalized by the following statements: “I am motivated to bake my own bread” (attitude), “I master to bake bread” (skills) and “I have time to bake bread” (perceived time). All three statements were answered by the use of a five-level scale (“totally agree”, “agree”, “either or”, “disagree”, “totally disagree”). These answer options were recoded from -2 to 2, with 2 being the highest score (i.e. “totally agree”).

### **TV/DVD/PC habits**

To determine sedentary behavior, number of hours spent on TV/DVD and PC on weekdays, weekends and yesterday was assessed. The questions, obtained from the ENERGY project <sup>(18)</sup>, had the following answer options; “None”, “Less than 30 minutes a day”, “30 minutes a day”, “One hour a day”, “One hour and 30 minutes a day”, “Two hours a day”, “Two hours and 30 minutes a day”, “Three hours a day”, “Three hours and 30 minutes a day”, “Four hours or more a day”. Before the statistical analysis, these answer options were recoded into number of minutes (i.e. from 0 to 240 minutes or more).

### **Process evaluation**

Process evaluation was assessed by measuring the *attractiveness* and *relevance* <sup>(19)</sup> of the intervention. These were operationalized by asking questions related to course enjoyment and course relevance, respectively. The assessment of course enjoyment included four questions: “How did you like the bread baking course/the bread baking/the lecture/the bread?” Following response alternatives were given; “very good”, “good”, “bad”, “very bad” and “neither good or bad”. The three questions related to course relevance included: “How relevant do you think the bread baking/the lecture was for you?” and “How much benefit do you feel that you have had of the course?” Following answer options were given: “very useful”, “useful”, “less useful”, “very little useful” and “neither useful or useless”, as well as

“large benefit”, “some benefit”, “little benefit”, “very little benefit” and “either or”. All the response alternatives in relation to the process evaluation were scored from -2 to 2, with 2 being the highest score (i.e. “very good”/“very useful”/“large benefit”). Enjoyment and relevance scales were developed by aggregating the variables related to each of them. The scales ranged from -8 to 8 (enjoyment) and from -6 to 6 (relevance).

### **Statistical analysis**

Statistical Package for the Social Sciences (SPSS, version 19.0) was used for all the statistical analysis. Mean values and standard deviations (SD) for age, gender and education were calculated for the whole sample. The effects of the intervention were analyzed by using Wilcoxon Signed Ranks Test to assess changes in the data between baseline and follow-up 1, and between baseline and follow-up 2.

Two-sided p-values were used to assess whether the associations were statistical significant. The significance level was set to 0.05.

## **Results**

### **Outcome evaluation**

A statistical significant increase in reported baking frequency during the last two weeks was observed; from 0.2 times at baseline to 2.7 times at follow-up 1 ( $p < 0.001$ ). By follow-up 2, the corresponding frequency had decreased to 1.2 times, but still, it was significantly higher compared with baseline ( $p < 0.001$ ). Furthermore, there was observed a significant increase in the percentage of participants reporting eating home-baked bread - from 4 percent at baseline to 33 percent at follow-up 1, and 40 percent at follow-up 2 (both  $p < 0.001$ ). Compared with baseline, the bread eaten was also significantly coarser at both follow-up 1 (58 % vs. 63 %,  $p = 0.05$ ) and follow-up 2 (63 %,  $p = 0.01$ ) (see Table 2).

Significant increases in the knowledge scores (i.e. in relation to the *Keyhole* and the *Bread scale*) were observed from baseline to follow-up 1 (28 % to 61 % ( $p < 0.001$ ), and 39 % to 72 % ( $p = 0.001$ ), respectively). These values remained stable at follow-up 2. Also the respondents self-rated knowledge score did increase; from 0.5 at baseline to 1.1 at follow-up 1 ( $p < 0.001$ ), and 1.0 at follow-up 2 ( $p < 0.001$ ) (see Table 2).

Regarding the other self-rated baking determinants (i.e. attitude, skills and time), a significant increase was only observed for skills – from 1.4 at baseline to 1.8 at follow-up 1 ( $p=0.008$ ), and 1.7 at follow-up 2 ( $p=0.01$ ).

The variables measuring time spent on TV/DVD indicated a non-significant decrease between baseline and the two follow-ups; from 96.9 minutes per day at baseline to 81 minutes per day at follow-up 1 ( $p=0.31$ ), and 82.2 minutes per day at follow-up 2 ( $p=0.23$ ) (based on minutes watched yesterday). In relation to the time spent on PC there was observed inconsistent changes, all non-significant (see Table 3).

### **Process evaluation**

The mean scores of the course enjoyment and course relevance scales were 6.5 and 4.2, respectively (see Table 4), and all participants rated the process evaluation items as “good” or “very good”.

With respect to baking frequency (last fourteen days) and TV/DVD habits (yesterday), there were not observed any changes between respondents with high vs. moderate enjoyment and relevance scores (data not shown). All groups followed the trends described above, i.e. a significant increased baking frequency and a non-significant decrease in time spent on TV/DVD.

### ***Discussion***

The purpose of the present study was to assess the outcome and process evaluation of an intervention developed to get people to start baking their own bread in order to; eat a healthier bread and reduce their sedentary behaviors (i.e. TV-watching). While the results indicated that the intervention failed in significantly affecting the participants TV-habits, it was observed that it was effective in increasing the bread baking frequency - also beyond the fourteen days of commitment time. According estimates from follow-up 2, 32 (i.e. 70 percent) of the respondents reported to have baked bread at least once over the last two weeks. The highest baking frequency reported in this context was eight times. However, as table 2 demonstrates, a high percentage (60 percent) was still reporting to obtain their bread from the grocery store or bakery. It may therefore be assumed that the respondents – in addition to bake their own –

still buy some of the bread they eat. The practical significance of an increased baking frequency is therefore rather unclear.

One of the strengths with the present bread baking intervention is its theoretical framework. Both *Intervention Mapping* and *Rothschild's Framework* are based on factors that are identified as crucial in relation to health behavior change <sup>(8,9,10)</sup>. However, despite a wide focus on facilitating the participants' attitude and perceived time to start baking (e.g. by the use of a motivation lecture and by providing them with baking ingredients, equipments and a recipe), the results indicated that none of these factors were significantly changed. In part, this may be explained by the fact that the participants were quite motivated to start baking already at baseline. A further increase in this parameter could therefore have been hard to obtain.

At the same time, it is important to emphasize that significant increases in the participants' knowledge and self-rated baking skills were observed. The question is, however, whether these two factors alone may explain the observed changes in baking habits. In spite of models like the KAP model (Knowledge-Attitude-Practice), claiming that knowledge is affecting our behaviours through influencing our attitudes <sup>(20)</sup>, knowledge alone is generally not considered strong enough to induce behavior changes <sup>(10)</sup>. Together with skills, knowledge is on the other hand claimed by Bandura's Social Cognitive Theory as an essential factor in building up self-efficacy <sup>(21)</sup>. Self-efficacy, which can be viewed as a persons confidence in his or hers ability to adapt to a specific behaviour, is identified as a crucial influencing factor by several health behaviour theories (e.g. Social Cognitive Theory, Theory of Planned Behaviour and the Health Belief Model) <sup>(10, 21)</sup>. In the case of the present intervention it is therefore reasonable to assume that an increased baking frequency to some extent may be explained by higher levels of self-efficacy among the participants. This could be due to the combined effect of improved knowledge and baking skills.

Limitations of this study include (1) its small and indefinable study sample with a high percentage of women. As the baseline characteristics indicated, the respondents were furthermore quite motivated to start baking already at that point. Partly, this may be explained by the fact that the sample largely consisted of people highly educated. This group is also suggested to be more prone to take part in and respond positively to health-promoting initiatives like the present intervention <sup>(19)</sup>. Again, this may have resulted in more beneficial outcomes than would have been achieved if the intervention included a more representative sample. All in all, these aspects may impair the external validity of the intervention and hence

the generalisability of the findings to a broader population. (2) Furthermore, the intervention was based on a one-group design, implicating that before-and-after measurements were done in one group without any controls. Such a design is generally criticized for being weak <sup>(19)</sup>, as it cannot provide compelling evidence that observed changes in the study sample is due to the concerned intervention. At the same time, this was only a pilot study testing the feasibility of the intervention, and in this context, a one-group study may have been the most suitable design <sup>(19)</sup>. (3) Despite relatively high compliance during the commitment period (each participant reported to have baked at least once, highest baking frequency reported was 7 times), this period may have been too short to provide enough time for behaviours (e.g. in relation to baking) to stabilize. Furthermore, the study may have had a too short follow-up-period to provide a realistic picture of the long-term effects of the intervention. (4) Except for the questions related to TV/DVD/PC habits, none of the questions in the questionnaires were validated. This may impair the study's internal validity. (5) Finally, the study may have had a too small sample size, and hence statistical power, to detect any significant changes in TV habits.

To our knowledge, there are no other studies reporting effects of a bread baking intervention. The present intervention did demonstrate a significant increase in the baking frequency among the participants. Despite the fact that it did not succeed in significantly reduce the time the participants spent on watching TV, the results did indicate a decreasing trend. These results call for further investigation. Further research will, however, acquire a stronger study design (e.g. a randomized controlled trial) with a larger study sample, a longer intervention period and a long-term follow-up.

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*Authorship responsibility:* LJ and KL contributed equally to this paper, and developed the intervention, conducted the study, analysed and interpreted the data, and wrote the article together. EB supervised the work. All authors have read and approved the final manuscript.

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**Table 1** The bread recipe

|   |
|---|
| <p><b>Ingredients (2 breads)</b></p> <ul style="list-style-type: none"><li>• 1 litre cold water</li><li>• 12.5 g yeast</li><li>• 10 g salt</li><li>• 2 dl flax seeds</li><li>• 4 dl oat flakes</li><li>• 3 dl white wheat flour</li><li>• 4 dl whole meal wheat flour</li><li>• 4 dl whole meal rye flour</li></ul>   |
| <p><b>Procedures</b></p> <p><b>Day 1</b></p> <ul style="list-style-type: none"><li>• Mix the yeast with the water. Thereafter, add in rest of the ingredients.</li><li>• Knead the dough thoroughly for minimum 20 minutes – preferably with some short breaks.</li><li>• Put the dough in the refrigerator for 24 hours.</li></ul> <p><b>Day 2</b></p> <ul style="list-style-type: none"><li>• Divide the dough into to baking tins.</li><li>• Bake the breads in the oven at 200°C for approximately one hour and fifteen to thirty minutes.</li><li>• Let the breads cool on a rack.</li><li>• The breads should be kept in a towel after they have cooled down.</li></ul> |

**Table 2** Effect of the intervention on bread and baking habits, as well as baking determinants (i.e. knowledge, attitude, skills and perceived time to bake) (N=46).

|  | Baseline  | Follow-up 1 | p <sup>c</sup> | Follow-up 2 | p <sup>d</sup> |
|--|-----------|-------------|----------------|-------------|----------------|
| <b>Bread and baking habits</b>                   |           |             |                |             |                |
| Baking frequency, last 14 days, mean (SD)        | 0.2 (0.7) | 2.7 (1.5)   | <0.001         | 1.2 (1.3)   | <0.001         |
| Slices of bread typically eaten a day, mean (SD) | 3.6 (1.7) | 3.8 (1.4)   | 0.22           | 3.6 (1.6)   | 0.88           |
| Slices of bread eaten yesterday, mean (SD)       | 2.9 (1.6) | 3.0 (1.5)   | 0.78           | 3.2 (1.6)   | 0.23           |
| Type of bread, percent coarseness, mean (SD)     | 58        | 63          | 0.05           | 63          | 0.01           |
| Home baked, percent                              | 4         | 33          | <0.001         | 40          | <0.001         |
| <b>Baking determinants</b>                       |           |             |                |             |                |
| Knowledge, Keyhole, percent correct answers      | 28        | 61          | <0.001         | 54          | 0.001          |
| Knowledge, Bread scale, percent correct answers  | 39        | 72          | 0.001          | 76          | <0.001         |
| Knowledge (self-rated) <sup>a</sup>              | 0.5 (0.8) | 1.1 (0.6)   | <0.001         | 1.0 (0.5)   | <0.001         |
| Baking attitude (self-rated) <sup>b</sup>        | 1.5 (0.6) | 1.6 (0.5)   | 0.38           | 1.4 (0.7)   | 0.71           |
| Baking skills (self-rated) <sup>b</sup>          | 1.4 (1.0) | 1.8 (0.4)   | 0.008          | 1.7 (0.6)   | 0.01           |
| Time to bake (self-rated) <sup>b</sup>           | 1.2 (0.9) | 1.5 (0.8)   | 0.02           | 1.3 (0.9)   | 0.15           |

<sup>a</sup> Very good (2), good (1), neither good or insufficient (0), insufficient (-1), very insufficient (-2)

<sup>b</sup> Totally agree (2), some agreement (1), either or (0), some disagreement (-1), totally disagreement (-2)

<sup>c</sup> Wilcoxon Signed Ranks Test, between baseline and follow-up 1. Significant at p<0.05.

<sup>d</sup> Wilcoxon Signed Ranks Test, between baseline and follow-up 2. Significant at p<0.05.

**Table 3** Effect of the intervention on TV/DVD/PC-habits (N=46)

|  | <b>Baseline</b> | <b>Follow-up 1</b> | <b>p<sup>a</sup></b> | <b>Follow-up 2</b> | <b>p<sup>b</sup></b> |
|--|-----------------|--------------------|----------------------|--------------------|----------------------|
| <b>TV/DVD-habits, minutes, mean (SD)</b> |                 |                    |                      |                    |                      |
| Weekdays                                 | 107.3 (62.5)    | 95 (62.7)          | 0.32                 | 97.8 (58.9)        | 0.36                 |
| Weekend                                  | 151 (55.4)      | 144.6 (55)         | 0.69                 | 145.8 (57.9)       | 0.64                 |
| Yesterday                                | 96.9 (76.3)     | 81 (73.2)          | 0.31                 | 82.2 (66.3)        | 0.23                 |
| <b>PC-habits, minutes, mean (SD)</b>     |                 |                    |                      |                    |                      |
| Weekdays                                 | 44.9 (51.1)     | 56.4 (62.9)        | 0.20                 | 53.5 (53.7)        | 0.27                 |
| Weekends                                 | 55.9 (49.6)     | 67.2 (65.6)        | 0.10                 | 57.1 (55.1)        | 0.94                 |
| Yesterday                                | 55.4 (67.8)     | 47.9 (67.2)        | 0.32                 | 44.4 (60.6)        | 0.13                 |

<sup>a</sup> Wilcoxon Signed Ranks Test, between baseline and follow-up 1. Significant at  $p < 0.05$ .

<sup>b</sup> Wilcoxon Signed Ranks Test, between baseline and follow-up 2. Significant at  $p < 0.05$ .

**Table 4** Process evaluation items; course enjoyment and course relevance and scales (N=46)

|  | <b>Range/response alternatives</b>  | <b>Mean</b> | <b>SD</b>  |
|--|---|-------------|------------|
| <b>Course enjoyment</b>  |   |             |            |
| 1. All in all, how did you like the bread baking course?         | Very good (2), good (1), bad (-1), very bad (-2), neither good or bad (0)                             | 1.7         | 0.6        |
| 2. How did you like the lecture?                                 | Very good (2), good (1), bad (-1), very bad (-2), neither good or bad (0)                             | 1.8         | 0.4        |
| 3. How did you like the bread baking?                            | Very good (2), good (1), bad (-1), very bad (-2), neither good or bad (0)                             | 1.7         | 0.5        |
| 4. How did you like the bread that was baked at the course?      | Very good (2), good (1), bad (-1), very bad (-2), neither good or bad (0)                             | 1.4         | 0.7        |
| <b>Scale</b>   | <b>-8, 8</b>  | <b>6.5</b>  | <b>1.5</b> |
| <b>Course relevance</b>  |   |             |            |
| 1. How relevant do you think the lecture was for you?            | Very useful (2), useful (1), less useful (-1), very little useful (-2), neither useful or useless (0) | 1.3         | 0.6        |
| 2. How relevant do you think the bread baking was for you?       | Very useful (2), useful (1), less useful (-1), very little useful (-2), neither useful or useless (0) | 1.3         | 0.6        |
| 3. How much benefit do you feel that you have had of the course? | Large benefit (2), some benefit (1), little benefit (-1), very little benefit (-2), either or (0)     | 1.6         | 0.5        |
| <b>Scale</b>   | <b>-6, 6</b>  | <b>4.2</b>  | <b>1.3</b> |



# ATTACHMENT 2

- *Poster*





# A Bread Baking Intervention

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## INTRODUCTION

There are several arguments for why we should bake our own bread. Some of them are related to factors like nutrition and everyday activity. In relation to the nutritional aspects, it is for example well-known that most industrial breads are high in both salt and food additives (1). By baking ourselves we are able to control what the bread contains and adjust the content of e.g. whole grains, fat, salt and water (the more water, the less energy). As an everyday activity, bread baking may furthermore be a contributing factor in breaking up and substitute sedentary behaviours (e.g. TV watching). Although baking only may be classified as a light-to-moderate intensity activity, it is suggested that there may be the lack of engagement in such type of activities that causes the adverse health-effects observed from a sedentary lifestyle (2,3,4) (i.e. weight gain and all-cause mortality) (5,6).

## PURPOSE

To assess the outcome evaluation of an intervention developed to get people to start baking their own bread in order to; eat a healthier bread and reduce sedentary behaviours (i.e. TV-watching).

## METHODS

The present bread baking intervention was a pilot study with a pre-experimental design (i.e. a one-group sample in which before-and-after measurements were performed). The intervention was developed with inspiration from *Intervention Mapping* and *Rothschild's Framework* of determinants affecting health behavior change (i.e. motivation, ability and opportunity) (7, 8). These determinants were further operationalized into the following factors: *attitude* (motivation), *knowledge* and *skills* (ability) and *time* (opportunity).

The intervention programme consisted of a two-day baking course (both practical and theoretical) and a commitment period in which the participants committed themselves to bake bread at home for a minimum of four times over the following two weeks after the course. All in all, the intervention was aiming at influencing the participants: *attitude* towards baking (by including a motivating lecture), *knowledge* and *skills* (by including an educational lecture, as well as a practical baking session), and *time* (by including an easy, timesaving and convenient bread recipe).

Baking habits (times per last 14 days) and TV/DVD/PC habits (minutes/yesterday) were measured by a questionnaire on three occasions – at baseline, two weeks (follow-up 1) and two-three months after the course (follow-up 2). Wilcoxon Signed Ranks Test was used to assess the impact of the intervention on baking and TV/DVD/PC habits.

## RESULTS

A statistical significant increase in the baking frequency was observed; from 0.2 times/last 14 days at baseline to 2.7 times/last 14 days at follow-up 1 ( $p < 0.001$ ), and 1.2 times/last 14 days at follow-up 2 ( $p < 0.001$ ).

Furthermore, a non-significant decrease in the prevalence of TV watching was indicated; from 97 minutes/day at baseline to 81 minutes/day at follow-up 1 ( $p = 0.31$ ) and 82 minutes/day at follow-up 2 ( $p = 0.23$ ).

|   | Baseline    | Follow-up 1 | P*     | Follow-up 2 | p**    |
|---|-------------|-------------|--------|-------------|--------|
| Baking frequency, last 14 days, mean (SD)   | 0.2 (0.7)   | 2.7 (1.5)   | <0.001 | 1.2 (1.3)   | <0.001 |
| TV/DVD-habits, minutes yesterday, mean (SD) | 96.9 (76.3) | 81 (73.2)   | 0.31   | 82.2 (66.3) | 0.23   |

\* Wilcoxon Signed Ranks Test, between baseline and follow-up 1. Significant at  $p < 0.05$ .

\*\* Wilcoxon Signed Ranks Test, between baseline and follow-up 2. Significant at  $p < 0.05$ .

## CONCLUSION

The bread baking intervention was effective in increasing bread baking frequency, also beyond the 14 days of commitment time. Whether increased bread baking results in a lower frequency of TV watching needs further investigation.

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# ATTACHMENT 3

- *Questionnaire*



# SPØRRESKJEMA 2



Dette spørreskjemaet er en del av brødbakingsprosjektet som du er deltager i. Du vil bli bedt om å besvare totalt tre spørreskjemaer – dette er det andre av de tre. Utfyllingen vil ta rundt ti minutter. Resultatene fra prosjektet vil kun bli brukt til vitenskapelige formål. All informasjon er anonymisert - vennligst ikke skriv ditt navn noe sted i skjemaet. Det er ingen rette eller gale svar.

## Hvordan skal du besvare spørreskjemaet?

- Bruk blå eller svart penn.
- Svar med et tydelig kryss.
- Sett kun et kryss per spørsmål (noen få spørsmål skal besvares med ord)

## Takk for hjelpen!

Ved spørsmål, ta kontakt: Line Jensen: Tlf: 41 45 82 91, [s270586@stud.hioa.no](mailto:s270586@stud.hioa.no)  
Kjersti Lilleberg: Tlf: 92 60 34 43, [s270621@stud.hioa.no](mailto:s270621@stud.hioa.no)

**1. ID-nummer:**

**2. Hva er din alder?**

\_\_\_\_\_ år

**3. Hva er din høyest fullførte utdanning?**

- Grunnskole (barneskole og ungdomsskole)
- Videregående skole (allmennfaglig eller yrkesfag)
- Høgskole/Universitet (3-4 år - tilsvarende cand.mag eller bachelorgrad)
- Høgskole/Universitet (5 år eller mer - tilsvarende hovedfag, master eller phd)

**4. Hvilken dag er det i dag?**

- Mandag
- Tirsdag
- Onsdag
- Torsdag
- Fredag
- Lørdag
- Søndag

**BRØDVANER**

**5. Hvor mange brødkiver spiser du gjennomsnittelig i løpet av en dag?**

Antall brødkiver: \_\_\_\_\_

**6. Hvor mange brødkiver spiste du i går?**

Antall brødkiver: \_\_\_\_\_

**7. Hva slags brød spiser du vanligvis?**

- Fint
- Halvgrovt
- Grovt
- Svært grovt

**8. Hvor kommer vanligvis brødet fra?**

- Hjemmebakt
- Dagligvarebutikk
- Bakeri
- Annet

**9. Hvor ofte baker du vanligvis brød i løpet av en periode på 14 dager?**

Antall ganger: \_\_\_\_\_

**10. Hvor ofte bakte du brød i løpet av de siste 14 dagene?**

Antall ganger: \_\_\_\_\_

**11. Bakte du brød i går?**

- Ja
- Nei

**BRØDKUNNSKAP**

**12. Hva er Nøkkelhullskriteriet for brød? Beskriv med egne ord.**

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**13. Hva indikerer tre kaker på Brødskala'n? Beskriv med egne ord.**

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**14. Hvordan vurderer du dine kunnskaper om brødets påvirkning på helsen?**

- Svært gode
- Gode
- Verken gode eller mangelfulle
- Mangelfulle
- Svært mangelfulle

**FAKTORER SOM PÅVIRKER BRØDBAKING**

**15. Jeg er motivert til å bake mitt eget brød.**

- Helt enig
- Litt enig
- Verken enig eller uenig
- Litt uenig
- Helt uenig

**16. Jeg mestrer å bake brød selv.**

- Helt enig
- Litt enig
- Verken enig eller uenig
- Litt uenig
- Helt uenig

**17. Jeg har tid til å bake brød selv.**

- Helt enig
- Litt enig
- Verken enig eller uenig
- Litt uenig
- Helt uenig



## TV- OG PC-VANER

**18. Omtrent hvor mange timer om dagen ser du vanligvis på TV/DVD på fritiden?** (Fyll ut et felt for hverdager og et for helgedager).

**a) Hverdager**

- Ingenting
- Mindre enn 30 min/dag
- 30 min/ dag
- 1 time/dag
- 1 time og 30 min/dag
- 2 timer/dag
- 2 timer og 30 min/dag
- 3 timer/dag
- 3 timer og 30 min/dag
- 4 timer eller mer/dag

**b) Helgedager**

- Ingenting
- Mindre enn 30 min/dag
- 30 min/ dag
- 1 time/dag
- 1 time og 30 min/dag
- 2 timer/dag
- 2 timer og 30 min/dag
- 3 timer/dag
- 3 timer og 30 min/dag
- 4 timer eller mer/dag

**19. Omtrent hvor mange timer så du på TV/DVD i går?**

- Ingenting
- Mindre enn 30 min/dag
- 30 min/ dag
- 1 time/dag
- 1 time og 30 min/dag
- 2 timer/dag
- 2 timer og 30 min/dag
- 3 timer/dag
- 3 timer og 30 min/dag
- 4 timer eller mer/dag

**20. Omtrent hvor mange timer om dagen sitter du foran PC-en på fritiden?** (Fyll ut et felt for hverdager og et for helgedager).

**a) Hverdager**

- Ingenting
- Mindre enn 30 min/dag
- 30 min/ dag
- 1 time/dag
- 1 time og 30 min/dag
- 2 timer/dag
- 2 timer og 30 min/dag
- 3 timer/dag
- 3 timer og 30 min/dag
- 4 timer eller mer/dag

**b) Helgedager**

- Ingenting
- Mindre enn 30 min/dag
- 30 min/ dag
- 1 time/dag
- 1 time og 30 min/dag
- 2 timer/dag
- 2 timer og 30 min/dag
- 3 timer/dag
- 3 timer og 30 min/dag
- 4 timer eller mer/dag

**21. Omtrent hvor mange timer satt du foran PC-en går?**

- Ingenting
- Mindre enn 30 min/dag
- 30 min/ dag
- 1 time/dag
- 1 time og 30 min/dag
- 2 timer/dag
- 2 timer og 30 min/dag
- 3 timer/dag
- 3 timer og 30 min/dag
- 4 timer eller mer/dag

## EVALUERING AV KURSET

### **22. Alt i alt, hvordan likte du brødbakingskurset?**

- Svært godt
- Godt
- Verken godt eller dårlig
- Dårlig
- Svært dårlig

### **23. Hvordan likte du selve foredraget?**

- Svært godt
- Godt
- Verken godt eller dårlig
- Dårlig
- Svært dårlig

### **24. Hvordan likte du selve brødbakingen?**

- Svært godt
- Godt
- Verken godt eller dårlig
- Dårlig
- Svært dårlig

### **25. Hvor godt likte du brødet som ble bakt på kurset?**

- Svært godt
- Godt
- Verken godt eller dårlig
- Dårlig
- Svært dårlig

**26. Hvor relevant synes du foredraget var for deg?**

- Svært nyttig
- Nyttig
- Verken nyttig eller unyttig
- Lite nyttig
- Svært lite nyttig

**27. Hvor relevant synes du brødbakingen var for deg?**

- Svært nyttig
- Nyttig
- Verken nyttig eller unyttig
- Lite nyttig
- Svært lite nyttig

**28. Hvor stort utbytte føler du at du har hatt av kurset?**

- Stort utbytte
- Noe utbytte
- Verken eller
- Lite utbytte
- Svært lite utbytte

**29. Det var enkelt å bake to ganger i uka.**

- Helt enig
- Litt enig
- Verken enig eller uenig
- Litt uenig
- Helt uenig

**30. Hvordan eltet du vanligvis brøddeigen?**

- For hånd
- Med maskin

**31. Kurset var tydelig på hva som er et sunt brød.**

- Helt enig
- Litt enig
- Verken enig eller uenig
- Litt uenig
- Helt uenig

**32. Selve brøddoppskriften var enkel å lære seg.**

- Helt enig
- Litt enig
- Verken enig eller uenig
- Litt uenig
- Helt uenig

**Var noe uklart under kurset. I så fall, hva?**

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**Har du forslag til forbedringer av kurset? Beskriv.**

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**Andre kommentarer?**

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**TUSEN TAKK FOR HJELPEN 😊**



# ATTACHMENT 4

- *NSD approval*







Elling Bere  
Institutt for helse, ernæring og ledelse  
Høgskolen i Oslo og Akershus  
Postboks 423  
2001 LILLESTRØM

Vår dato: 13.09.2011

Vår ref: 27822 / 3 / MSS

Deres dato:

Deres ref:

## KVITTERING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 24.08.2011. All nødvendig informasjon om prosjektet forelå i sin helhet 13.09.2011. Meldingen gjelder prosjektet:

|                      |  |
|----------------------|--|
| 27822                | Brødbakingsintervensjonen                              |
| Behandlingsansvarlig | Høgskolen i Akershus, ved institusjonens øverste leder |
| Daglig ansvarlig     | Elling Bere  |
| Student              | Line Jensen  |

Personvernombudet har vurdert prosjektet og finner at behandlingen av personopplysninger er meldepliktig i henhold til personopplysningsloven § 31. Behandlingen tilfredsstiller kravene i personopplysningsloven.

Personvernombudets vurdering forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, eventuelle kommentarer samt personopplysningsloven/-helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, [http://www.nsd.uib.no/personvern/forsk\\_stud/skjema.html](http://www.nsd.uib.no/personvern/forsk_stud/skjema.html). Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, <http://www.nsd.uib.no/personvern/prosjektoversikt.jsp>.

Personvernombudet vil ved prosjektets avslutning, 30.06.2012, rette en henvendelse angående status for behandlingen av personopplysninger.

Venlig hilsen  
  
Vigdis Namtvedt Kvalheim

  
Marie Strand Schildmann

Kontaktperson: Marie Strand Schildmann tlf: 55 58 31 52  
Vedlegg: Prosjektvurdering  
Kopi: Line Jensen, Finnerudveien 17, 3041 DRAMMEN



# ATTACHMENT 5

- *Salt calculations*  
(*chapter 6.4.1*)



### **Salt calculations – bread baking books**

The calculations are based on the water amount and the weight of the “ideal” bread (presented in chapter 6.8), i.e. 1 l water and 900 g bread:

100 g salt contains 39 g sodium (Matportalen, 2012). Meyer (2009) recommends 35 g salt per l liquid. This gives:

$$(39 \text{ g Na}/100 \text{ g salt}) \times 35 \text{ g salt} = \underline{13.65 \text{ g Na/bread}}$$

To find the sodium content per 100 g bread:

$$13.65 \text{ g Na per bread} / 900 \text{ g} = 13.65 \text{ g Na} / 9 \times 100 \text{ g}$$

$$= \underline{\underline{1.52 \text{ g Na}/100 \text{ g bread}}}$$



# ATTACHMENT 6

*- Keyhole calculations*





## Keyhole calculations – intervention bread

**Step 1:** Halved the recipe and converted it into g and kg:

- ½ l water    ½ kg water
- 6.25 g yeast                                      6.25 g yeast
- 5 g salt    5 g salt
- 1 dl flax seeds                                    75 g flax seeds
- 2 dl oat flakes                                    80 g oat flakes
- 1,5 dl white wheat flour                      90 g white wheat flour
- 2 dl whole meal wheat flour                120 g whole meal wheat flour
- 2 dl whole meal rye flour                    120 g whole meal rye flour

**Step 2:** Calculated the bread's percentage of *whole grains*. To fulfil the Keyhole criteria, this share should account for *at least 25 percent of the bread's dry matter basis* (Forskrift om frivillig merking med Nøkkelhullet, 2009).

Added the amounts of coarse ingredients (i.e. oat flakes and whole meal flours) and divided this sum with total dry matter content (i.e. all types of flours and oat flakes):

$(80 \text{ g oat flakes} + 120 \text{ g whole meal wheat flour} + 120 \text{ g whole meal rye flour}) / 410 \text{ g flour/oat flakes} = \underline{0.78}$

**= 78 percentage whole grains/bread**

**Step 3:** Calculated the bread's content of *dietary fiber*. To fulfil the Keyhole criteria, the bread should contain *at least 5 g dietary fiber per 100 g bread* (Forskrift om frivillig merking med Nøkkehullet, 2009).

Identified, by the use of the food composition table (Matportalen, 2012), the content of dietary fiber per 100 g of the different ingredients. Each amount was multiplied with the amount of the given ingredient added in the recipe:

**Oat flakes:** (10.6 g dietary fiber/100 g) x 80 g oat flakes = 8.5 g dietary fiber

**White wheat flour:** (3.4 g dietary fiber/100 g) x 90 g white wheat flour = 3.1 g dietary fiber

**Whole meal wheat flour:** (11.0 g dietary fiber/100 g) x 120 g whole meal wheat flour  
= 13.2 g dietary fiber

**Whole meal rye flour:** (14.8 g dietary fiber/100 g) x 120 g whole meal rye flour  
= 17.8 g dietary fiber

**Flax seeds:** (34.8 g dietary fiber/100 g) x 75 g flax seeds = 26.1 g dietary fiber

**In total:** (8.5 g + 3.1 g + 13.2 g + 17.8 g + 26.1 g) = 68.7 g dietary fiber per bread

To calculate the amount of dietary fiber per 100 g bread, we had to find the weight of a bread after the baking. The intervention bread weighs 900 g. This results in the following formula:

(68.7 g dietary fiber per bread / 900 g)

68.7 g dietary fiber per bread / 9 x 100 g

**= 7.6 g dietary fiber/100 g bread**

**Step 3:** Calculated the bread's amount of salt/sodium. To fulfil the Keyhole criteria, the bread should *not contain more than 0.5 g sodium per 100 g bread* (Forskrift om frivillig merking med Nøkkehullet, 2009).

100 g salt contains 39 g sodium (Matportalen, 2012). The recipe contains 5 g salt. This gives:

(39 g Na/100 g salt) x 5 g salt = 1.95 g Na/bread

To find the sodium content per 100 g bread:

1.95 g Na per bread / 900 g = 1.95 g Na / 9 x 100 g

**= 0.22 g Na/100 g bread**

**Maximal Na limit = 0.5g Na/100g bread**

$$0.5\text{g}/0.22\text{g} = \underline{\underline{2.27}}$$

The intervention bread can contain up to 22.7 times more salt and still fulfil the Keyhole salt criteria.

**Step 4:** Identified the bread's content of sugar and fat by the use of the cost calculation program "Mat på data" (Matportalen, 2012d). To fulfil the Keyhole criteria, the bread should *not contain more than 5 g sugar or 7 g fat per 100 g bread* (Forskrift om frivillig merking med Nøkketallet, 2009). The results showed that the bread contained, per 100 g:

|                    |          |
|--------------------|----------|
| <b>Energy</b>      | 173 kcal |
| <b>Fat</b>         | 3.5 g    |
| <b>Added sugar</b> | 0 g      |



## ATTACHMENT 7

*- Salt levels - intervention vs.  
industrial bread*



**Industrial bread:**  $120 \text{ g bread per day} * 356 \text{ days} * 0.0047 \text{ g Na per g bread}$   
= 205.9 g Na per year

**Intervention bread:**  $120 \text{ g bread per day} * 365 \text{ days per year} * 0.0022 \text{ g Na per g bread}$   
= 96.4 g Na per year

**Difference:** 109.5 g Na per year





# ATTACHMENT 8

*- n-6 to n-3 ratio*



**Half recipe (one bread)**

75 g flax seeds

80 g oat flakes

90 g white wheat flour

120 g whole meal wheat flour

120 g whole meal rye flour

n-6 and n-3 values were identified in USDA (2012)

**Flax seeds****n-6:**

$$(5.9\text{g}/100\text{g}) * 75 \text{ g} = \underline{4.4 \text{ g}}$$

**n-3:**

$$(22.8\text{g}/100\text{g}) * 75 \text{ g} = \underline{17.1 \text{ g}}$$

**Oat flakes****n-6:**

$$(2.4\text{g}/100\text{g}) * 80 \text{ g} = \underline{1.92 \text{ g}}$$

**n-3:**

$$(0.1\text{g}/100\text{g}) * 80 \text{ g} = \underline{0.08 \text{ g}}$$

**White wheat flour****n-6:**

$$(0.8\text{g}/100\text{g}) * 90 \text{ g} = \underline{0.72 \text{ g}}$$

**n-3:**

$$(0.02\text{g}/100\text{g}) * 90 \text{ g} = \underline{0.018 \text{ g}}$$

**Whole meal wheat flour****n-6:**

$$(1.1\text{g}/100\text{g}) * 120 \text{ g} = \underline{1.32 \text{ g}}$$

**n-3:**

$$(0.07\text{g}/100\text{g}) * 120 \text{ g} = \underline{0.084 \text{ g}}$$

**Whole meal rye flour**

**n-6:**

$$(0.6\text{g}/100\text{g}) * 120 \text{ g} = \underline{0.72 \text{ g}}$$

**n-3:**

$$(0.1\text{g}/100\text{g}) * 120 \text{ g} = \underline{0.12 \text{ g}}$$

The bread's total content of **n-6**: 9.08 g

The bread's total content of **n-3**: 17.4 g

**n6 to n3 ratio: 0.5**