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Abstract

Eating wheat bran has many positive effects on human health including reduced risk of cardio vascular diseases and type 2 diabetes. Still, many food products on the market are made from refined wheat flour because consumers tend to prefer the quality and texture in these products. Knowledge on factors influencing quality and texture in products containing whole grain wheat or added wheat bran making them less attractive is therefore of value.

This study aimed to examine the influence of bran particle size and different bran fractions on the quality of pasta. Pasta incorporated with high levels of different bran fractions (coarse bran, fine bran and pollard flour) and different bran particles sizes (85-150 µm, 150-250 µm and 250-400 µm) were developed. Relative water absorption was measured and a descriptive sensory analysis was used to evaluate the quality in cooked pasta. Stained and unstained cross sections of 5 µm thick pasta was also studied using light microscopy.

The result indicated that bran particle size but not bran fraction influenced the relative water absorption. Small bran particles had a significant lower water absorption compared to pasta with medium and large bran particles. The sensory evaluation of the pasta indicated that bran particle size had an impact on the quality attributes stickiness, surface roughness and likeability. Surface roughness in pasta became more evident with larger bran particles. Stickiness decreased with decreasing bran particle sizes and the pasta containing the smallest particles were significantly less preferred compared to the pasta with larger bran particles. The particle size of bran did not have any significant effect on the quality attributes whole grain flavor, elasticity and firmness.

The microscopy evaluation indicated a small difference in the degree of gelatinization of starch granules across a section of the pasta. This difference indicated a higher degree of gelatinization of starch granules in the outer and intermediate parts of the pasta containing medium and large bran particles compared to the pasta containing the smallest bran particles.

Keywords: Pasta, Durum wheat bran, Particle size, quality, texture

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1. Introduction

1.1 Background

The outer part of the wheat kernel, known as wheat bran, is an important source of dietary fiber. High intake is associated with several positive effects on human health including reduced risk of type 2 diabetes (Liu *et al.,* 2000; Salmerón *et al.,* 1997; Meyer *et al.*, 2000) and cardio vascular diseases (Liu *et al.*, 1999; Jacobs *et al.*, 2000; Wolk *et al.*, 1999). Although wheat bran has considerable nutritional potential, most wheat-based food products in Europe are made from refined endosperm where the bran and germ has been removed (Hemery *et al.*, 2007).

Many consumers seem to prefer products made of refined wheat flour over whole grain products since texture and taste are considered to be less attractive compared to refined wheat products (Noort *et al.,* 2010). However, from a health perspective, an increased consumption of whole grain- and fiber rich products would be desirable. The intake of whole grain products in Sweden are considerably below the recommended intake of 70 and 90 g/day for women and men respectively (Amcoff *et al.*, 2012). The Swedish authority Livsmedelsverket is therefore especially encouraging the nutritional recommendation to increase the intake of whole grain products. (Amcoff *et al.*, 2012).

A way to encourage an increased intake of whole grain products and products containing wheat bran is to improve the texture and quality of these products making them more attractive to the consumer. Knowledge on factors influencing quality and texture in whole grain products is therefore of value in order to identify new opportunities for improvement.

In a current project at The Swedish University of Agricultural Sciences in cooperation with the Swedish food company Lantmännen Cerealia, structure and dynamics in carbohydrate rich food materials are investigated. Pasta has been used as a model system for the project as it constitutes a carbohydrate rich food product that is consumed in large quantities worldwide. This thesis is a part of that project and will serve as a way to gain knowledge on how bran influences the structure and sensory quality in whole grain pasta.

1.2 Objectives

The objective of this thesis was to develop pasta with high content of different durum wheat bran fractions and different bran particle sizes in order to evaluate how the particle size and fraction affect the quality in texture and sensory properties of whole grain pasta.

In a longer perspective, the aim is to contribute with knowledge that can lead to new ideas and ways to develop whole grain pasta with more attractive sensory, texture and quality attributes than current products available on the market.

1.3 Delineation

This thesis includes the manufacturing of a product in lab scale but does not deal with any form of market research to assess the potential of the products on the market. The added value health is of focus for the developed products but environmental or ethical aspects concerning the products have not been covered.

Due to time limitation and the fact that the study reached a dead end concerning the pasta containing different durum wheat bran fractions, major focus of this thesis has been on the pasta incorporated with different bran particle sizes.

2. Theoretical background

2.1 Wheat

Wild and cultivated wheat belongs to the group large grass family. There are several different species of wheat, but *Triticum aestivum* (common or bread wheat) and *Triticum durum* (durum or macaroni wheat) are the most cultivated (Wiseman, 2001). Different wheat varieties have different characteristics that are more or less suited to different types of food. Durum wheat has been found suitable for manufacturing of pasta (Wiseman, 2001).

Nutritionally, wheat grains comprise 65-75% starch and fiber, 7-12% proteins, 2-6% lipids, 12-14% water and micronutrients (Pomeranz, 1988). They are also abundant in minerals (especially magnesium), B-vitamins, vitamin E and antioxidants (Slavin *et al.*, 1999).

The wheat grain is composed of several parts and layers with varying content and structure (Figure 1).

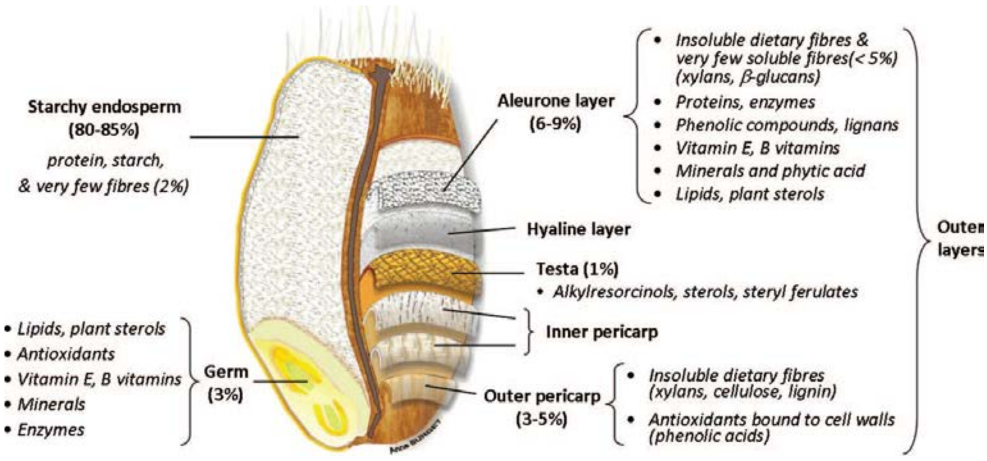

Figure 1. Composition of a wheat grain. Figure adapted from Brouns *et al.,* (2012) who used the image of the wheat kernel by Surget & Barron (2005).

The germ contain lipids in the form of plants sterols as well as antioxidants, vitamin E, B vitamins, minerals and enzymes (Hemery *et al.*, 2007). The starchy endosperm comprises the major part of the grain and consists of cells filled with starch. Starch is composed of the polysaccharides amylose and amylopectin. Amylose is insoluble at low temperatures and has mainly a linear structure while amylopectin has a branched structure and is soluble in water. In the starchy endosperm, amylose and amylopectin are arranged in semi-crystalline granules called starch granules that are embedded in a protein matrix (Stick & Williams, 2009). When starch is placed in heated water it starts to gelatinize. This is a process where the starch granules start to swell and loses its semi-crystalline structure. As a consequence, amylose starts to leach out from the granules and forms a network together with proteins that retain water and increases the viscosity.

Outside the starchy endosperm are a number of layers rich in dietary fibers which together form the bran. These layers are named (from surface to the starchy endosperm) inner- and outer Pericarp, Testa, Hyaline and

Aleurone. The outermost layers contain high amounts of insoluble dietary fibers such as cellulose and hemicellulose with a high proportion of xylose and arabinose. The Pericarp and Testa layer are also abundant of the insoluble dietary fiber lignin (Hemery *et al.*, 2007).

The aleurone layer contains bioactive substances surrounded by thick cell walls made of arabinoxylans. These arabinoxylans contain high amounts of phenolic acids with the major part being ferulic acids which is known for its antioxidant properties (Antoine *et al.*, 2003; Hernanz *et al.*, 2001). The aleurone layer also comprise β-glucans (Hemery *et al.*, 2007,), the major part of B-vitamins and about half the total mineral content of the wheat kernel (Pomeranz, 1988). Unfortunately, there are also large amounts of phytate in the aluerone layer. This substance has a negative impact on the uptake of minerals from whole grains in the intestines as it binds minerals, making them less available (Hemery, 2007).

2.1.1 Durum wheat

Durum wheat grains have a hard kernel and differs in appearance compared to common wheat by being larger and having a more elongated shape (Wiseman, 2001). They also have higher protein content, larger flour particles and the large starch granules are smaller compared to common wheat (Heneen & Brismar, 2003). The endosperm is hard and yellow which gives the durum pasta its yellowish color. It is suitable for pasta production due to its high content of yellow pigments and high content of proteins that are favorable when it comes to the cooking quality of pasta (Aalami *et al.*, 2007).

Upon milling of durum, the starchy endosperm is ground into a coarse yellow granular product known as semolina (Wiseman, 2001). According to Fuad & Prabhasankar (2010), semolina should have a nice yellow color, enough gluten proteins, few black or brown spots, uniform granulation and a moisture content of 13.5 to 14.5% to obtain the best quality in pasta.

2.1.2 Durum wheat bran

Wheat bran is rich in insoluble dietary fibers with the major part being cellulose, hemicellulose and lignin (Hemery *et al.*, 2007). The bran is usually removed from the endosperm during the milling process. Depending on where in the milling process the bran is removed different fractions are developed with various bran sizes and composition. The bran fractions are by-products in the milling process and are often used for animal feeding (Hemery *et al.*, 2007).

Most of the wheat bran cannot be digested by human enzymes in pollard flour the small intestine. Instead it remains relatively undigested in the gastrointestinal passage until it reaches the large intestine where it is completely or partially fermented by gut bacteria (Mongeau, 2003).

2.2 Production of pasta

The term pasta describes food products like "macaroni, pasta, vermicelli, noodles etc. which are traditionally made from semolina milled from hard durum wheat" (Kent and Evers, 1994b, p 233).

Pasta products are generally comprised of water and milled wheat that have been mixed together. Other ingredients such as eggs and dietary fiber are sometimes also added (Fuad & Prabhasankar, 2010). However, water and semolina (flour) are the essential ingredients and all the others can be seen as optional. Different kinds of flours may also be used to produce pasta products. Some examples include unbleached flour, semolina flour, whole grain flour, buckwheat flour, brown rice flour and corn meal flour (Fuad & Prabhasankar, 2010). In North America and Europa, pasta products like macaroni and pasta are almost exclusively made from *durum* wheat flour (Fuad & Prabhasankar, 2010).

Production of pasta can be achieved in many different ways. However, in large scale production there are four critical steps that have impact on the final quality: milling of wheat, mixing of ingredients, extrusion and drying. The section below will provide a brief overview of these steps.

2.2.1 Milling of durum wheat

Milling is one of many food processes used for size reduction. There are several different types of milling processes depending on the characteristics of the food (Fellows, 2009a). During the milling process, the wheat kernel is mechanically separated into various components. The outcome of the separation depends on how the wheat is composed structurally (Evers & Bechtel, 1988). In an ideal milling process, the endosperm is separated from the wheat kernel in the form of semolina without being contaminated by the bran and the germ (Turnbull *et al.,* 2001). As mentioned earlier, the tissues that are removed from the endosperm during the milling are called bran fractions and are mentioned as by-products (Hemery *et al.*, 2007).

Before the actual milling process begins, the wheat kernels are washed. This process removes impurities such as metal pieces, foreign grains, stones and other unwanted particles and cleans the grain surface from pesticides, rodent droppings, insect fragments, sand and dust. The grains are also classified according to weight, shape and size. The washing process also involves a process called tempering where the wheat kernels are conditioned with water to reach optimal mellowness and a bran layer that is more loosened from the endosperm (Turnbull *et al.,* 2001).

Wheat, including durum wheat, is often ground in roller mills. A roller mill is equipped with pairs of smooth steel rollers (between 3-8 pairs depending on the property of the food) that revolve towards each other. When wheat kernels pass through the nip (the space between the rollers) they are crushed by the force of compression into smaller particles. The wheat particles then carry on due to gravity to the next pair of rollers where the nip becomes narrower the further ahead in the milling process they get. The wheat is thereby crushed into progressively smaller particles. The rollers for wheat are often fluted, meaning that they have shallow ridges along the length of the roller. Thus, the wheat particles are also subjected to shearing forces (Fellows, 2009a).

The milling process can be further divided into three stages, all made up of different types of roller mills. The first stage is the break system where the grains are opened and the starchy endosperm is scraped off from the bran. The second stage is the detacher system where possible remnants of flakes of bran on the semolina particles are gently scraped off, and the third stage include rolls that reduces the size of large semolina particles so that all particles have a uniform and small size (Kent & Evers, 1994a).

For decades, pasta manufacturers used durum wheat flour with a particle size of between 125 to 630 µm (Turnbull *et al.*, 2001). However, in more recent years pasta manufacturers are using semolina with finer particle size. The reason is because it reduces the time for mixing ingredients and because newer manufacturing technology requires semolina with a finer particle size. It is common to use sizes between 125 to 425 µm (Turnbull *et al.,* 2001).

2.2.2 Mixing and extrusion

In traditional pasta manufacturing, semolina and water are first mixed together into a dough before being extruded. The dough should have a moisture content of about 30% as this gives the dough suitable viscosity for the extrusion process (Kent & Evers, 1994b).The water should have a temperature of about 40-50 °C as it has shown to have a positive influence on water absorption rate and dough development time (Dawe *et al.,* 2001). The mixing time for semolina with particles less than 500 µm should be about 15 minutes in order to reach desirable moisture content (Dawe *et al.,* 2001). According to Kent & Evers (1994b), the moisture content of the pasta dough in the extrusion process should be about 28%.

In the extrusion of pasta, high pressure is used to push dough through a shaped die (one or more restricted openings) which gives the pasta its final form. There are many types of different dyes that can produce several kinds of shape to the pasta (Fuad & Prabhasankar, 2010).

Extruders consist of either one or two screws that are contained in a horizontal barrel. For both types of extruders, the process is based on feeding raw materials into the extruder barrel where the screw or screws convey the food along the barrel. Further on in the barrel, the food is compressed due to reduced volume, building up a pressure. At this point, the screws start kneading the food under pressure into a semi-solid, plasticized mass before it is finally forced through the dies at the outlet of the barrel (Fellows, 2009b).

2.2.3 Drying procedure

Traditionally in Italy, the pasta was dried outdoors in the sun. Today, the drying process has evolved into a complex procedure involving several steps where temperature and humidity are controlled with special equipment (Kent & Evers, 1994b).

If the pasta is dried too quickly, cracks and curling will easily arise. However, if the drying rate is too slow, moulds can easily develop, the color may not be desirable, and the pasta may get sour (Kent & Evers, 1994b). It is therefore important to find a good balance between these two parameters.

Drying pasta at high temperatures has been shown to be effective because it contributes to both high quality in the final product and a shorter drying time (Zweifel *et al.,* 2003). Best results are achieved when high temperatures are used at the end of the drying process, as this contributes to the formation of the most stable protein network that encapsulates the starch granules (Zweifel *et al.,* 2003). After the drying process, the pasta should have a moisture content of about 12.5% (Kent & Evers, 1994b; Pagani *et al.,* 2007).

2.3 Pasta quality

What is good pasta quality? Firmness, elasticity, surface stickiness, cooking tolerance, water absorption, degree of swelling and solids lost to the water are factors and characteristics that are usually mentioned when pasta cooking quality are discussed (Dexter *et al.,* 1983). According to Feillet (1984) good quality of pasta may be defined as the ability of the proteins in pasta to form an insoluble network that surrounds and entraps gelatinized and swollen starch granules in the pasta matrix. The interaction between starch gelatinization and protein network formation in the presence of water is of crucial importance for the final texture, and thus the quality of cooked pasta (Resmini & Pagani, 1983).

The major quality parameters for pasta, from a consumer's point of view, are appearance and textural properties (Cole, 1991). According to Pagani *et al.,* (2007), pasta of high quality should be free from fractures or fissures and have no black specks or white spots. It should also have a typical yellow color. Furthermore, cooked pasta of good quality should have an optimal consistency, which includes low stickiness. In many parts of the world, high quality of cooked pasta is associated with the term "al dente", which means that it should have a firm and elastic structure when cooked (Pagani *et al.,* 2007). According to Bruneel *et al.,* (2010), cooked pasta of good quality should show high levels of water absorption, low cooking loss, and good texture, encompassing high firmness and low stickiness.

2.3.1 Method for evaluating sensory quality in pasta

Sensory quality of cooked pasta can be evaluated by the use of a sensory panel. Several different sensory methods can be used when evaluating foods, but a descriptive analysis is a common tool when there is a need to know how different ingredients or processes affect a product (Lawless & Heymann, 2010). The assessment of a food can be done in many different ways, but a common technique is to use linear scales when the panel rates different attributes of a food product.

Descriptive analysis often use taste panels comprising 8-12 people. The panel receives training on the product before the assessment in order to make the panel well acquainted with the product and the attributes to be assessed (Lawless & Heymann, 2010).

2.3.2 The effect of adding wheat bran on the quality of pasta

Addition of wheat bran into pasta reduces the caloric content and may provide a positive effect on faecal bulking and laxation (Aravind *et al.,* 2012). It will also increase vitamin and dietary fiber content since most of the vitamins and minerals are found in the bran.

Adding bran to pasta gives a pasta matrix that is less homogenous and the particles may interfere with the development of the gluten network (Manthey & Schorno, 2002). Enriching pasta with dietary fiber will affect the water uptake in pasta, making it unevenly distributed as the added dietary fiber has a hydration tendency and will compete against starch for water (Fuad & Prabhasankar, 2010). This may lead to areas in the pasta matrix where the starch has not swelled due to limited water availability (Fuad & Prabhasankar, 2010).

Adding dietary fiber and bran to pasta can be noticeable to the consumer by feeling a reduction in elasticity and firmness (Fuad & Prabhasankar, 2010). Color, cooking and sensory properties has been reported to become less favorable in pasta made from flour enriched with bran, compared to pasta made solely from semolina (Edwards *et al.,* 1995; Kordonowy & Youngs., 1985; Sahlstrom *et al.,* 1993; Chen *et al.,* 2011; Shiau *et al.,* 2012). However, Chen *et al.,* (2011) reported that an addition of 5-10% of fine bran (particle size of 160-430 µm) or 5% medium bran (430-1000 µm) in chinese noodles was perceived as satisfactory. Shiao *et al.,* (2012) reported similar results and suggested that an addition of 4-8% fine wheat bran (particle size of 149-420 µm) did not interfere with good quality in cooked noodles.

Because of its high content of antioxidants, bran will cause a more bitter flavor and darker color in food (Aravind *et al.,* 2012). The color of pasta becomes darker even at an addition of only 10% of durum wheat bran with a particle size of 150-500 µm, giving it a reddish brown color (Aravind *et al.,* 2012).

A 30% wheat bran inclusion in pasta has also shown to result in reduced water absorption, as well as a decrease in the Optimum Cooking Time (OCT) (Aravind *et al.,* 2012). OCT decreased by 1.5 min for pasta with 30% bran incorporation compared to regular durum pasta. The authors suggested that a reason may be because bran causes a reduction in gluten content or a physical disruption in the gluten matrix allowing water to more easily penetrate into the pasta and thus shorten the OCT. Aravind *et al.,* (2012) also concluded that adding durum wheat bran with a particle size of 150-500 µm at levels of 10, 20 and 30% in durum wheat pasta had a negative impact on many sensory and some technological properties such as reduced firmness. However, adding 10% of bran had similar sensory texture scores as durum pasta with no added bran and pasta with 30% added durum wheat bran was similar in texture as commercial whole meal pasta (Aravind *et al.,* 2012).

2.3.3 The effect of bran particle size on the quality of food

Studies on different particle sizes of bran and its effect on food are contradictory. Some studies have reported that smaller particle sizes of bran gives a less adverse effect on the quality of pasta and bread (Shiau *et al.,* 2012; Chen *et al.,* 2011; Majzoobi *et al.,* 2013; Lai *et al.,* 1989). At the same time there are studies suggesting the opposite (Noort *et al.,* 2010; Zhang & Moore 1999; de Kock *et al.,* 1999).

Majzoobi *et al.,* (2013) examined the incorporation of wheat bran of different particle sizes and its effect on the quality of flat bread. They concluded that increased particle size gave darker, more reddish and less yellowish color of the crust and had a negative impact on the taste compared to smaller bran particles.

Zhang & Moore (1997) studied wheat bran particle size and its effect on bread dough rheological properties and reported that coarse bran retain significantly more water than medium or fine bran.

Noort *et al.,* (2010) added wheat bran in bread-making and reported that reduced particle size led to an enhancement in the adverse effects. According to the authors, the two most potential explanations for this was that smaller bran particles provide larger interaction surfaces between gluten proteins and reactive components such as ferulic acid monomers that are present in the cell wall material in the bran. Since these dietary fiber-gluten interactions are the largest contributor to the negative impact of the bran according to Noort *et al.,* (2010), it becomes even worse when the particles are smaller. The second reason mentioned by the authors was that more reactive components are released from smaller bran particles because the cell breakage is greater the smaller the particles are. The cells in the outer layers of the wheat kernel, especially in the aleurone layer contains components (such as reducing components, phytate and conjugated ferulic acid monomers) that may directly or indirectly interact with the gluten proteins.

There is a lack of studies that have investigated particle sizes of bran and its effect on pasta. However, there are two studies on noodles where this has been evaluated. Shiau *et al,* (2012) evaluated the effect of adding different levels of wheat fibers as well as different wheat fiber particle sizes in raw, dried and cooked noodles. Noodles are very similar to pasta when it comes to texture and taste, and just as for pasta, the eating quality of noodles largely depends on textural characteristics, elasticity and surface smoothness (Shiau *et al.,* 2012). The result from the study showed that cooked noodles enriched with small particle sizes (149-420 µm) had higher breaking force and extensibility (related to elasticity), as well as lower cutting force compared to cooked noodles with large particle sizes (420-840 µm). However, the color in noodles was not affected by the particle size. Furthermore, it was seen that the extensibility (closely related to elasticity) in cooked noodles generally was reduced with increasing wheat fiber level and particle size. The authors suggested that this may be due to "the negative effect on the formation of gluten network using excess or coarse wheat fiber" (Shiau *et al.,* 2012, p 212).

Chen *et al.*, (2011) also investigated the effect of adding different levels and particle sizes of wheat bran in dry white noodles. They concluded that hardness, gumminess and chewiness of cooked noodles decreased with increasing bran addition level and particle size. On the contrary the parameter adhesiveness increased with increasing bran addition level and particle size. They also concluded that when increasing the particle size of wheat bran, from 160 to 2000 µm, total sensory score of cooked noodles decreased. Adding coarse bran with an average particle size larger than 530 µm had mainly a negative effect on the quality parameters color, appearance, palate, smoothness, and taste, and could for these reasons not readily be accepted by the evaluators. The authors also concluded that their results indicated that a 5% addition level of fine and middle size bran with an average particle size of 210 and 530 µm respectively, had the potential to receive high total sensory score. (Chen *et al.,* 2011).

3. Materials and methods

3.1 Raw materials

Three different fractions of durum wheat bran, as well as durum wheat flour and durum whole grain flour were obtained from AB Nord Mills, Malmö, Sweden. According to the product specification, the durum wheat flour and the durum whole grain flour had a particle size of up to 400 µm with the main part (63%) being between 85-250 µm for the wheat flour and the main part (57%) between 150-400 µm for whole grain flour. The three bran fractions were called; coarse bran, fine bran and pollard flour and had main particle sizes between 600-1000 µm, 250-600 µm and 75-250 µm respectively. The different bran fractions had been removed from the mill at different processing steps in the milling process. Coarse bran had been taken out after grinding with two or three rolls; fine bran had been removed after further grinding in a number of additional rolls; and pollard flour had been removed after milling with a rotary mill.

3.1.1 Preparation of wheat bran fractions

The fractions with coarse bran, fine bran and pollard flour were further ground to obtain smaller particles. The fractions were milled in a Perten 3100 laboratory mill and in a pilot station classifier mill consisting of an impact beater mill (Alpine ZPS 50 mill) assembled with an air classifier from Hosokawa (Alpine 50 ATP Turboplex). Depending on the type of bran, the rotational frequency of the classifier mill was set at between 4000 and 16000 rpm. The air flow was set to 10 mbar, and the classifier was set at between 1700 and 1800 rpm. The bran fractions were then divided into series A and B that underwent different preparation as explained below.

Series A: The remaining fractions after grinding were shaken in a mechanical shaker over two sieves; 400 µm and 250 µm to receive final products from each fraction with a particle size of 250-400 µm. 100 gram was shaken each time for a total of 10 minutes.

Series B: The three milled bran fractions were mixed together into a final mix consisting of 30% pollard flour, 48% fine bran and 22% coarse bran. This composition corresponds to the content of the various bran fractions in Lantmännen's whole grain flour used in their current whole grain pasta. The mixed product was shaken in a mechanical shaker over four sieves: 400 µm; 250 µm; 150 µm and 85 µm to produce bran fractions with three different particle sizes; 85-150 µm, 150-250 µm and 250-400 µm. 100 gram was shaken for a total of 10 minutes.

The chemical composition of the resulting bran fraction powders were analyzed by Eurofins Food and Agro Testing Sweden AB (Table 1).

Table 1. Chemical composition of six different wheat bran fractions

	Series A		Series B			
	Coarse bran	Fine bran	Pollard flour	250-400 µm	150-250 µm	85-150 µm
Dietary fiber (g/100g)	69.5	57.1	49.3	56.9	37.8	20.1
Starch (g/100g)	2.5	8.0	11.9	8.6	25.8	39.0
Crude protein (g/100g)	18.0	15.9	14.2	14.9	14.0	11.1
Moisture content (g/100g)	6.8	8.1	7.8	7.8	8.2	8.7
Crude fat (g/100g)	7.3	7.8	7.1	7.5	5.8	5.3

3.2 Production of pasta

A number of test doughs were prepared to find the necessary moisture content to achieve good consistency of the dough, while containing as much dietary fiber as possible. The dough held desirable quality when it had a water content of 36.6% and hence, a dry matter content of 63.4%. The objective became to make pasta with a dietary fiber content of between 16-18%. Hence, durum wheat semolina was substituted with bran to reach this dietary fiber content. The amount of flour and water in the different doughs are shown in Table 2, 3 and 4.

Table 2. Formulation to prepare pasta with different amounts of whole grain flour (g/100g flour).

Pasta sample	Durum wheat flour	Tap water	Durum whole grain flour
1A	100	34.1	-
1B	50	36.1	50
1C	-	37.1	100

Table 3. Formulation to prepare pasta with different bran fractions of same particle size - 250-400 µm (g/100g flour).

Pasta sample	Durum wheat flour	Tap water	Coarse bran	Fine Bran	Wheat middling
2A	79.5	38.2	20.5	-	-
2B	73.0	38.3	-	27.0	-
2C	68.4	38.7	-	-	31.6

Table 4. Formulation to prepare pasta with a mix of bran factions (22% coarse bran, 48% fine bran, 30% pollard flour) and varying particle sizes (g/100g flour).

Pasta sample	Durum wheat flour	Tap water	Bran; 250-400 µm	Bran; 150-250 µm	Bran; 85-150 µm
3A	72.9	38.3	27.1	-	-
3B	58.0	39.5	-	42.0	-
3C	14.4	42.9	-	-	85.6

Pasta in the form of spaghetti was produced in pilot scale using an Edelweiss Extruder Pasta machine TR/75C. A die form no. 7 was used to create the spaghetti shape with 4 of 7 die openings closed. The pasta doughs were prepared by mixing durum wheat semolina with the different bran fractions and by adding water with a temperature of about 40-50 °C. Half of the water was added at the start of the mixing procedure and the rest was added after 5 min. The dough was mixed for about 15 min.

During the extrusion process, a fan on the pasta machine was turned on as it made the separation of the pasta strands easier. The strands were hung over wooden sticks on a rack and separated from each other by hand before being placed in a combi steamer oven (Rational, Germany).The pasta was dried for a total of 6 hours and 15 minutes at temperatures between 40 and 90 °C according to Table 5.

Table 5. Drying procedure of the pasta

Interval	1	2	3	4	5	6	7	8
Temperature (°C)	40*	50	60	70	80	90	~50	50**
Time (minutes)	30	120	30	10	5	30	30	120

*Steam was added for ~15 sec counted from the time the vapor became visible
~Temperature was decreased gradually from 90 to 50 °C during 30 min.
** Relative humidity was set to 50% with the help of the “ClimaPlus”-function of the oven

Pasta was removed after various drying times to measure moisture content in a moisture analyzer (Satorius, USA). Measurements were made in duplicates.

3.3 Pasta quality evaluation

3.3.1 Water absorption

Single strands of pasta (25±2 mm) were boiled in cultivated glass tubes containing 10 ml of tap water and 0.7% sodium chloride. Pasta strands were removed after 30 sec, 1, 2, 4, 6, 8 and 10 min. After removal, the pasta stands were cooled in water and surface water was wiped of using paper towels, before being weighed. Water absorption was measured in duplicate and calculated as: [[Weight of cooked pasta (W1) - Weight of raw pasta (W2)] / weight of raw pasta (W2)] * 100.

3.3.2 Optimum Cooking Time (OCT)

According to the American Association of Cereal Chemists (AACC International, 2000) the OCT is the time when a pasta strand loses its white uncooked core. This is determined by pressing a small piece of pasta between two glass plates and record the time when the white spot in the core of the pasta disappears. In this study, the pasta was cooked in tap water with 0.7% sodium chloride and was checked every 15 seconds after 6-7 minutes of boiling until it reached OCT.

3.3.3 Sensory evaluation

A sensory evaluation in the form of a descriptive analysis was carried out using a taste panel of eight experienced pasta tasters. The following attributes in the pasta were evaluated by the panelists:

- *Whole grain flavor* - Is determined by how clearly the whole grain flavor emerges in the pasta
- *Stickiness* - The force with which the cooked pasta adhere to other materials e.g. tongue, teeth, and fingers. The attribute is judged visually by observing how well two pieces of pasta strands stick together when being separated.
- *Firmness* - The initial force required to cut through the pasta using the teeth. The attribute is judged by biting through a pasta strand with the front teeth and assess how much force that is required to bite through the whole pasta strand.
- *Surface roughness* - The degree of coarseness and irregularity that is perceived on the surface of the pasta strand. The attribute is assessed by placing a piece of pasta in the mouth, near the back of the front teeth and move the tongue along the pasta in different directions.
- *Elasticity* - The ability of a solid material to return to its original size and shape after a deforming force has been removed. In pasta, this is assessed visually by observing how well a pasta strand returns to its original length after being stretched.

The panel assessed the attributes on a linear scale with minimum and maximum values of -6 and +6 (cm). A reference was placed in the center of the scale (see appendix 2). The panel assessed the pasta by comparing how much more or less intense a certain attribute was compared to the reference. The reference consisted of pasta made of 100% whole grain flour. The panel was also asked to rate the likeability of the pasta on a scale that was 10.3 cm with “liked very little” anchored on one side and “liked very much” on the other (see appendix 2). The result from the sensory evaluation was calculated by measuring the distance from the reference to a cross on the linear scale made by the panelists. Likeability was calculated by placing 0 at the far left of the scale at “Liked very little” and the distance from 0 to a cross made by the panelists was measured.

Before evaluating the pasta, the panel met once for a training session where they were introduced to the attributes to be judged. The purpose of the training was to get the attributes to have the same meaning for all panelists. The panel was also trained to use the scale in the same manner in order to minimize the risk of having participants who used the scale in different ways.

During the evaluation, the panel was served four samples of pasta and the reference. One of the four samples contained the same pasta as the reference. The pasta had been boiled in tap water with 0.7% sodium chloride for 10 minutes, which corresponded to their OCT + approximately 2 minutes. All samples except the reference were labeled with three digit codes and served in a randomized order. The evaluation was executed twice to ensure that the panel was reproducible. The panelists were provided with drinking water and wafers to clean their palates and reset their taste buds in between the samples.

3.3.4 Statistical analysis

The results from the sensory evaluation, water absorption measurement, and moisture content analysis were expressed as the mean of two replicates. All data were subjected to analysis of variance (ANOVA, General linear model). Grouping information was received using the Tukey Method with a 95.0% confidence interval. P-values less than 0.05 were considered significant. Analyses were performed using the software program Minitab 16 Statistical Software (Minitab Inc., USA).

3.4 Light microscopy evaluation

The microstructure of cooked pasta was determined by light field microscopy. The pasta had been cooked in the same way as mentioned in section 3.3.3. Small pieces of cooked pasta were fixed with glue on small containers and were then rapidly frozen in about -20 °C for 10-15 minutes. When the pasta was frozen, 5 µm thick cross sections were made using a cryostat microtome (Leica CM 1850, Germany). The pasta sections were placed on glass slides and examined in a microscope (Nikon Eclipse Ni-U equipped with the camera Nikon DS-Fi2) at 4, 10 and 20 times magnification. Pictures of the pasta were taken in bright field and polarized light and were processed in the software program NIS Elements BR (Nikon, Japan).

Some samples of the pasta were also stained with iodine and light green. The sections were stained with light green for 30 minutes and washed with distilled water. Thereafter, the pasta was stained with iodine for 40-50 seconds and washed with distilled water. Light green stains proteins green while iodine stains amylose-rich starch blue and amylopectin-rich starch brown/violet (Heneen & Brismar, 2003).

4. Result and discussion

4.1 Production of pasta

In the following thesis, three series (1-3) of pasta which together comprised 9 pasta samples were produced. A summary of the pasta samples are shown in Table 6. A picture of the pasta samples can be seen in Appendix 1.

Table 6. Summary of the composition of pasta samples that were produced in this study

Pasta sample	Description
1A	100% Durum wheat flour
1B	50% Durum wheat flour and 50% Durum whole grain flour
1C	100% Durum whole grain flour
2A	Durum wheat flour + Coarse bran with a particle size of 250-400 µm
2B	Durum wheat flour + Fine bran with a particle size of 250-400 µm
2C	Durum wheat flour + Pollard flour with a particle size of 250-400 µm
3A	Durum wheat flour + mixed bran factions (22% coarse bran, 48% fine bran, 30% pollard flour) with a particle size of 250-400 µm
3B	Durum wheat flour + mixed bran factions (22% coarse bran, 48% fine bran, 30% pollard flour) with a particle size of 150-250 µm
3C	Durum wheat flour + mixed bran factions (22% coarse bran, 48% fine bran, 30% pollard flour) with a particle size of 85-150 µm

As can be seen in Table 6, pasta series 1 (1A-1C) were not substituted with any of the bran fractions that were produced in this study. This series served as a reference and were used as a comparison to the pasta with added bran. They were also used as extremes in the training session that the taste panel received. During the sensory evaluation, pasta 1C was used as the reference as it contained all parts of the bran and all particle sizes that were included in the pasta to be evaluated.

Pasta in series 2 was produced in order to evaluate how different bran fractions affect the quality in whole grain pasta. After a preliminary sensory evaluation it was found that it was difficult, if possible, to observe any differences between these samples. Therefore, and due to time limitations, only pasta from series 3 were evaluated by a descriptive sensory analysis. As a consequence, the results and discussion in this thesis will almost exclusively deal with the evaluation of the pasta from series 3. If more time had been available, it would have been of interest to perform a discrimination test, such as a triangle test, on the pasta in series 2 in order to see whether a difference between the samples would be observable or not.

The diameter of the final pasta samples were 1.5±0.05 cm. As can be seen in Table 7, there was no significant difference in moisture content between the samples. The moisture content in the doughs were also close to the recommended level of 30% (Kent & Evers, 1994b).

Table 7. Moisture content before and after drying (%w/w.)

Pasta sample	Before drying	After drying
1A	32.15 [a]	4.58 [a]
1B	31.20 [a]	5.36 [a]
1C	31.13 [a]	4.11 [a]
2A	33.05 [a]	4.36 [a]
2B	34.29 [a]	6.24 [a]
2C	33.84 [a]	6.06 [a]
3A	34.72 [a]	5.91 [a]
3B	33.25 [a]	5.57 [a]
3C	32.33 [a]	6.36 [a]

Mean of two measurements. Values in the same column sharing the same letter are not significantly different.

The decision to add bran to the pasta in series 3 in order to reach the same dietary fiber content is questionable. This series was incorporated with the bran fraction powder from series B where the smallest particle size (85-150 µm) had a significantly lower dietary fiber content compared to the fractions with larger particle sizes (see Table 1). As a result, large amounts of this bran fraction powder had to be added to reach the right dietary fiber content. This is problematic as it makes it difficult to determine whether a possible effect on the quality of pasta was due to a certain particle size, or if it was due to the significantly greater amount of bran fraction powder that had to be added. As this may have affected the results, it would have been of interest to further investigate a possible effect by producing an additional series of pasta containing different particle sizes but with the same amount of bran. This would have made it possible to rule out whether a possible effect was due to the particle size or due to the high quantity of bran fraction powder.

4.2 Pasta quality evaluation

4.2.1 Water absorption

The pasta with the smallest particle sizes (3C) had lower water absorption per minute compared to the other samples (Figure 2). The difference increased with cooking time and was significant from 6 minutes and onward. This observation is in accordance to the findings by Noort *et al.,* (2010) who examined the water absorption with a Farinograph of two dietary fiber fractions; wheat bran and aleurone enriched wheat bran with different particle sizes. They reported that water absorption decreased with decreasing particle size but did not observe any difference between different bran fractions.

Observing no difference between the bran enriched pasta and the regular durum wheat pasta when it comes to water absorption was unexpected since water absorption normally increases when flour is being replaced by dietary fiber fractions as dietary fiber typically bind more water compared to flour (Noort *et al.,* 2010).

According to Bruneel *et al.*, (2010) cooked pasta of good quality should show high levels of water absorption. Hence, according to this test, cooked pasta with the smallest particle size therefore had inferior cooking quality compared to the other pasta samples.

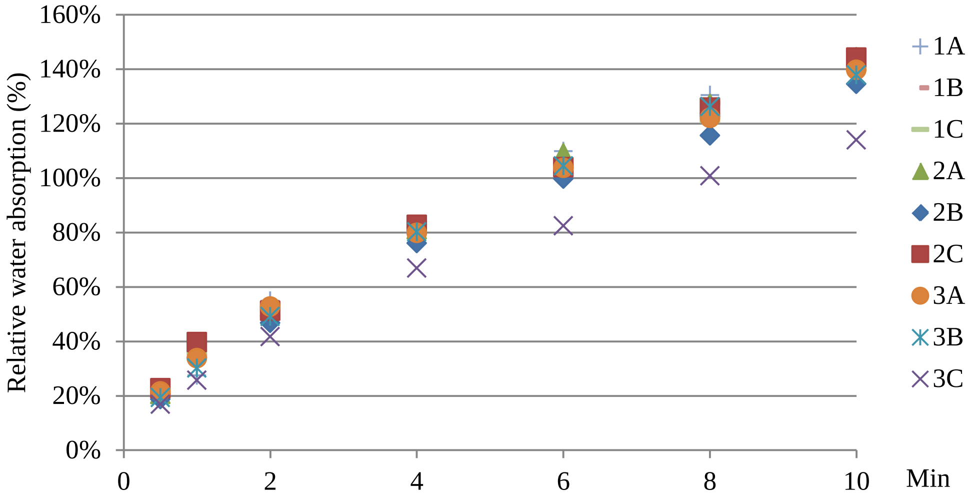

Figure 2. Relative water absorption in the pasta at different time intervals

4.2.2 Optimum Cooking Time (OCT)

The pasta in series 1 had similar OCT of approximately 10 min (Table 8). The OCT for all pasta samples with added bran was approximately 2 min shorter. No difference could be seen depending on the bran particle size or type of bran fraction. These findings are similar to Aravind *et al.*, (2012) who reported that OCT was reduced with 1.5 min. for pasta incorporated with 30% durum wheat bran compared to regular durum wheat pasta.

Table 8. Optimum Cooking Time (OCT) of pasta enriched with wholegrain flour and bran fractions of varying source and particle sizes.

Pasta sample	OCT
1A	10 min
1B	9 min 45 sec
1C	9 min 45 sec
2A	7 min 45 sec
2B	7 min 45 sec
2C	7 min 45 sec
3A	7 min 45 sec
3B	8 min
3C	7 min 45 sec

The method approved by the AACC for determining OCT is developed for regular durum pasta (AACC International, 2000). As was seen in this study, the method was also effective for pasta 1A and 1B, but was more difficult to apply on pasta containing high levels of bran and especially with large particles. Determining OCT was not only difficult when looking at the pasta visually, but also when being inspected with polarized light microscopy. The white uncooked core in the pasta was not as visible as in regular durum pasta and the time of its disappearance was therefore difficult to determine. Hence, the values from the determination of OCT in pasta 1C, 2 A-C and 3 A-C may have large errors and may further have affected the outcome of the sensory evaluation of the pasta.

4.2.3 Sensory evaluation

The result from the sensory evaluation is shown in Table 9. The values are means from two evaluations and represent the distance in centimeters measured from the reference in the middle of the scale to the point on the scale where the panel made its assessments. The scale was 2 x 6 cm and can be seen in appendix 2. An attribute with a minus sign in front, means that the attribute was perceived as less intense compared to the reference, which comprised pasta 3C. For values without a minus sign, the same procedure was applied but reversed. The attribute could at most get -6 and 6. The likeability of the samples was assessed without being compared to a reference and could get a minimum value of 0 and a maximum value of 10.3. A low number around 0 means that the panel liked the product very little, while a high number around 10 means that the panel liked the product very much.

The control in the evaluation consisted of the same pasta as the reference and was included as a way to estimate how skilled the panel was on evaluating the pasta. A value around zero for the control means that they did not perceive much difference compared to the reference.

One of the participants in the panel was not reproducible for several of the attributes and the panelists' assessments differed significantly from the others. As a consequence, the assessments from this panelist were excluded and the results from the sensory evaluation are therefore based on seven panelists.

Table 9. Sensory evaluation and overall likeability of pasta enriched with bran of 3 different particle sizes.

Sensory attribute	Sample			
	Control	3A	3B	3C
Whole grain flavor	$0.3^{b} \pm 1.1$	$2.8^{a} \pm 1.7$	$3.3^{a} \pm 1.3$	$3.7^{a} \pm 1.5$
Stickiness	$0.0^{a} \pm 1.0$	$-3.5^{b} \pm 1.5$	$-4.1^{bc} \pm 1.3$	$-4.9^{c} \pm 1{,}4$
Firmness	$-0.5^{a} \pm 1.0$	$-2.1^{a} \pm 2.8$	$-2.0^{a} \pm 2.1$	$-2.5^{a} \pm 3.2$
Surface roughness	$0.2^{c} \pm 0.9$	$4.3^{a} \pm 2.2$	$3.2^{ab} \pm 1.1$	$2.5^{b} \pm 2.3$
Elasticity	$-0.4^{a} \pm 1.1$	$-3.5^{b} \pm 1.3$	$-3.1^{b} \pm 1.3$	$-4.3^{b} \pm 1.2$
Overall likeability	$6.8^{a} \pm 1.4$	$3.3^{b} \pm 1.8$	$3.6^{b} \pm 1.6$	$2.0^{c} \pm 1.1$

Values are presented as means and S.D. Means in the same row, sharing the same letter, are not significantly different ($p > 0{,}05$)

There were no significant difference between the control and the reference for any of the attributes. This is an indication that the panel made accurate and precise assessments.

The attribute whole grain flavor was rated significantly higher for all samples containing added bran compared to the reference, but there was no significant difference between them.

The attribute elasticity was perceived as significantly lower for all samples with added bran compared to the reference but there was no significant difference between them. This is in accordance to the findings by Chen *et al.,* (2011) who reported that elasticity in noodles decreased when 20% bran was added. They could also see that this observation was reinforced the larger the bran particles, but the difference between fine, medium and coarse bran was not significant. Shiau *et al.,* (2011) reported that increasing bran size reduced the extensibility in noodles, which is an attribute that is similar to elasticity.

Moreover, there was no significant difference between the samples when it came to the attribute firmness. They did not differ significantly from the reference either, even though there was an indication that the panel perceived them as less firm compared to the reference. Firmness, however, had high standard deviation for samples 3A-C compared to the other attributes, indicating that this attribute was difficult to assess. This was also pointed out by the panel during the training session. Aravind *et al.*, (2012) reported that incorporation of bran in pasta led to a reduction in firmness when measured instrumentally. However, this reduction was not possible to confirm when a sensory panel did the assessment. Contrary to the instrument, the panel considered firmness to increase in pasta incorporated with 20% bran, but did not experience any difference in pasta with 10% and 30% bran, which is yet another indication that the attribute is difficult to assess.

The panel perceived sample 3A-C as less sticky compared to the reference. The assessment also indicated that stickiness decreased with decreasing bran particle sizes. Samples 3 C with small particle size were perceived as significantly less sticky compared to sample 3A with the largest bran particles. This result is contrary to the results by Chen *et al.,* (2011) where stickiness of noodles decreased as bran particle size increased. However, both Chen *et al.,* (2011) and Aravind *et al.,* (2012) reported that bran inclusion led till a reduction in stickiness.

As expected, the surface roughness of the pasta was perceived as more prominent the larger the bran particles it contained. All samples with added bran showed significantly higher values compared to the reference.
Surface roughness in the pasta with the largest bran particles was also perceived as significantly higher compared to the pasta containing the smallest bran particles. This is in line with the findings by Aravind *et al.,* (2012) who reported an increase in surface roughness when bran was added.

Regarding the likeability of the pasta, the panel liked the reference pasta significantly more compared to pasta 3A-C. Pasta 3C was furthermore assessed to be significantly less liked compared to pasta 3A and 3B. This is contrary to the result by Shiau *et al.,* (2011) who reported that taste perception of bran enriched noodles decreased with increasing bran particle size, although the differences between the particle sizes were not significant. As mentioned by Noort *et al.,* (2010), adverse effects for small bran particle sizes may be explained by the fact that smaller bran particles provide larger interaction surfaces between gluten proteins and reactive components that are present in the bran wall. Another explanation mentioned by the same authors is that cell breakage is greater in smaller particles which could make reactive components in the cell wall become released to a greater extent and interact with gluten proteins.

Looking at the joint assessment for the complete panel, there was no significant difference between the two assessment rounds for any of the attributes (data not shown). This strongly suggests that the panel as a group was reproducible. However, in order to receive accurate data, the panelist should have had to replicate the assessments several times to control the consistency of both the individual panelists and of the panel as a group (Lawless & Heymann, 2010). Due to limited time, this was not feasible and the results should therefore be seen as an indication. Furthermore, it is important to emphasize that data from descriptive analysis should be viewed as relative values and not as absolutes (Lawless & Heymann, 2010).

4.3 Light microscopy

Microscopic images of cooked pasta from series 1-3 can be seen in Figure 3. These images are showing complete cross sections of cooked pasta in bright field light and polarized light at 4 × magnification. Figure 4 include images of pasta 3 A-C that were stained with light green and iodine at three different magnifications. These images demonstrate a complete cross section of pasta at 4 × magnification; the central part of a cross section at 10 × magnification; and a section from the outer left surface towards the core of the pasta at 20 × magnification.

Bran particles could readily be observed in polarized light (Figure 3, lower row). In polarized light, light waves that are oscillating in on plane passes through a filter and reaches the observed object. Objects with crystalline structure, such as wheat bran, will refract these light waves, why they become more visible in this type of light. Judging by these images, it seemed as if the bran particles were distributed differently in the pasta depending on their size. The medium and largest particles appeared to be distributed more centrally in the pasta compared the smallest bran particles that were more evenly distributed throughout the cross section of the pasta.

As can be seen in Figure 4, the amount of gelatinized starch increased from the core to the surface. The images of pasta at 20 × magnifications showed dark purple, almost blue starch granules that were intact in the center of the pasta. Further away from the center, starch granules were slightly swollen and surrounded by proteins. Closer to the surface, starch granules and proteins had started to interact with each other. At this point, the starch granules are no longer intact and amylose begins to leak out from the granules. These observations are in accordance with observations made by Cunin *et al.*, (1995) who used light microscopy to examine the changes in inner structure and surface of pasta during cooking. After observing 9-14 µm thick pasta slices that had been made in a cryostat, they could see that protein and starch mainly interact in the outer and intermediate layer of cooked pasta (Cunin *et al.*, 1995).

Interpreting the images from the microscopic evaluation and assess whether there were any differences between the pasta containing different bran particle sizes was difficult. Judging by the pictures, there were few differences and pasta 3A, 3B and 3C were quite similar in texture and appearance. However, a possible difference could be sensed in the amount of gelatinized starch. Both pasta 3A and 3B seemed to have a higher degree of gelatinized starch granules in the outer and intermediate layer of the pasta compared to the starch granules in pasta 3C. This observation may be related to the fact that the water absorption in pasta 3C also was significantly lower compared to pasta 3A and 3B. As mentioned earlier, starch granules that start to swell and lose it semi-crystalline structure leads to the creation of a network made of starch and proteins that retain water. The smaller bran particles may have interfered with the diffusion of water into the pasta or with the development of the starch and protein network leading to reduced water absorption.

It also appeared as if there was a clearer layer of violet color, in pasta 3A than 3B. This could be because the gelatinization of starch had also progressed further into pasta 3B compared to 3A.

Unfortunately, it looked as if pasta 3C absorbed more of the staining product light green, making the interpretation of the images even more complicated. The amounts of violet color in the outer and intermediate parts of pasta 3C appeared to be present in smaller amounts compared to pasta 3A and 3B. However, this could also be due to the fact that excess light green may have affected the staining of starch with iodine and therefore resulted in different colors compared to the other pasta samples.

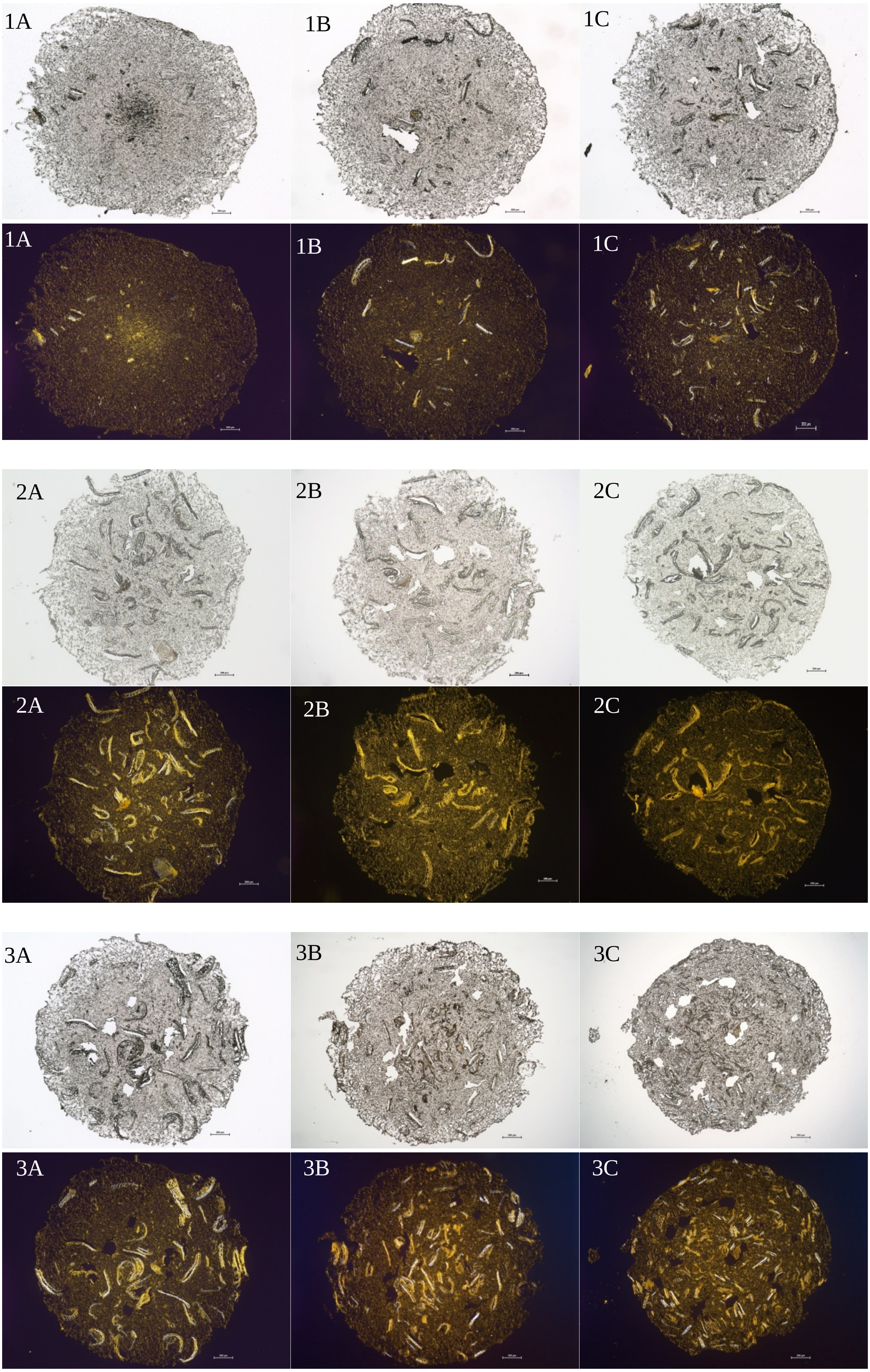

Figure 3 - Microscopic view of thin sections (5 µm) of cooked spaghetti from sample 1A-C, 2A-C and 3A-C in bright field light (upper row) and polarized light (lower row) at 4X magnifications.

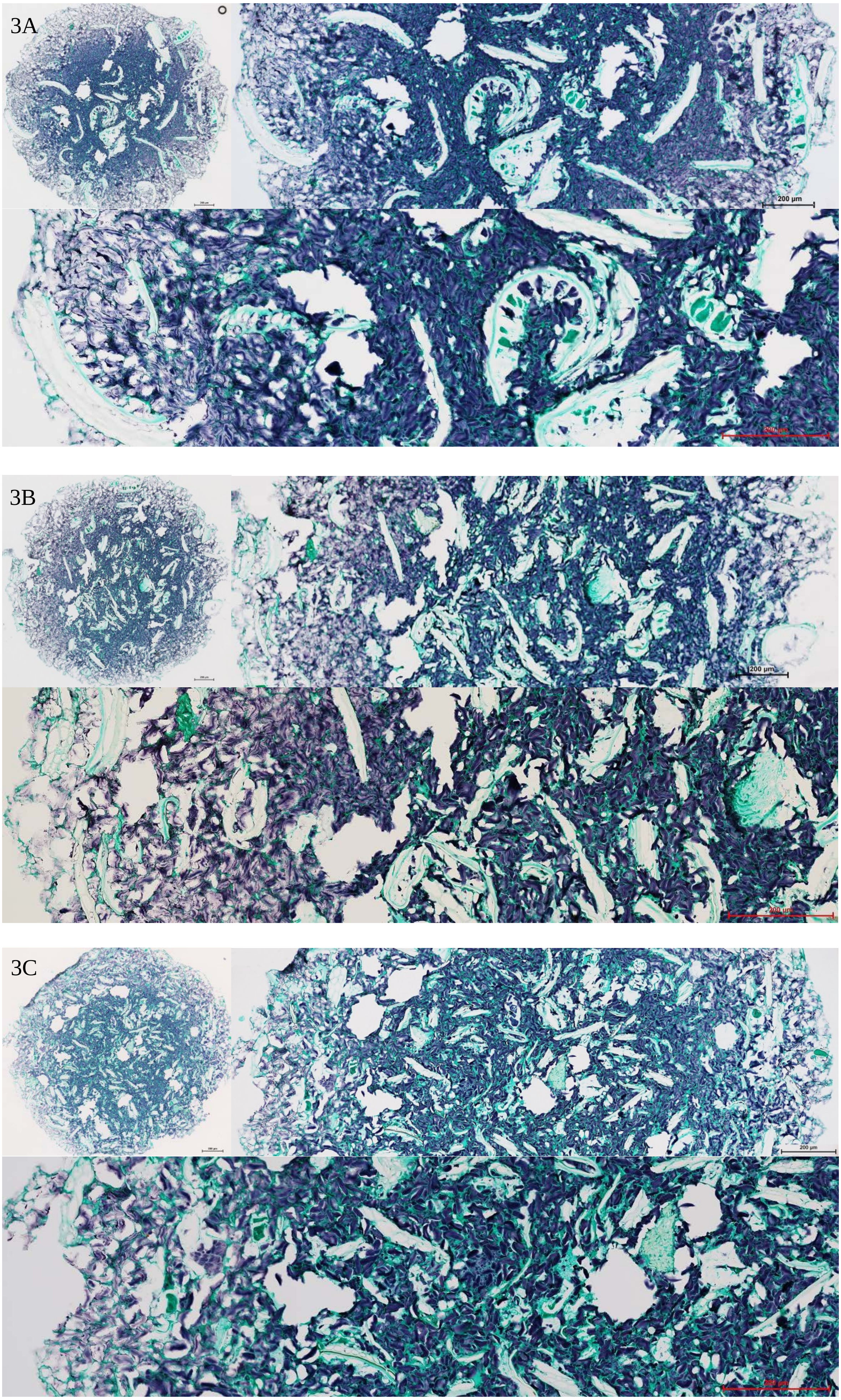

Figure 4 - Microscopic view of thin sections (5 µm) of cooked spaghetti from sample 3A-C stained with light green and iodine. Each sample is shown in 4, 10 and 20 X magnifications.

5. Conclusion

The aim of this thesis was to examine how incorporation of different bran fractions and particle sizes of bran in pasta influenced the quality of cooked pasta. The quality in final cooked pasta was evaluated by measuring relative water absorption and by the use of a sensory evaluation. The pasta was also evaluated by observing thin sections of pasta in light microscopy.

This study suggests that bran particle size have an impact on the sensory quality attributes stickiness, surface roughness and likeability. Surface roughness became more evident in pasta with increasing bran particle sizes. Stickiness decreased with decreasing bran particle sizes and the pasta containing the smallest bran particles was significantly less preferred compared to the pasta with larger bran particles. The particle size of bran did not affect the sensory quality attributes whole grain flavor, elasticity or firmness.

The results from this study also indicated that bran particle size had an impact on water absorption during cooking of pasta. This could be observed between small particles of 85-150 µm and larger particles of 150-400 µm. However, there was no difference between bran particles of 150-250 µm and 250-400 µm indicating that smaller particles had a more pronounced effect on the water absorption. Light microscopic images of the pasta also indicated a small difference for the pasta with the smallest particles showing a lower degree of gelatinized starch granules in the outer and intermediate layer of the pasta compared to the starch granules in pasta with larger particle sizes.

A preliminary sensory evaluation indicated no difference between pasta containing different bran fractions and therefore, these samples were not included in the sensory evaluation. Different bran fractions did not to effect the relative water absorption.

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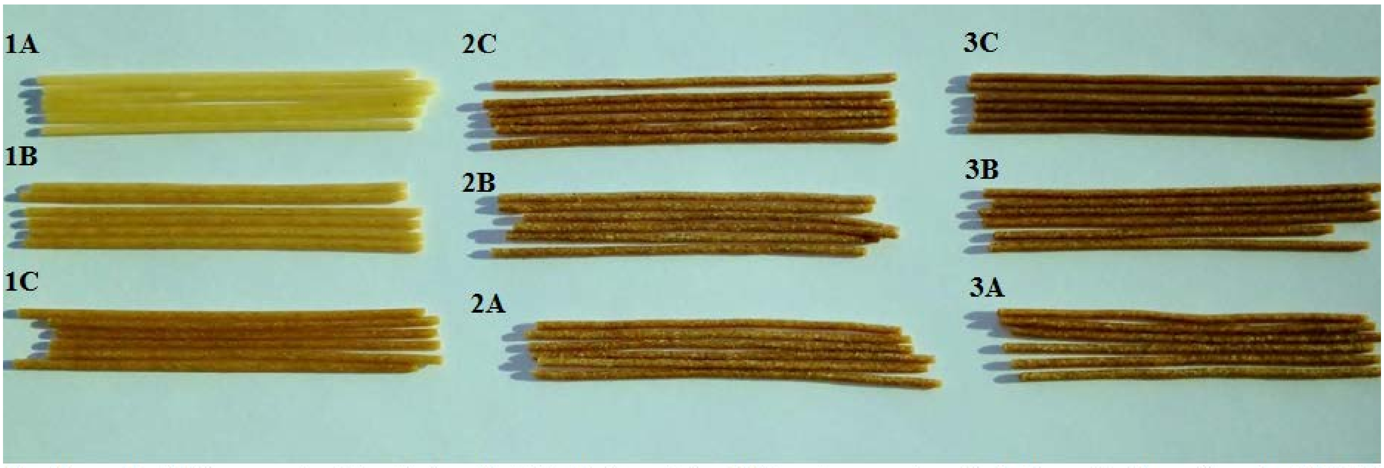
Appendix 1 – Final spaghetti samples



Final spaghetti from series 1 to 3. Spaghetti 1 A-C contain different amounts of whole grain flour. Spaghetti 2A-C contain different bran fractions (coarse bran, fine bran and pollard flour) of the same particle size (250-400 µm). Spaghetti 3A-C contain a mix of bran fractions (22% coarse bran, 48% fine bran and 30 % pollard flour) of varying size (85-150 µm, 150-250 µm and 250-400 µm).

Appendix 2- Form for sensory evaluation

Sensorisk bedömning av spagetti

Var god fyll i nedstående:

Namn:________________________
Serienummer:_________________
Omgång 1 eller 2:______________

Hej och välkomna till denna sensoriska bedömning av spagetti!

Nedan finner du en instruktion som beskriver hur bedömningen ska genomföras. Läs noga igenom den innan du börjar och fråga gärna om något är oklart.

Du kommer att bli serverad fyra prov med spagetti. Proven ska bedömas var och en för sig och du börjar bedömningen från vänster till höger prov. Skölj gärna ur munnen med det vatten som du har blivit tilldelad både före och mellan proven. Du kan även äta en bit smörgåsrån mellan varje prov för att neutralisera smaklökarna. Om du inte känner för att svälja proven går det bra att spotta ut dem i den vita plastmuggen som du har fått.

När du har börjat smaka spagettin ska du bedöma intensiteten av varje attribut som vi gick igenom under träningssessionen igår. En kort förklaring till attributen finner du även på baksidan av detta papper. Du bedömer attributen genom att sätta ett kryss, samt provets nummer ovanför krysset, på de horisontella linjerna på nästa blad. På mitten av skalan står det *ref* (referens) vilket betyder att du ska bedöma om du upplever intensiteten mer eller mindre jämfört med referensprovet som du har blivit tilldelad. Du kommer även att bli frågad hur mycket du gillar proven. Den här bedömningen är subjektiv och du ska i detta fall **inte** jämföra med referensprovet i mitten. I slutet av formuläret har du även möjlighet att lämna kommentarer om proverna.

När du är färdig lämnar du formuläret till testledaren.

Tack för din medverkan!

Förklaring av attribut

1. Fullkornsmak

Bedöms av hur tydligt fullkornsmaken träder fram i pastan

2. Klistrighet

Den kraft med vilken kokt spagetti vidhäftar till andra material. t.ex. tunga, tänder, och fingrar. Bedöms genom att visuellt se hur mycket två spagettistrån häftar ihop när man försöker separera dem.

3. *Fasthet*

Den initiala kraft som krävs för att bita igenom spagettin med hjälp av tänderna. Attributet bedöms genom att bita i ett spagettistrå med hjälp av framtänderna och bedöma hur mycket kraft som krävs för att bita igenom hela spagettistråt.

4. Ytgrovhet / Strävhet på ytan

Graden av skrovlighet/strävhet på spagettins yta bedöms genom man placerar en bit spagetti i munnen på baksidan av framtänderna och för tungan längs med pastan i olika riktningar.

5. Elastisitet

Elasticitet är egenskapen hos ett fast material att återgå till sin ursprungliga form och storlek efter att en deformerande kraft har tagits bort. Hos spagetti bedömer man detta genom att titta på hur väl ett spaghetti strå återgår till sin ursprungliga längd efter att den har sträckts ut.

Bedömningsformulär

1. *Fullkorns smak*

   Mindre ______________________________ *ref* ______________________________ Mer

2. *Klistrighet*

   Mindre ______________________________ *ref* ______________________________ Mer

3. *Fasthet*

   Mindre ______________________________ *ref* ______________________________ Mer

4. *Ytstruktur/Ytgrovhet*

   Mindre ______________________________ *ref* ______________________________ Mer

5. *Elasticitet*

   Mindre ______________________________ *ref* ______________________________ Mer

6. *Hur mycket gillade du spagettin?*

Väldigt lite ____Väldigt mycket

Kommentarer:____

____

____

____

Appendix 3 – Popular science summary

The particle size of wheat bran – does it affect the quality in whole grain pasta?

Traditional pasta is made from durum wheat flour and water and is a popular food product in both Sweden and worldwide. As part of the Swedes' desire to become healthier and eat more healthy food, regular durum wheat pasta has received competition from pasta made of whole grain flour or pasta that has been enriched with dietary fiber.

Bran is the outer layer of the wheat kernel and is removed along with the germ during the milling of wheat. The bran is seen as a by-product of the milling process and is often used in animal feed. In whole grain flour, the bran is not removed but is milled and then passed back to the ground wheat flour.

Wheat bran is rich in dietary fiber and antioxidants and a diet rich in wheat bran is associated with reduced risk of common health diseases such as type 2 diabetes and heart diseases. Swedes should increase their intake of whole grain food products since their average intake today is lower than the recommendations made by Livsmedelsverket. Despite the positive effects of wheat bran, many consumers prefer to eat foods such as pasta that is made from refined wheat flour because they tend to prefer the quality in taste and texture of these products. Knowledge on why the quality of whole grain food products like pasta become less attractive is therefore of value in order to identify new ideas on how to create and develop improved whole-grain products that are more attractive to the consumers.

This study aimed to investigate whether the particle size of wheat bran influence quality in terms of water uptake and sensory characteristics of pasta. To find the answers, pasta in the form of spaghetti enriched with large amounts of bran with three different size intervals: 85-150 µm, 150-250 µm and 250-400 µm were developed. The developed pasta was then evaluated using a sensory panel that had to taste the pasta and assess various attributes associated with quality. In addition, the relative water uptake during cooking was measured and the pasta was also studied using light microscopy.

The results showed that particle size of wheat bran influenced surface texture of the pasta. The larger the particles that were added, the more the roughness on the surface of the pasta increased. Also stickiness of pasta was affected by the particle size of wheat bran. Pasta of high quality should have low stickiness. In this assessment, stickiness decreased with smaller bran particles and small bran particles therefore contributed to higher quality. However, it was found that when the panel had to assess the likeability of the pasta, the pasta with the smallest particle sizes received significantly lower scores compared to the pasta with larger bran particles. The bran particle size was furthermore found not to influence the quality attributes elasticity, firmness and whole grain flavor.

The particle size also affected water uptake in the pasta. Cooked pasta of high quality should have high levels of water absorption. In this case, the pasta with the smallest bran particle size had significantly lower water absorption compared with pasta with larger bran particles.

Observing the pasta in light microscope showed that bran particle size may have an impact on the swelling of starch in the pasta during cooking. There was a slight indication that the pasta with the smallest bran particle size had a lower degree of swollen starch near the surface of the pasta.