Whole grain wheat – effects of peeling and pearling on chemical composition, taste and colour

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ABSTRACT

The EU-project HEALTHGRAIN has suggested a new definition for whole grain which allows a small part of the grain to be removed during processing. By removing the outer part or the grain the hygienic quality will increase but it is not clear how the taste and colour is affected. So therefore in this study three different debranning methods, peeling, pearling and polishing, which remove the outer parts of the grains have been used on common and durum wheat. The dietary fibre and ash content, as well as germination was analysed in untreated, peeled, pearled and polished grains. The decrease in dietary fibre and ash was higher in grains that had been pearled compared to those that had been peeled or polished. With approximately 2% of the grain removed there was a 4.2 – 12.2% decrease in dietary fibre content for the pearled samples while the peeled sample had a decrease of 2.4% and the content was not affected by polishing. Peeling seems to be a more gentle process compared to pearling and will preserve most of the dietary fibres and keep the aleurone layer intact which will give a more nutritious end-product.

To get an indication of how the different milling techniques affects colour and taste of the end-product and if these processes are of interest as a raw material for the next generation of whole grain products, a small sensory test was performed on pasta produced in a pilot scale from untreated, pearled (~2.5%) and peeled samples. The sensory test was small but gave an indication that the pasta produced from wheat where approximately 2% of the grain had been removed tasted slightly better than the pasta made from untreated wheat. The colour analysis of the pasta flour showed that the flour got a brighter colour with a higher degree of removal with peeling or pearling.

Bran from different producers was also analysed to investigate if there is a natural variation in dietary fibre content in wheat. The results obtained from this investigation on bran showed a wide variation of dietary fibre content from 37-50% and the ash content varied from 4-7%.

Key words: Dietary fibre, whole grain definition, milling methods, debranning, peeling, pearling, polishing

SAMMANFATTNING

EU-projektet HEALTHGRAIN har kommit med ett förslag på en ny fullkornsdefinition, den tillåter att en liten del av spannmålskärnan tas bort vid processning. Genom att ta bort den yttre delen av kärnan så förbättras den hygieniska kvaliteten, men det är osäkert hur det påverkar smak och färg. I den här studien har därför tre olika metoder (peeling, pearling och putsning) som tar bort det yttre lagret använts på vanligt vete och durumvete. Kostfiberinnehåll, askhalt och grobarhet analyserades hos obehandlade, peelade, pearlade och putsade prover. Minskningen av kostfiber- och ask-halten var högre i vete som hade behandlats med pearling jämfört med de som var behandlade med peeling eller putsning. När cirka 2 % tagits bort från vetekärnorna minskade kostfiberinnehållet med 4,2 – 12,2 % för det pearlade provet och med 2,4 % för det peelade provet medan det putsade provet förblev oförändrat. Peeling verkar vara en skonsammare process jämfört med pearling och bevarar det mesta av kostfiberinnehållet samtidigt som aleuron-skiktet förblir intakt vilket medför en mer näringsrik slutprodukt.

För att få en indikation på hur de olika metoderna påverkar färgen och smaken på den färdigställda produkten, samt om de här processerna går att använda i nästa generations fullkornsprodukter, utfördes ett mindre sensoriktest med pasta producerad från obehandlade, pearlade (~2.5%) och peelade prover i pilotskala. Det sensoriska testet var inte tillräckligt stort för att kunna ge några signifikanta resultat, men det gav en indikation på att den pastan som var producerad från vete där ca 2 % av kärnan hade avlägsnats smakade något bättre än det som var obehandlat. Färgmätning av fullkornsmjöl som användes visade att mjölet fick en ljusare färg ju mer som hade avlägsnats av kärnan med antingen peeling eller pearling.

Vetekli från olika producenter analyserades för att undersöka om det fanns någon naturlig variation i kostfiberinnehållet i vete. Resultatet visade på en stor variation med kostfiberinnehåll från 37-50 % och askhalten varierade från 4-7 %.

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INTRODUCTION

Whole grain has been an ongoing topic for some time now, but what counts as whole grain? There is still no commonly used definition of whole grain in the world and different definitions are often used. As long as there is no united whole grain definition in the EU, it will not be possible to use health claims on any new whole grain foods. In Sweden, the Nordic keyhole definition of whole grain is used. The EU-project HEALTHGRAIN has suggested a definition that allows that a small part of the grain is removed during processing such as peeling and pearling, which scrape of the outer parts of the grains by using different methods. By removing the outer part, the hygienic quality will increase but it is not clear how the taste and colour is affected. Therefore the interest for the whole grain definition and new processing technologies has been raised.

The work in this project was threefold, a literature review and two practical parts. The literature review covers different whole grain definitions and how these can be used in the labelling of whole grain products, the different milling processes and equipments used in the study are also described. The aim with the practical part was to study how peeling and pearling of common wheat and durum wheat affected the composition of dietary fibre as well as colour and taste. Germination trials were performed to get an idea of how intact the kernels were after different treatments. To get an indication of how the different milling techniques affects colour and taste of the end-product, a small sensory test was performed on pasta produced in a pilot scale. The colour of the flour used to produce the pasta was measured in order to estimate if the flour would get a more preferred colour.

As a side issue, wheat bran from different producers was analyzed for the dietary fibre content and composition in order to study if there is any variation in those parameters between suppliers.

LITERATURE REVIEW

Characteristics of a wheat grain

Cereals belong to the grass family (Gramineae) which produces dry, one-seeded fruits. The fruit is called caryopsis, grain or kernel. The grain has different types of anatomical components and those mostly mentioned is bran, germ and starchy endosperm but as seen in Figure 1 there are several more (Delcour and Hoseney, 2010). Bran is a milling fraction that is highly enriched in a total of eight different layers excluding the aleurone layer. Some of the layers are the outer and inner pericarp (fruit coat), seed coat, the nucellar epidermis and the aleurone layer (Dexter and Wood, 1996).

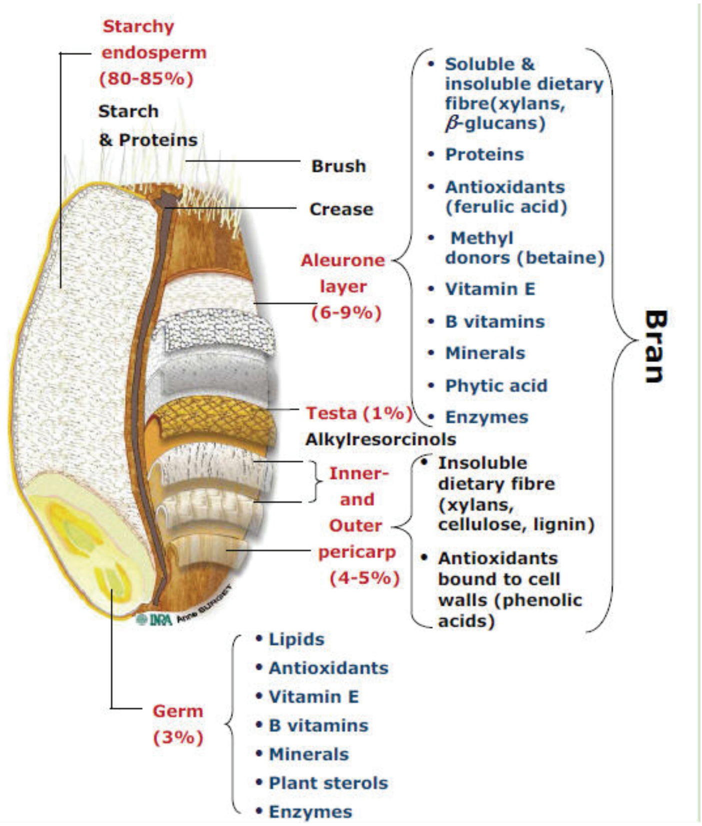

Figure 1. Wheat grain with different anatomical components and the distribution of the bio-active compounds (adapted from HEALTGRAIN, Surget and Barron, 2005)

Wheat is a "naked" grain, which means that the hull is separated from the grain during threshing. Wheat grains contains around 65-75% of carbohydrates, 7-12% protein, 2-6% lipids and 12-14% water and micronutrients. Wheat is also a good source for B vitamins. There is a variation of nutrient content depending on factors such as cultivar, growing conditions and hardness of the wheat (Hemery *et al.*, 2007). The wheat grains are slightly oval and rounded on the germ side. Along the opposite side of the germ is a crease with a depth in to the centre. The crease makes it difficult to get pure white flour for millers and is a source for microorganisms and dust (Dexter and Wood, 1996; Delcour and Hoseney, 2010). Pericarp makes up approximately 5% of the grain while the aleurone layer makes up 6-9%. Pericarp has several cell layers and is the outermost layer of the grain. The aleurone layer belongs to the endosperm and is only one cell layer thick in wheat. The cells in the aleurone layer has thicker cell walls and contains a higher enzyme activity and has a higher content of ash, protein, B vitamins and total phosphorus. Bran has a high content of dietary fibre and approximately 30% of the fibre found in bran consists of arabinoxylan. The content of arabinoxylan in the wheat grain is about 6-7% (Delcour and Hoseney, 2010).

The germ is also called embryo and is the main source of oil in the wheat grain but also has a high amount of protein, sugar and ash. It also has a rather high amount of enzymes and vitamin B and E (tocopherol) (Delcour and Hoseney, 2010). The germ is divided in two different parts, the embryonic axis and scutellum. The scutellum function as a storage organ for the root and shoot which orients from the embryonic axis (Dexter and Wood, 1996; Delcour and Hoseney, 2010). The starchy endosperm is composed of starch, which is packed in granules and storage proteins. The cell walls in the endosperm are where the dietary fibres are found and the main component is arabinoxylan with 1.5-2.5% of the endosperm. Small amounts of β-glucan are also found in the endosperm cell walls (Delcour and Hoseney, 2010). The starchy endosperm is the substantial part of the wheat grain with 80-85% as seen in Figure 1.

There are many different types of wheat and they vary both in size, colour and hardness. The pigment is mostly located in the seed coat of the grains and common colours are white and red. Durum wheat is a kind of wheat ultimate for pasta production, it is a hard wheat that has a high amount of the pigment carotenoid. The durum wheat is what gives the pasta the yellow colour (Delcour and Hoseney, 2010).

Whole grain definition

To date there is no international whole grain definition and the definitions used vary a little between different countries. This section will map out and compare some of the different definitions. The three first definitions described are used in the USA, but the definition by AACC International is the one most commonly referred to worldwide.

The American Association of Cereal Chemists, since 2005 named AACC International, decided on a definition in 1999 that was supposed to be understandable for both producers and consumers: "Whole grains shall consist of the intact, ground, cracked or flaked caryopsis, whose principal anatomical components - the starchy endosperm, germ and bran - are present in the same relative proportions as they exist in the intact caryopsis."

In 2004 the Whole Grain Council came with a definition with a different type of phrasing which also include processed products: "Whole grains or foods made from them contain all the essential parts and naturally-occurring nutrients of the entire grain seed. If the grain has been processed (e.g., cracked, crushed, rolled, extruded, and/or cooked), the food product should deliver approximately the same rich balance of nutrients that are found in the original grain seed."

The U.S Food and Drug Administration (FDA, 2006) also have a whole grain definition posted on their website, which is similar to the AACC International's definition: "The FDA document clarifies that the agency considers "whole grain" to include cereal grains that consist of the intact, ground, cracked or flaked fruit of the grains whose principal components -- the starchy endosperm, germ and bran -- are present in the same relative proportions as they exist in the intact grain."

HEALTHGRAIN is a European research project that aimed to improve the health of the people in the European countries. Their main conclusion was that an increased intake of whole grain products would reduce the risk for diseases related to metabolic syndrome. This project have used the AACC Internationals definition as a base for their definition, but is more specific when it comes to how much of the grain or bran that is allowed to remove during processing: "Whole grains shall consist of the intact, ground, cracked or flaked kernel after the removal of inedible parts such as the hull and husk. The principal anatomical components - the starchy endosperm, germ and bran - are present in the same relative proportions as they exist in the intact kernel. Small losses of components - i.e. less than 2% of the grain/10% of the bran - that occur through processing methods consistent with safety and quality are allowed.“ The definition also include that temporary separation of the different constituents is acceptable if they later are assembled in the original composition (HEALTHGRAIN, 2010).

The definitions of the Technical University of Denmark (DTU) (Mejborn, 2008) and the Nordic Keyhole (LIVSFS 2009:6) are similar to those already mentioned. They state that whole grain is supposed to contain endosperm, bran and germ in the same proportions as in the original grain, even if the grains are processed like ground, cracked or flaked. In Sweden there is no whole grain definition except for the Nordic Keyhole which is also used in Norway and Denmark. The Whole grain guidance in UK (2007) has just like HEALTHGRAIN more details in there definition; as it is allowed to temporary separate the constituents if they later are put together in the original composition. But they also has one part that is unique for the UK Whole grain guidance; that it is not allowed to put germ, bran and endosperm together as separate ingredients and call it a whole grain product. Neither is it allowed to combine constituents from different cereal types and call it whole grain.

Whole grain products

In order for processed cereal foods to be called whole-grain products, the proportions of whole grain must be defined. That proportion differs between different foods and legislations.

FDA defined in 1999 what a whole grain food should be: “For purposes of bearing the prospective claim, the notification defined "whole grain foods" as foods that contain 51 percent or more whole grain ingredient(s) by weigh” (extract).

The Whole Grain Council (2006) allows certifications with the basic stamp (Figure 2) of products that contain 8 grams of whole grain per serving where 51 % of the grains are whole grain. Grams per serving are normally calculated on dry weight, the total grams of whole grain are divided by the products total number of serving. They claim that studies have shown that all increases of whole grain in the diet have a beneficial effect on health. In order to mark with “100% stamp” (Figure 2) the product must contain 16 grams of whole grain per serving and all the grains in the product must be whole grain.

In the UK there is no agreed minimum level of how much whole grain a cereal product should contain in order to be called whole grain. UK Whole grain guidance (2007) says that packed food that is labeled with “contain” or “with” whole grain on the packaging should at least contain 8 grams whole grain per serving based on the final products proportions. But this definition is not intended for what is called “a whole grain food” which gives the illusion that the major part is whole grain based. If there is a statement of “with whole grain” or “made with whole grain” there is a requirement to follow Quantitative Ingredient Declaration, QUID.

According to the DTU, Danish whole grain products should contain a certain amount of whole grain, in order to avoid misleading information to the consumers. Flour, grains and rice must consist of 100% whole grain calculated on dry matter (DM), while processed food should have a minimum of 50% of whole grain of DM (≥ 51%). If there is a whole grain claim on the packaging it has to be a declared according to QUID. A minimum of ≥ 51% of DM will according to QUID correspond to 35% whole grain in bread but 55% in crisp bread, breakfast cereals and dry pasta and noodles (Mejborn, 2008).

Figure 2. Examples of whole grain symbols: Whole Grain Council (2006) basic stamp and 100% stamp, Vælg fuldkorn først (2008) and the Nordic keyhole (SLV, 2007)

In Denmark they have a logo called "Vælg fuldkorn først" (Figure 2) that is used on whole grain foods. Behind the label is a partnership that has a vision to increase whole grain consumption as well as availability. To be able to mark the product with the symbol "Vælg fuldkorn først"; flour, rice and grains must be 100% whole grain, bread must contain 50% whole grain of DM and at least 30% whole grain according to QUID. Crisp bread, pasta, noodles and breakfast cereals must consist of at least 60% whole grain of DM. Besides whole grain there are other requirements that have to be fulfilled considering the content of fat, sugar, salt and fibre (Vælg fuldkorn først, 2008).

In the Nordic keyhole constitutions (LIVSFS 2005:9) states what has to be followed in order to label the product with the keyhole symbol (Figure 2). Pie, pizza and dessert pies that contain cereals should consist of at least 15% whole grain of the DM in the cereal part. Soft breads and meal-mixes with yeast has to include at least 25% whole grain of the DM. Crisp bread, pasta, breakfast cereals, muesli and porridge has to include 50% whole grain calculated on the DM. Furthermore, it should be 100% whole grain for flours, flakes and groats made from cereals in order to be labeled with whole grain. There are several more requirements that need to be fulfilled in order to label with the symbol, for example fibre, sugar and salt.

Milling process

The first part of the milling process is cleaning of the grains. Which method or machines that are used varies from plant to plant. The idea is to remove foreign material, straw, stones etc. (Delcour and Hoseney, 2010). A scourer is a cleaning device that removes, among others, dust, sand and soil but it also reduces the bacterial count (Bühler, 2010). In the scourer the grains are rubbed against either each other, an emery surface or through a metal plate. The dirt that loosens is removed by an attached aspiration channel (Delcour and Hoseney, 2010). Polishing could be used on wheat or barley and is part of the cleaning steps in the milling process (Green, personal communication, 2010). Debranning is a relatively new pre-treatment for grains and will be described in more detail under the heading “debranning” (Delcour and Hoseney, 2010, Mousia *et al.*, 2004).

After cleansing the grains are subjected to tempering, which is when the grains rests in water for some time to make sure that the entire grain absorbs water. Tempering is done in order to toughen the bran parts and to soften the endosperm. This makes the endosperm easier to grind while the bran will be kept in larger fragments so that they later can be separated by sieving. Conditioning is when both water and heat is used to weaken the endosperm. The water uptake is higher at higher temperatures but the temperature should not exceed 50°C because the gluten proteins can then be damaged (Delcour and Hoseney, 2010).

Roller milling is a technique where the grains are grinded between two rolls that rotates in different directions at different speeds. One of the rolls has a speed 2.5 times faster than the slower one and due to the differences in speed the roll mill exposes the grains for both a crushing and a shearing force. The roller mill is commonly used, especially for grains with a crease. A set of rolls is called a break and many mills have a break system composed of several breaks which process the grains. Shearing force is ideal for getting pure flour while crushing would break the bran into too small pieces. In the beginning the grains are broken into big pieces which then are further processed. The last break flattens the grain particles and there the germ can be removed by sieving. Every break is connected to a sieving system which classifies by size and sends the particles to further grinding except the smallest partials that are saved as flour. After each break some flour is produced. The reduction system is where the endosperm gets the flour fineness and the last parts of the bran and germ are removed (Delcour and Hoseney, 2010). It is common that some bran particles pass through to the flour. Ash content and colour of the flour are used as an indication of bran contamination in the flour (Mousia *et al*., 2004, Hemery *et al*., 2009).

When producing whole grain flour the grains are subjected to the same procedure as normal, the different particle sizes are separated to undergo further treatment. The difference is that in the end all different fractions are collected to one (Green, personal communication, 2010).

Debranning

Debranning is a treatment usually used on rice but has been adapted for wheat. Debranning is a controlled process where the outer grain layers are removed. There are two types of debranning either by friction which is also called peeling or abrasion that is called pearling. These two can be used separately or in combination (Hemery *et al.*, 2007). During debranning the conditioning time is reduced to around 20 minutes compared to conventional where the grains are kept in water for 12-36 hours. This is done so that the water only penetrates the outermost regions. It will allow the seed coat layers to be removed layer by layer separate from the aleurone layer. While in conventional conditioning the seed coat and the aleurone layer fuses together and are removed together as bran (Dexter and Wood, 1996; Delcour and Hoseney, 2010; Hansson, personal communication, 2010). By using conditioning prior to debranning the bran holds together better and the grains can be exposed to a higher force without breaking of the grains. One disadvantage is that it will use more energy to remove the bran because the machine has a lower capacity when using wet kernels. If the grains are not conditioned the bran will be harder to remove and it will be more of a polishing effect (Hansson, personal communication, 2010). It has been shown that the contamination in cereals is concentrated in the outer regions of the grains. By using debranning to a degree so that the aleurone layer is not completely removed products which are more nutritious and has a better microbial quality could be produced. The degree of contamination is of great importance when it comes to stability and shelf-life of cereal products. A 4% removal would give a more pure product with hardly any microbial contamination (Laca *et al.*, 2006).

Peeling is a gentle process where the grains are rubbed against each other and an interaction between the rotor and the screen jacket removes the peripheral layers (pericarp) of the grain. Before the grains go in to the peeler they are once again damped. By using a peeler the contamination of microorganisms and heavy metals is reduced, the bacterial count can be decreased by 40-50%. Because the peeler is so efficient in reducing the bacterial count as well as the heavy metals it is suitable for producing whole grain products (Bühler, 2010). Light peeling will remove approximately 0.5% of the grains while peeling removes around 2%. With a peeler it is harder to regulate how much of the grain that is peeled off compared to a pearler. The only way to adjust the peeler is by regulating the addition of water (Hansson, personal communication, 2010).

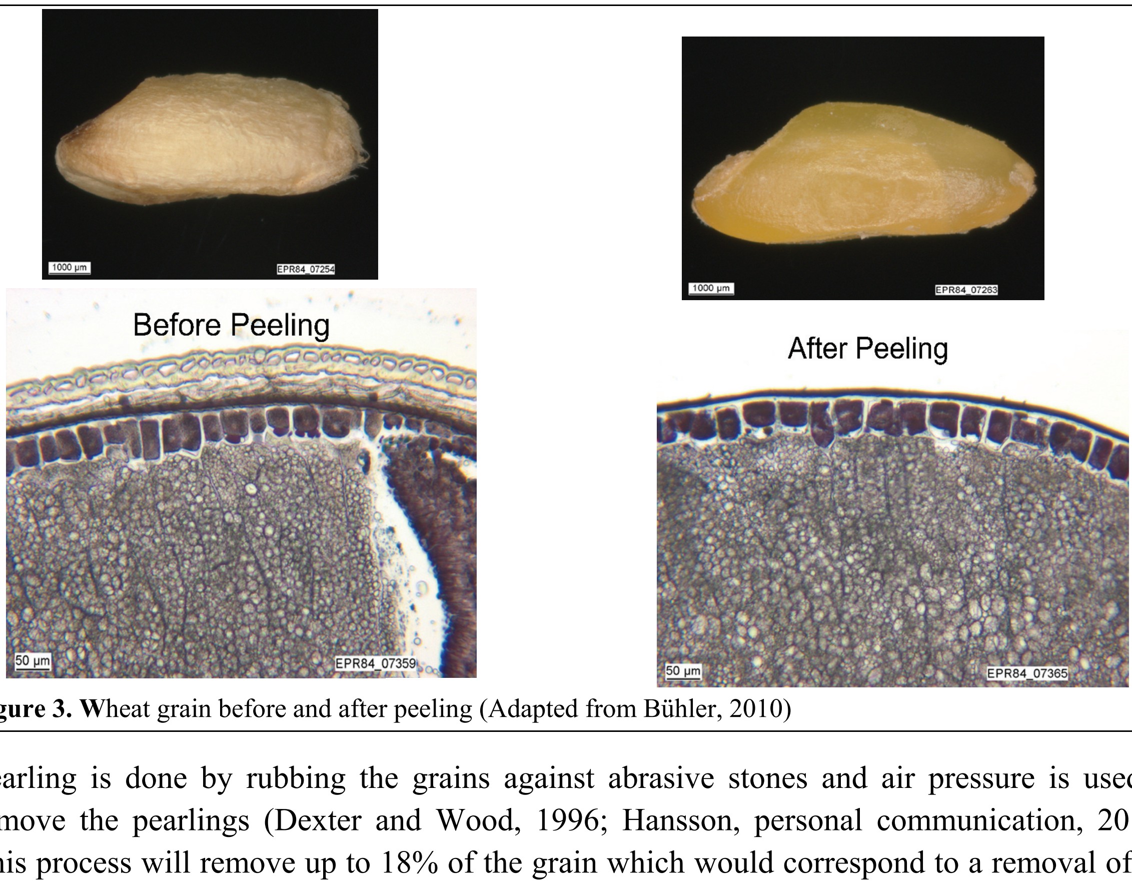

Figure 3. Wheat grain before and after peeling (Adapted from Bühler, 2010)

Pearling is done by rubbing the grains against abrasive stones and air pressure is used to remove the pearlings (Dexter and Wood, 1996; Hansson, personal communication, 2010). This process will remove up to 18% of the grain which would correspond to a removal of the entire bran. The degree of removal can be regulated by controlling the time for pearling and by adjusting the space between the abrasive stones and the screen (Hansson, personal communication, 2010). Removing approximately 4% with pearling will decrease the microbial contamination with approximately 90% (Mousia *et al*. 2004) Pearling is according to Bühler (2010) a good pre-treatment for durum wheat milling in order to get the best semolina fraction, but it is also suitable to refine other types of grains. The outer layers are removed prior to grinding and this will in durum wheat milling give speck-free and more yellow semolina.

Laca *et al.* (2006) analysed five different pearling fractions from wheat. The wheat samples were pearled for 5, 15, 30, 50 and 80 seconds which corresponds to a removal range of 1.4-22.0% (w/w) of the grain. They showed that the ash content was related to how much surface that was removed by pearling. There was a decrease in ash content with a higher removal percentage of the grain. After 15% removal, the ash content was however kept at an approximately constant level and at this point the aleurone layer is also completely removed. The aleurone layer was still detectable with scanning by an electron microscopy after 8.2% removal, but not after 13.7% removal.

Peeling will give an end product with hardly any damage to the aleurone layer (Figure 3) and the by-products will mostly be pericarp (Dexter and Wood, 1996, Mateo Anson *et al*., 2008). Pearling is a rougher treatment and will remove larger parts of the outer seed coat except from the crease, which cannot be reached. The starchy endosperm will be kept intact and the by-product will mostly be aleurone tissue (Dexter and Wood, 1996).

One advantage with debranning is that lower quality wheat can be produced to a good quality mill product, which will lower the cost. The mill plant will get an increased capacity and get a better mill flow, as well as by-products with a higher value. Debranning has been shown to have more advantages on durum wheat than on common wheat. As an example pearled durum wheat will get a better refinement which means lower ash content, fewer specks and the semolina will get a brighter colour. The number of grinding steps is also reduced by using debranning. There has been shown that spaghetti that is done from pearled durum wheat will get a less brown colour, due to that the discolouring seed coat is removed (Dexter and Wood, 1996). The yield of flour milling was shown to be higher for pearled wheat compared to untreated wheat in the study by Mousia *et al*. (2004).

MATERIAL & METHODS

Both bran and grain samples were analyzed in this study. All samples were analysed for chemical composition (dietary fibre components and ash) while the grain samples were also tested for germination and milled to a whole grain flour which was analysed for colour. Pasta was produced from these flours and a sensorical test was performed.

Bran samples

In this study 6 bran samples and 4 coarse bran samples were analysed for dietary fibre content and composition as well as ash content. The samples were obtained from Lantmännen and had been produced at different plants in Sweden, Denmark and Norway (Bran K1, Bran K2, Coarse bran L1, Coarse bran N1, Bran N2, Bran D1). Four samples (Bran eco1, Bran eco 2, Coarse bran eco 1 and Coars bran O1) were manufactured by other producers and had been obtained in local supermarkets. The sample preparation and chemical analysis were performed in the same manner as for the grain samples.

Grain samples
A total of 12 grain samples were included in this part of the study, whereof 7 were common wheat varieties (winter wheats) and 5 were durum wheat varieties. The analysed grain samples were untreated, pearled, peeled or polished.

Winter wheat Olivin (WWO) and French durum wheat (FDW) supplied by Lantmännen were used for pearling. The pearling was performed on a Strong-scott 17810 (Elektromekano) mill, which is a small laboratory devise at the Department of Food Science at SLU in Uppsala. 50 grams of grains were pearled for different time periods in order to obtain a similar pearling degree. The grain was weighed before after pearling in order to calculate the pearling degree. WWO was pearled for 7 and 18 seconds which correspond to 2.6% and 5.4% removal. FDW was pearled for 5 and 15 seconds which correspond to 2.3% and 5.4% removal.

The untreated mixed wheat sample and the sample that was peeled was a kind gift from KAMPFFMYER Food innovation GmbH in Hamburg. The wheat was of a mixture of French, German and Hungarian wheat and 2% of the grain had been removed by peeling. The grains were hydrated a shorter period before peeling.

Spanish durum wheat (SDW) and winter wheat Gnejs (WWG) supplied by Lantmännen were polished with a Schule Quartus 800 at Lantmännens mill in Malmö. The grains were collected at three separate occasions during one day and pooled before analysis. In order to evaluate the degree of removal thousand kernel weight (TKW) was determined before and after polishing.

Chemical analysis
All samples were milled with a Retsch ZM 1 mill (Brinkman) to a particle size of 0.5 millimetres before chemical analysis and they were analyzed in duplicates. Samples were dried in 105°C for 16 hours to determine the dry matter content (AACC method 44-15A, 2000), and all results are presented on a dry matter basis. To determine the ash content samples were placed in a muffle furnace at 600°C for 3 hours, and weight before and after (AOAC, 1984).

To determine the total dietary fibre content and the dietary fibre components, the Uppsala method was used (AOAC – NMKL methods no. 162, 1998). In the Uppsala method total dietary fibres are defined as amylase-resistant polysaccharides and Klason Lignin. Removal of sugars and starch was done with α-amylase and amyloglucosidase in an acetate buffer. Using 80% ethanol, soluble polymers are precipitated and the precipitated and insoluble polymers are hydrolysed with sulphuric acid. The released neutral monosaccharides are quantified by gas-liquid chromatography as alditol acetates. The sulphuric acid hydrolysate is also used to determine the uronic acids content, which is done by colorimetry. The insoluble residue from the acid hydrolyse are used to determine Klason Lignin gravimetrically after a correction of the ash content. Total dietary fibre content is the sum of neutral monosaccharides, uronic acids and Klason Lignin. The gas chromatograph used was a Hewlett Packard 5890. 1µl of sample was injected and ethyl acetate was used as solution. The temperature program used was 160°C for the initial 6 minutes, thereafter an increase with 4°C/ minute to 220°C which was the final temperature kept for 4 minutes. The arabinoxylan (AX) and arabinogalactan (AG) content was calculated from arabinose, xylose and galactose that are identified with a gas chromatography. The calculations were adapted from Delcour *et al.* (1999) which for AX was; %Ara – 0.7 × %Gal + %Xyl and for AG; 1.7 × %Gal.

Germination trial

To be able to call a product whole grain even after processing, the anatomical components should have the same principle proportion as in the intact grain. Therefore a germination test was executed to investigate if the germ was kept intact after processing. A high germination percentage would indicate that the product still could be called whole grain. The germination trial was done on all grain samples, before and after pearling, peeling or polishing, in duplicates of 50 grains. The winter wheats were frozen overnight in order to get a vernalization but the durum wheat was kept at room temperature. The grains were sterilized by soaking in 10% chlorine solution for 10 minutes and then rinsed with sterilized water. The grains were then soaked in 50 ml of sterilized water over night before they were placed in petridishes with filter paper for growing in room temperature. After 4 days the seedlings were counted and percentage of growth was calculated.

Pasta production

To evaluate how debranning affected the taste and colour on the end-product, pasta was produced from some of the milled wheat samples both before and after processing. The grains of WWO untreated, pearled 2.6% and 5.4%, FDW untreated, pearled 2.3% and 5.4%, mixed wheat untreated and peeled were milled with a Laboratory mill 3303 (Falling number) with setting 0 in order to make pasta flour. As the effect on dietary fibre and ash content of polishing was very small these samples were not included in the pasta trial. The 5.4% pearled samples were not included in the pasta trial.

Tagliatelle pasta was produced using an Edelweiss TR750. The pasta was made from a flour mixture of 20% of the different wheat sample flours and 80% sieved durum wheat flour (approximately 45% French durum wheat and 55% Spanish durum wheat). The pasta doughs were prepared by mixing 500 g flour and water to a good consistency (approximately 200g). The tagliatelle was formed by hand to a tangled hank. The drying process started with 10 min on each side of the hank in 90°C and then placed in an oven at 70°C for 3.5 hours.

Sensory analysis of pasta

To get an indication of how the different treatments would affect the taste of the end-product and if the processes could be used in the next generation of whole grain pasta, a sensory test was performed on the produced pasta. The pasta was boiled for 7 minutes in 1.5 litres of water with a teaspoon of salt. Thereafter the pasta was drained and put in to ceramic bowls that had been preheated in a 70°C oven. The samples were each given a three digit randomly chosen number. The samples were then tested in pairs where WWO untreated was compared to WWO 2.6% pearled, FDW untreated with FDW 2.3% pearled and the peeled with the untreated mix wheat sample. It was not possible to perform a full scale sensory test due the small amount of tagliatelle produced. The sensory test was preformed with five participants; four females and one male. The test started with a liking with a graded scale from 1 – 7 where 1 refereed to “do not like at all” and 7 to “like very much” (Appendix 1). The participants were asked to comment on appearance/colour, taste/scent and consistency. Finally they were asked which of the samples they preferred.

Colour analysis of flour
The colour analysis was performed by measuring the different whole wheat flours used for the pasta production with a Minolta Chromameter CR-310. The colour was measured to investigate if pearling, peeling and polishing had affected the colour. The samples were measured in duplicates of 2 tablespoons of flour and the mean value was determined. The Minolta Chromameter CR-310 measures three times and then gives the mean value of the three coordinates; L*, a* and b*. The L* coordinate indicates brightness of the samples, the higher value the brighter samples. a* measures redness-greenness where higher values is more red and b* shows yellowness-blueness where higher value is more yellow.

RESULTS & DISCUSSION

Bran samples
Wheat bran from different producers was analyzed for dietary fibre content and composition to investigate if there was any variation among them. The type of wheat was unknown so variation among wheat varieties could not be determined, but as they came from several producers in different countries it may be assumed that they originated from different wheat cultivars.

The results obtained from the bran and the coarse bran samples varied among the different samples, with dietary fibre content from 37-50% and the ash content from 4-7% (Table 1). Haskå *et al*. (2008) also showed that there were differences in the dietary fibre content in bran of different wheat cultivars. It could be expected that the bran samples would have a lower level of dietary fibre compared to the coarse bran samples, but this is not consistent with the results that was obtained. Bran eco 1, 2 and N2 had a larger particle size than the other bran samples. They were more similar to the coarse bran samples in particle size. The dietary fibre content for theses bran samples were higher than for other bran samples (K1, K2 and D1), with a content in the same range as the coarse bran samples. Bran eco 1 and 2 were from the same producer but had a large variation in dietary fibre content, 41.3% and 44.6% respectively. One explanation could be that they were from different batches. Bran K1 and K2 were also from one producer but from different batches and had however similar results for dietary fibre and ash content. The ash content for bran eco 1 and 2 was also different from the other bran samples. Eco 1 which had a lower dietary fibre content than eco 2 had a higher ash content than eco 2 (5.9 and 4.3%, respectively). In the other samples higher dietary fibre content were followed by higher ash content. The producers might have used different wheat varieties for the different batches which could explain these results.

The content of total dietary fibre, uronic acid, arabinoxylan, arabinogalactan and ash in the bran and coarse bran was in the same range as in bran studied by Haskå *et al*. (2008), but the content of Klason Lignin was lower. In that study they had one organically grown sample which had lower values compare to the other samples. In this study there were three organically grown samples, but only one; the coarse bran eco 1, which showed to have lower values. Coarse bran eco 1 had the lowest values of all the bran samples even though it was a coarse bran sample which then is consistent with the findings by Haskå *et al*. (2008). However the different results obtained from the bran samples could be due to the natural variation in wheat and that the bran are produced in different mills which Haskå *et al*. (2008) also declared as a possible explanation. The dietary fibre consisted of more than 50% of arabinoxylan, which is also in agreement with Haskå *et al.* (2008).

Table 1. Content of ash, total dietary fibre and dietary fibre components (% of DM) of bran samples from different producers

Samples	Ash	Tot[a]	Ara[a]	Xyl[a]	Man[a]	Gal[a]	Glc[a]	KL[a]	UA[a]	AX[a]	AG[a]
Bran K1	4.5	38.4	7.9	14.3	0.69	0.79	9.5	3.8	1.5	21.6	1.3
Bran K2	4.4	38.5	7.9	13.8	0.77	0.81	9.5	4.1	1.6	21.1	1.4
Coarse bran L1	7.2	45.8	8.8	17.9	0.55	0.76	11.3	4.7	1.7	26.2	1.3
Coarse bran N1	6.3	49.1	9.9	18.8	0.66	0.88	12.3	4.6	2.0	28.1	1.5
Bran N2	6.0	48.9	9.9	18.6	0.71	0.88	12.2	4.7	2.0	27.9	1.5
Bran D1	4.8	40.5	8.3	14.3	0.70	0.89	10.3	4.3	1.7	21.9	1.5
Bran eco 1	5.9	41.3	8.3	15.1	0.58	0.85	10.6	4.0	1.8	22.8	1.5
Bran eco 2	4.3	44.6	8.7	16.4	0.64	0.85	11.5	4.7	1.8	24.5	1.4
Coarse bran eco 1	5.4	37.2	7.3	13.7	0.47	0.67	9.7	3.7	1.6	20.6	1.1
Coarse bran O1	6.6	49.8	9.7	19.3	0.60	0.86	12.3	5.0	2.0	28.4	1.5

[a]Tot – total dietary fibre, Ara – arabinose, Xyl – xylose, Man – mannose, Gal – Galactose, Glc – glucose, KL – Klason Lignin, UA – uronic acid, AX – arabinoxylan, AG – arabinogalactan

Grain samples

The grain samples were exposed to different processes; pearling, peeling and polishing. Chemical composition and germination of the grains, as well as colour and taste of flour and pasta produced from the grain samples was analyzed for both untreated and treated wheat in order to determine if any of the debranning techniques would be suitable for the next generation whole grain pasta.

Pearling

There was some difference in pearling time to get the same approximately removal degree for WWO and FDW. The WWO required a bit longer time, but according to Singh and Singh (2010) there is a difference in debranning time of different wheat varieties. They showed that the differences depended on the protein content in the wheat and the size of the grains. Larger grains generally need less debranning time compared to smaller ones. This would explain the difference in pearling of WWO and FDW. As seen in Figure 4 and 5 the WWO has smaller grains and required a longer pearling time than FDW which has larger grains.

Figure 4. Winter wheat Olivin (WWO) from the left: untreated, pearled 2.6% and pearled 5.4%

Laca *et al* (2006) had much longer pearling times than in the present study with lower percentage of the grains removed. The time difference is most likely due to the low amount of grains that was pearled in this project. In larger scale the time would probably be longer.

In Figure 4 and 5 it is also shown that there are more of the outer parts that have been removed with higher degree of pearling. It is difficult to know the depth of the pearling and if the depth of removal is even over the entire grain. The pearling may have rubbed of the edges of the grain to deep which would harm the germ and therefore the germination test was performed.

Figure 5. French durum wheat (FDW), from the left untreated, pearled 2.3% and pearled 5.4%

Polishing

Since the Schule Quartus 800, used for polishing of the grains, does not make an online estimate of how much of the grains that is removed, the TKW was determined for WWG and SDW before and after polishing. The weight difference between untreated and polished samples was noted in percentage. For WWG there was a removal of 1.9% of the grain and for SDW there was a removal of 4.4%.

Content of ash and dietary fibre

The purpose for examining the dietary fibre content for the different treated grains was to investigate how the different processes affected the end product and their nutritional value.

As expected, the dietary fibre content decreased with pearling degree for both FDW and WWO (Table 2). This trend was also shown for ash content which is in accordance to Laca *et al.* (2006). The decrease in dietary fibre content was larger in WWO than in FDW. The 2.6% pearled WWO had a decrease of 12.2% of dietary fibre content and the 5.4% pearled had a decrease of 23.6%, compared to the untreated grains. The FDW only decrease with 4.2% in the 2.3% pearled grains and 14.2% in the 5.4% pearled grains. As shown in Table 2, WWO had higher fibre content in the starting material compared to FDW but after the pearling they were at similar levels. This show that WWO had higher fibre content then FDW and a larger amount is concentrated in the outermost parts. The level of arabinoxylan decreased with a longer pearling time for both WWO and FDW, which was expected since the dietary fibre content decreased and arabinoxylan constitutes approximately 50% of the total dietary fibre content (Haskå *et al*, 2008).

The peeled mixed wheat had a 2.4% decrease in dietary fibre content compared to the untreated mixed wheat, which not is a large difference. The ash and arabinoxylan content was the same for both samples. The decrease was seen in the content of arabinose, glucose, Klason Lignin and uronic acid. Compared to the 2.6% pearled WWO sample, which is a common wheat, there was a much larger reduction (12.2%) in dietary fibre which could indicate that peeling is a more gentle treatment. It may be difficult to compare the peeled samples with the pearled samples since the peeled samples have been conditioned which the pearled samples has not. As described earlier, conditioning enable removal layer by layer and make the grains more tolerant against higher force. Pearling might have caused the grains to break or removed outer layers unevenly.

On the other hand in SDW and WWG there was hardly any difference between the polished and untreated samples, which would imply that the removal with polishing was so small that it did not affect the dietary fibre content or the ash content at all. However this is not consistent with the fact that 1.9 and 4.4 % of the grains was removed during polishing (calculated from the TKW), while it is consistent with the results from the germination trial and the colour analysis (Table 3). All other samples which had approximately the same amount or more of the grains removed also had a large decrease in dietary fibre content at pearling or peeling. Based on the results from the dietary fibre analysis it is not likely that the sample collection had been performed correctly.

Table 2. Content of ash, total dietary fibre and dietary fibre components (% of DM) of untreated, pearled, peeled and polished wheat samples

	Ash	Tot[a]	Ara[a]	Xyl[a]	Man[a]	Gal[a]	Glc[a]	KL[a]	UA[a]	AX[a]	AG[a]
WWO[a] untreated	1.6	10.8	2.3	3.8	0.39	0.31	2.6	0.90	0.42	5.9	0.53
WWO 2.6% pearled	1.5	9.5	1.9	3.3	0.37	0.27	2.3	1.01	0.36	5.0	0.46
WWO 5.4% pearled	1.4	8.2	1.7	3.0	0.32	0.26	2.0	0.71	0.32	4.5	0.44
FDW[a] untreated	1.8	9.4	2.2	3.2	0.40	0.27	2.4	0.54	0.42	5.1	0.45
FDW 2.3% pearled	1.7	9.0	2.0	3.1	0.43	0.31	2.1	0.53	0.38	5.0	0.52
FDW 5.4% pearled	1.5	8.0	1.8	2.8	0.41	0.22	1.9	0.52	0.34	4.5	0.37
Mixed wheat untreated	1.7	10.2	2.2	3.8	0.40	0.27	2.6	0.46	0.45	5.8	0.45
Mixed wheat 2% peeled	1.7	9.9	2.1	3.9	0.40	0.28	2.4	0.42	0.43	5.8	0.48
WWG[a] untreated	1.5	11.1	2.3	4.1	0.37	0.29	2.8	0.89	0.48	6.1	0.50
WWG polished	1.5	11.4	2.4	4.2	0.38	0.31	2.7	0.91	0.47	6.4	0.52
SDW[a] untreated	1.5	10.2	2.3	3.4	0.41	0.28	2.5	0.71	0.47	5.6	0.48
SDW polished	1.6	10.5	2.5	3.6	0.39	0.29	2.6	0.67	0.48	5.9	0.49

[a]WWO – Winter wheat Olivin, FDW – French durum wheat, WWG – Winter wheat Gnejs, SDW – Spanish durum wheat, Tot – total dietary fibre, Ara – arabinose, Xyl – xylose, Man – mannose, Gal – Galactose, Glc – glucose, KL – Klason Lignin, UA – uronic acid, AX – arabinoxylan, AG – arabinogalactan

Germination trial

A germination trial was performed in order to investigate if the germ was harmed or removed during the different treatments. This trial was carried out since in the definition for whole grain it is stated that the germ must be included to be called whole grain. In general all the common wheat samples had a better growth than the durum wheat samples. For the untreated WWO there was a good growth with 96% of the grains having seedlings, and then a decrease to 40% for WWO 2.6% pearled and almost no growth for WWO 5.4% pearled. In the 2.6% pearled sample the grains were a bit sticky but it was worse in 5.4% pearled. There was hardly any difference between WWG polished and untreated which both had a high growth, 96-100%. The untreated mixed wheat sample had just like WWO and WWG a high growth of 92% while in the peeled mixed wheat the growth had decreased to 49%. In the peeled wheat samples there was a large difference (20%) between the duplicates. Compared to the WWO sample that had removed 2.6% by pearling and had a growth of 40% it seems reasonable that the wheat sample that had 2% removed by peeling should have had a bit higher growth. It also indicates that a higher removal and tougher pre-treatment seems to affect the germ.

The FDW samples only had growth in the untreated samples (84%). For pearled FDW samples the grains where very moist and sticky, and when they were soaked in water the water became cloudy which might indicate that some starch was leaking out from the grains. Another explanation for the smaller or lack of growth in the pearled samples could be that the germ had been removed and/or damage to such degree that growth was not possible. In the study by Hemery et al. (2004), there was 7-13% of germ in the pearling faction. Pearling will give the grains a more rounded shape and this could be a reason for the lack of growth for the pearled FDW samples. Polished and untreated SDW had a growth between 75-86% and there were no difference between the samples, but they had some mould growth which might have caused reduced growth.

Sensory analysis of pasta
The sensory test was held at the Lantmännen headquarter in Stockholm and the purpose was to investigate if the participants could identify any difference in taste between the untreated and treated samples. Six samples were tasted and compared in pairs. The participants were asked to answer which of the two samples they preferred and in all three cases the majority choose the pasta produced with wheat that had been treated. One of the participants thought that there was no difference in taste between any of the samples. Three out of five participants preferred the pasta produced from 2.6% pearled WWO and three out of five also preferred the peeled mixed wheat pasta. Four of the participants preferred the 2.3% pearled FDW pasta over the untreated one. In all three test rounds there was only one person that preferred an untreated sample over the treated one and it was the pasta produced from the untreated mixed wheat.

The untreated WWO pasta got the grade 5.4 and the 2.6% pearled WWO pasta got a slightly higher grade, 5.8. Comments on the untreated WWO pasta was that it had a good and neutral taste, good but a bit scratchy consistency, a slight scent of cereals and that it had a nice light white/brown colour. The participants reviewed that the 2.6% pearled WWO pasta had a better and stronger taste than the pasta made from untreated WWO wheat with a nice shape and consistency, but it also had a scent of cereals and felt scratchy. Two of the participants could not identify any difference in the two samples.

Both the pasta made from untreated and peeled mixed wheat got comments about a rough and scratchy consistency and that they had a nice colour. The pasta made from untreated mixed wheat got the grade 5.0, had a greyer colour than the pasta made from peeled wheat, a prominent scent of cereals and one of the participants preferred the untreated and thought it was tastier. The peeled sample appeared to scent like pasta, had a nice and neutral but sweet taste and got the grade 5.4.

The pasta made from FDW flour was not as good as the other samples according to this sensory test. They thought that both pasta made from untreated and pearled FDW had a neutral taste, a scent of cereals or no scent, some visible fibres but looked fine and was only a bit scratchy. Both samples got comments as being darker as well as brighter than the other sample. The pasta produced from the pearled FDW sample was preferred with a 5.2 grade compared to 4.6 for the untreated FDW pasta. The comments did not differ that much between the samples. The untreated had a mealy flavour but two expressed that they did not like the taste. The pearled FDW pasta got a comment on having a more salty taste and another thought it tasted better than the untreated pasta.

The participants were also asked to comment on the colour of the pasta but the lightening in the room was not optimal, which meant that the participants had dissimilar lightening so the results must be considered objectively. The pasta contained some bigger parts of fibres which made it hard to establish the cooking time and therefore the samples may have had dissimilar consistency, which was also commented. A new test round with better lightening, an established cooking time and more participants would perhaps give another result.

Colour analysis of flour

The colour measurements were executed on the flour used for the pasta production. The purpose was to see if the removal of the outermost part of the grain would have a positive effect on the end product. There is still a preference for brighter and more yellow pasta and here it is possible to see if peeling and pearling would produce brighter pasta colour and still be a whole grain product.

The results from the colour analysis are presented in Table 3, and they show that the processed samples had brighter colour (increase in L*) with a higher degree of pearling and peeling. The samples of common wheat have a brighter colour compared to the durum varieties. Singh and Singh (2010) also showed that common wheat varieties had a brighter colour compared to the durum varieties with darker colour. But they also stated that the brightness in colour was related to grains size, where smaller grains would be darker and larger would be brighter, which is not consistent with the findings for WWO and FDW.

There was an increase in L* but a decrease in a* (decrease in redness) with the degree of pearling, which could be an indication of removal of outer layers that are rich in pigment (Singh and Singh, 2010). The b* values were increasing for both WWO and FDW with degree of pearling, but FDW had higher values which was expected as durum wheat has higher amount of yellow pigment (carotenoids). Common wheat had a whiter endosperm while durum wheat had an endosperm rich in yellow pigment (Singh and Singh, 2010), which would explain why there is not as large increase in b* for WWO compared to FDW. The increase in WWO could be a result of removal of more blue-pigments in the pericarp. The peeled mixed wheat sample had a lower value in b* compared to the untreated, the difference from WWO could be explained by the fact that there are different kinds of wheat. In the results from WWG and SDG there were hardly any differences between the polished and the untreated wheat. Although there was an indication that the result was following the other samples trend, except for SDW where L* decreased in the polished samples compared to the untreated.

Table 3. Colour analysis with Minolta Chromameter on pasta flour

	L*	a*	b*
WWO untreated	102.7	3.3	13.8
WWO 2.6% pearled	104.7	3.2	14.4
WWO 5.4% pearled	106.2	2.9	14.4
FDW untreated	101.2	2.5	24.9
FDW 2.3% pearled	102.1	2.4	26.3
FDW 5.4% pearled	103.4	2.0	26.7
Mixed wheat untreated	102.4	3.4	15.4
Mixed wheat peeled	104.4	3.0	15.1
WWG untreated	103.8	3.6	15.2
WWG polished	104.0	3.6	15.1
SDW untreated	102.9	3.2	24.2
SDW polished	102.6	3.3	24.3

L*- brightness, a* - redness-greenness, b*- yellowness-blueness

CONCLUSIONS

The chemical analysis of wheat bran and coarse bran showed that there was a difference in dietary fibre content, as well as ash content in bran from different producers. It is likely that variety and milling method affected these results. Other researchers have also shown such difference.

Peeling seems to be a more gentle process compared to pearling and will preserve most of the dietary fibres and keep the aleurone layer intact which will give a more nutritious end-product. This indicates that peeling may be a good pre-treatment for whole grain production. Peeling will only remove 2% of the grain which is allowed according to HEALTHGRAIN's definition, but will still remove a large part of the microbial contamination as well as heavy metals. The flour produced form the peeled wheat had a brighter colour which is more susceptible for consumers. The pasta made from the peeled mixed wheat did however not differ that much in taste compared to the untreated mixed wheat. It would have been interesting to also analyse flour and pasta made from peeled durum wheat to see how the colour and taste would have been affected and also if the dietary fibre would be maintained.

Peeling would also be of interest for conventional milling of white flour because it can increase the millings capacity and the bran would have lover microbial contamination as well as heavy metals. Pearling may perhaps increase the capacity of the mill even further but conditioned grains require more energy which is not good from environmental conditions.

It would have been ideal if the same wheat varieties had been used for both pearling, peeling and polishing. It would then have been easier to compare the results from the different methods used in this study. Now it is not possible to exclude that the difference could depend on wheat variety or that the peeled sample were the only one conditioned. Conditioning makes it possible to remove layer by layer from the grains. The outermost layer, removed by peeling, did not contain as much dietary fibre but instead some of the pigment in the seed coat was removed which made the pasta flour brighter. Pearling resulted in a greater loss of dietary fibre which possibly could have been avoided if the grains had been conditioned before treatment. Still the pearled WWO 2.6% have in principle got the same brightness in colour as the peeled sample.

The sensory test gave an indication that the pasta produced from wheat where approximately 2% of the grain had been removed tasted better than the pasta made from untreated wheats. The opinions varied but the overall assumption was that there was not big difference between the treatments which was shown by the grading. To get a better understanding if these processes are of interest for the next generation pasta a sensory test should be performed with a larger panel.

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APPENDIX 1

Bedömningsformulär

Produkt:……………………………………………………..

Namn:…………………………………………………….   Datum:……………….

Titta, lukta och smaka på de två proverna. Skölj munnen noga mellan varje provsmakning. Ange hur mycket du tycker om dem. Sätt kryss för det alternativ som passar.

Skriv gärna motivering, det är mycket betydelsefullt för oss!

Prov ……………………..

◯ tycker mycket bra om (7)

◯ tycker bra om

◯ tycker något bra om (5)

◯ tycker varken bra eller illa om

◯ tycker något illa om (3)

◯ tycker illa om

◯ tycker mycket illa om (1)

Kommentarer kring;
- Utseende/färg
- Smak/lukt
- Konsistens

………………………………………….

………………………………………….

………………………………………….

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Prov ………………………

◯ tycker mycket bra om (7)

◯ tycker bra om

◯ tycker något bra om (5)

◯ tycker varken bra eller illa om

◯ tycker något illa om (3)

◯ tycker illa om

◯ tycker mycket illa om (1)

Kommentarer kring;
- Utseende/färg
- Smak/lukt
- Konsistens

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…………………………………………

Av de två proverna föredrar jag prov…………………

Motivering:

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……………………………………………………………………………………...

I denna serie publiceras större enskilda arbeten (motsvarande 15-30 hp vid Institutionen för Livsmedelsvetenskap, Sveriges lantbruksuniversitet.