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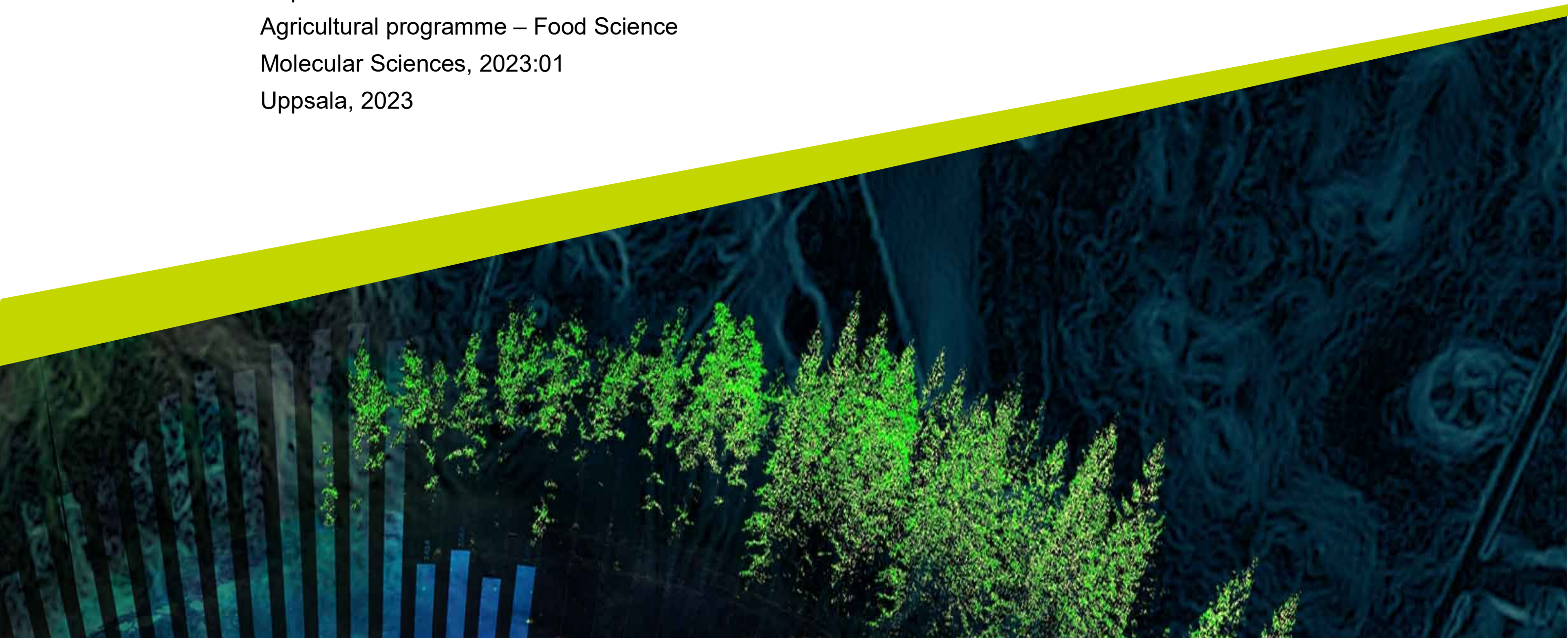

Mildly nutritious or mild and nutritious - A study on the effect of low phenolic content in wheat and rye kernels and its sensory effect on whole grain breads

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Abstract

Recent studies on the dietary habits of the Swedish population show that only 30% reaches the recommended levels of dietary fibres. As a high fiber intake is associated with health benefits and a decrease in the risk of developing lifestyle disease, there may be a need for new types of fibre and wholegrain products.

Phenols are present in all plant-based food with the main function to protect the plant though it also affects their appearance, taste, and smell. Previous studies have found that the usage of low phenolic white varieties of wheat in wholegrain products results in baked goods with a lighter colour and a milder taste. Although not as extensively tested, studies also indicates that low phenolic rye may be used to produce whole grain bread without the characteristic dark colour and bitter taste of rye.

This study focused on analysing whole grain bread baked with white wheat and rye verities. The aim of the study was to investigate whether it is possible to produce a wholegrain bread with sensory properties more similar to those of white bread but with a fibre content of wholegrain bread. Colour was analysed with a colorimeter, texture with a texture analysis and dough behaviour was analysed through mixing time. A discrimination test was done with consumers to test the flavour of the bread.

Results suggests that usage of low phenolic white rye and wheat varieties may be an opportunity to create breads with characteristics of refined white bread. A lighter and more yellow tone was measured in the bread baked with white wheat graham flour and white rye flour, and this combination could therefore be promising for further research.

Keywords: White rye, white wheat, low phenolic flour, sensory characteristics of bread

Sammanfattning

En nationell studie av svenskars kostvanor visar att endast 30 % av befolkningen når upp till de rekommenderade halterna för intag av fibrer och fullkorn. Då höga intag av dessa visat sig ha hälsofördelar så som minskad risk för livsstilssjukdomar kan det behövas en ny typ av fiber och fullkornsprodukter.

Fenoler finns i alla växter med funktionen att skydda växten, vilket de bland annat gör med hjälp av pigment och ämnen som påverkar utseendet och smak på växten. Tidigare studier gjorda på vita vetesorter med lågt pigmentinnehåll har visat att just dessa typer lämpar sig bra i fullkornsprodukter då det ger en mildare smak och ljusare färg. Gällande råg finns det inte lika många studier. Det har dock visat sig att vit råg är lovande för att producera ljusare fullkornsbröd utan den karaktäristiska bittra rågsmaken.

Denna studie som gjorts i samarbete med Polarbröd har fokuserat på att utreda vilken effekt vitt fullkornsrågmjöl och vitt fullkornsvetemjöl har på brödets sensoriska profil. Färgmätning, texturanalyser samt ett diskrimineringstest gjordes. Resultaten visar att vit råg och vitt vete har potential att producera mildare och ljusare fullkornsbröd. Bland annat uppmättes en ljusare och varmare färg för bröd bakat med en kombination av vit råg och vitt vete.

Nyckelord: Vitt vete, vit råg, mjöl med låg fenolhalt, sensoriska parametrar bröd

Table of contents

Introduction

Bread is one of the most consumed foods throughout history and has always been of great importance in the Nordic diet (Berg & Bodin, 2020). Cereals have been cultivated in Sweden since the stone age, and historical findings shows bread baked as a staple food since the 800s.

Even today, the tradition of bread as a staple food in Sweden continues. According to the Swedish national dietary survey Riksmaten from 2011 (Amcoff et al., 2012), bread was the largest source of fibre and accounted for 28% of the total intake. It also showed that bread was the largest source of whole grain intake. The survey concluded that 51% of the total wholegrain intake came from bread.

Recommendations for food intake in Sweden is based on the Nordic nutritional recommendations (NNR) with the aim of promoting a nutritionally adequate diet to maintain health and lower the risk of lifestyle disease (Nordic Nutrition Recommendations, 2012). However, according to Riksmaten only 30% follows the recommended intake of dietary fibres.

Statistics from Sweden shows that younger generations and families with children are more likely to consuming bread made from refined wheat flour (Sandvik et al, 2014). As children are more prone to consuming familiar food products with more neutral or sweet flavour profile, convenience is one part of the explanation to the decrease in wholegrain consumption (Nørgaard et al, 2007).

Although large quantities of bread are consumed in Sweden, the nutritional value differs among different bread types. Consumption of wholegrain products and a fibre rich diet is associated with health benefits (Nordic Nutrition Recommendations, 2012).

As wholegrains contain a mix of both soluble and insoluble fibres together with minerals and bioactive compounds it has been proved to have a variety of positive effects on our health.

Evidence from epidemiological research consistently supports theories that a fibre rich diet lowers the risk of cardiovascular disease (Evans, 2020), diabetes (Reynolds, Akerman & Mann, 2020), and certain cancers (Gonzalez &Riboli,

2010). Whole grain consumption may also play a positive role in weight management, as shown in several prospective cohort studies, case–control studies and interventions (Fogelholm et al, 2012).

1.1 Aim and objective

The importance of bread in the Swedish diet cannot be denied. Although the interest for healthy foods and diets are high among many consumer groups, the total intake of dietary fibres and wholegrains are lower than the recommended levels.

To make it easier for consumers to reach the recommended fibre intake and get the health benefits associated with a fibre rich diet, there is a need for new types of whole grain bread.

The aim of this study was to investigate whether it is possible to produce a wholegrain bread with sensory properties more similar to those of white bread, but with a fibre content of wholegrain bread. This was done by using three types of wholegrain flour made from a white wheat cultivar and a white rye cultivar in a recipe for wholegrain bread.

1.2 Delimitations

This project was conducted in collaboration with Polarbröd. The study may be considered a preliminary study on further research to evaluate how well these new types of flour could be incorporated into their range of products.

The delimitation for this study was therefore to evaluate only these two varieties of rye and wheat and to focus only on their sensory properties in manually baked wholegrain bread.

Background

The making of yeast or sourdough leavened bread is one of the oldest biotechnological processes (Mondal & Datta, 2008). The makeup of bread is primarily flour, water, salt, and a yeast or sourdough. These constituents are then mixed up to a viscoelastic dough, fermented and baked. While all constituents and steps in the baking process contribute to the overall quality of bread, flour is the main ingredient and of great importance for the final product.

2.1 Cereals and flours

Wheat and rye are classified as cereals, which are part of the cultivated grasses grown for food and feed around the world.

Although the size and composition of each specific grain and variety varies the same type of structure remains in most kinds of cereals (Delcour & Poutanen, 2013). There are three main parts in the kernel: the germ and the starchy endosperm, which makes up the inner parts of the kernel, and the outer parts also called the bran (Brouns et al, 2012). The outer parts can then be further divided into the aleurone layer, which is closest to the kernel, the testa, the inner pericarp, and the outer pericarp.

Most cereals on the market are refined grain products that lacks parts of the original kernel. In classic refining processes the bran and the germ are separated from the starchy endosperm. The endosperm is then further processed and milled. Through this process, a fine flour with good baking qualities is produced, and the most nutritional parts of the kernel are lost (Barette et al, 2019). The most common flour for baking is wheat flour, although other cereals such as rye is also popular to add texture, fibre, and flavour to baked goods.

2.1.1 Wholegrain

Wholegrain product utilizes the whole kernel rather than just the starchy endosperm and are associated with health benefits due to rich fiber content and high amounts of bioactive compounds. The Cereal and Grain Association defines wholegrain as follows:

> 'Whole grains consist of the intact, ground, cracked, flaked, or otherwise processed kernel after the removal of inedible parts such as the hull and husk. All anatomical components, including the endosperm, germ, and bran must be present in the same relative proportions as in the intact kernel.' – (van der Kamp et al, 2019)

The outer layers of the kernels consist of higher amounts of fats and proteins and dietary fibres compared to the starchy endosperm. As the composition of the layers of the kernel differ, flour made from whole grain has different properties than refined flour (Brouns et al, 2012).

Among these properties, a more intense flavour profile associated with bitter and sour taste have been described for wholegrain products compared to their refined counterparts. This flavour profile has been connected to the increased concentration of phenolic compounds in the outer layers of the grain (Brouns et al, 2012).

2.1.2 Dietary fibres

Dietary fibres (DF) are parts of the plant structure which are resistant to digestion by human enzymes. DF are primarily found in the cell wall of plants and are consumed through whole grain cereal, fruits, and vegetables (Barber et al, 2020).

There are different ways of classifying DF, such as classification through chemical structure (non-starch polysaccharides, resistant starch, and resistant oligosaccharides) and solubility (soluble and insoluble fibres). When incorporated into our diets the different classes of DF have different effects on our bodies (Lattimer & Haub, 2010).

Most insoluble DF are slowly or non-digested and work as a faecal bulk agent. Both soluble and insoluble fibres have a water binding capacity and helps with satiety (Makki et al, 2018). Soluble DFs are also digested by the gut microbiota through anaerobic fermentation. From this fermentation, the main end-product is short chain fatty acids who have key roles in various metabolic processes (Cronin et al, 2021).

2.1.3 Wheat

Cereal production in Sweden is a great part of the agricultural sector and the most common cereal in Swedish production is wheat. According to preliminary data from 2022, wheat production stands for close to half of the cultivated areas designated for cereals in Sweden (Olsson, 2022).

There are thousands of varieties of wheat known that differ in both growing conditions and physiological properties (Dziki & Laskowski, 2005). Though the composition varies with variety and growth condition there are some characteristics shared by most varieties.

The main storage carbohydrate in wheat is starch followed by proteins. Starch constitutes about 60-75% of the kernel and is mainly stored in the endosperm (Shewry et al, 2002). Meanwhile, most lipids are found in the germ and aleurone layer. The outer layers of the wheat kernel, the wheat bran (WB), has a high amount of DF. Around 50% of the WB consist of DF including fructan, xylan, cellulose, and lignin. Other components of the WB are vitamins, minerals, and bioactive compounds such a as carotenoids, phenolic acids, and anthocyanins (Lachman et al, 2017).

2.1.4 Rye

Although they classify into the same family and share similar traits, the production and popularity of rye is much lower than for wheat. In Scandinavia and eastern Europe, rye has been a traditional grain used in breadmaking. However, with the rise of refined wheat products, the popularity of rye bread has decreased.

As with wheat, there are many different varieties of rye though the composition is similar in most varieties. The starchy endosperm constitutes about 80-85% of the weight of the whole kernel, the germ 2-3% and the outer layers about 10-15% (Vinkx & Delcour, 1996). The starch content is concentrated to the endosperm while the germ holds most of the lipids, which are mainly unsaturated fatty acids.

2.2 Phenolic compounds in grains

Phenols are present in all plant-based food with the main function to protect the plant though it also affects their appearance, taste, smell, and oxidative stability (Boussahel et al, 2020).

Phenolic compounds are generally described as compounds which includes a benzene ring with hydroxyl groups and are further classified in a range of groups according to their structure (Vuolo et al, 2019). Plant tissues contain phenols in both bound and free form and the phenolics found in free form are generally more prone to provide flavour (Ceccaroni et al, 2020).

For cereals, the most common types of phenolic compounds are phenolic acids and flavonoids. Phenolic acids in cereals are mainly present in bound form and ferulic acid is the most common one. Flavonoids is the largest group with over 8000 compounds found in food, making the composition varying extensively among food groups (Del Rio et al, 2013). This large group can then be further divided into flavanols, flavanones, isoflavones, flavones and anthocyanins (Brodowska, 2017).

The most common type of flavonoids found in cereals are anthocyanins. This group works as natural pigments and are responsible for blue, red, purple, and orange colours (Zhu, 2018).

2.2.1 Phenolic compounds and effect on baking

As phenolic compounds are distributed in the grains, they are also part of flour base for most baked goods. The effects of these compounds during baking have been studied, and heat and chemical reactions that takes place during baking affects the phenols (Jiang & Peterson, 2010). Phenolic acids have been shown to interact with the Maillard reaction. Bound phenolic acids have been shown to be released during this thermal process. This increases the concentration of free phenolic acids in the crust where the Maillard reaction is most active, thus altering the flavour (Moore et al, 2009).

Studies have also shown that the phenolic profile of the flour may affect the formation of the gluten network. In these cases, it is mainly the free phenolic acids and the phytate content that has had a negative effect on the formation of the gluten network resulting in lower loaf volume (Challacombe et al., 2012; Park, 2016).

2.2.2 White wheat

White wheat is defined as wheat that lacks or has deficiency in colouration. Even though each wheat cell has over a thousand of genes only a few of those code for colour of the seed coat and kernel. Therefore, if none of those genes code for production of colour producing flavonoids the seed remains white rather than blue, or red as most commercial varieties (Lang & Walker, 1990).

Even though the composition differs in different studies, research on white wheat (WW) varieties shows that the total phenolic content in WW is often lower and in a bound form compared to coloured varieties (Sun et al, 2014; Ma et al, 2016; Anita et al, 2022).

As the phenolic compounds adds to the flavour of the flour, studies show that white wheat cultivars are suitable for wholegrain products as they provide a more neutral flavour (Morris, Engle & Kiszonas, 2020). Due to their colour, they are also popular to use in noodles and cakes as they give the final product a light colour favoured by consumers (Toyokawa et al, 1989).

2.2.3 White rye

The popularity and usage of rye is globally on a much lower level compared to wheat. Consequently, breeding programs and research is not as extensive as for wheat. There is currently not a market for defined white rye cultivars.

However, the phenolic content in rye has been subjected by research, and studies regarding phenolic profile have been done. Some of these studies aim to profile the phenolic compounds to produce rye cultivars with modifications on the typical bitter flavours connected to rye (Heiniö et al, 2008; Liukkonen et al, 2003).

These studies suggest that as the free phenolics is the main compounds providing flavour, rye cultivars with lower phenolic content and lower amount of free phenolics may be an option to produce wholegrain rye flour without the bitter notes.

2.3 Sensory properties of bread

Despite the many proven health effects of wholegrain products, consumer acceptance for wholegrain breads remains an issue (Sandvik et al, 2014). Refined wheat breads have been the most popular choice over the past years. Soft white bread made from refined wheat flour has a mild taste and these types of bread has set the standards for many consumers (Pohjanheimo, Luomala & Tahvonen, 2010).

With grainier texture, darker colour, and a more intense flavour profile with bitter and sour notes, wholegrain bread does not reach the criteria many consumers look for in bread (Lang & Jebb, 2003).

Evaluations of consumers perception of good bread indicates that soft, airy, white bread is perceived by consumers as fresher and more desirable than darker bread with more texture and intense flavour (Heenan et al, 2008; Sajdakowska, et al 2021). As expectations in the store during the purchasing process is based on previous experience, products with familiar features tends to be more appealing to consumers (Steenkamp 1990).

2.3.1 Sensory evaluation methods

Description of the human perception is a difficult task, though nevertheless an important parameter for delivering products that meets the consumers expectations. Sensory evaluation methods measures, analyses, and interprets responses of people to products as perceived by the senses (Delarue, 2015).

In food science, sensory methods are used to evaluate how humans perceive different products. Depending on the situation, problem and product, different methods can be used to measure different aspects.

The method of choice for this study was a discrimination test in form of a triangle test combined with an analysis of colour and texture.

Triangle test

Triangle tests focuses on determination of differences between two types of products (Kunert & Meyners 1999). As there are natural variations in all breads the test shows if the difference is detectable by enough subjects to conclude that the result is not due to chance.

Texture analysis

Texture analysis is often done to get a comparable value of the textural attributes of the product. During the analysis the food sample is exposed to pressure through a probe. Different parameters can be obtained from the measured stress and strain. Parameter of interest for the bread samples in this experiment are hardness, cohesiveness, springiness, and chewiness.

These are parameters that covers the breads perceived textural attributes. Furthermore, by combining a compression test with a penetration test, result will be obtained regarding both perceived handling of the bread as well as the biting sensation.

Colour analysis

Colour analysis is done to determine the colour coordinates of a product in a three-dimensional colour spectrum. The measured colour points are L, a, and b. The achromatic colours are measured on the L-axis and represents dark to light going from 0 to 100. The chromatic colours are represented on the a- and b-axis. A-axis goes from negative (green) to positive (red), while b-axis goes from negative (blue) to positive (yellow). These colour pointes are then used as coordinates in the colour spectra (Wei, 2012).

Materials and method

The methods were chosen to evaluate the sensory properties of the whole grain bread baked with the sample flours. The study was conducted in Bredbyn, in Örnskoldsvik and at the Swedish University of Agricultural Sciences (SLU) in Uppsala.

3.1 Materials

Two samples of wholegrain flour from white wheat milled from the same variety with two different techniques: “White wheat-Graham” (WG) and “White wheat-Victory” (WV) and one sample of rye: “White rye” (WR) was provided by one of Polarbröd's suppliers. Recipe for the bread “Pärlan fullkorn” and the remaining ingredients were supplied by Polarbröd. The baking was conducted in Polarbröd's premises in Bredbyn. Other equipment used throughout the project was provided by SLU.

3.2 Method:

3.2.1 Baking

The baking was conducted for three days, and all six samples, described in table 1 (control and dough 1-6), was baked each day. The breads were baked on trays aimed to produce three bags of eight representative breads for each batch baked during each day. Due to shortage of white wholegrain rye flour only two batches of WV+WR could be produced over the three baking days. Due to the shortage breads baked during day 1 had to be used for statistical analysis? in replacement for breads that were planned to be baked during day 3 throughout the project.

Table 1. Flour mixed into the wholegrain portion of the recipe for each batch of bread

Dough	**Mix of wholegrain portion**
control	control rye (CR)+ control wheat (CW)
1	white wheat, Graham (WG)+ control rye
2	white wheat, Victory (WV) + control rye
3	wheat control + white rye (WR)
4	white wheat, Graham (WG)+ white rye (WR)
5	white wheat, Victory (WV)+ white rye (WR)

Dough behaviour

After all ingredients were weighed to a total weight of 5 kg with a water temperature around 26 °C the dough was mixed. The blender was set to mix at two different speeds in two intervals. The first being a slower setting of 70 rpm for 120 seconds. The second interval was a faster setting of 130 rpm set to mix until the dough reached a mixing force of 5.5 Wh/kg.

The first batch of dough 2 and 3 proved to be sticky and difficult? to bake and the water content was therefore lowered by 4% for dough 2, 3 and 4 for the remaining batches. As dough 5 proved to be sticky despite adjusted water content, it was further reduced to a total of 8% for the remaining batches.

Processing

The mixed dough was set to rest for 30 minutes in room temperature. It was then further processed through kneading, which was set to 5 stages of thickness, 15 mm →10mm →6mm →4mm →3mm. Docking was done using a zigzag patterned rolling pin, the dough was then cut to squares and placed on a baking tray to proof.

Proofing cabinets were set to 38 °C with a humidity of 52%. The breads were proofed for 12 minutes. Thereafter the breads were baked on the trays with the oven set to a program with 300 °C, 5 seconds of steam at the start and a baking time of 4 minutes. After baking, the breads were set to cool in room temperature for 15 minutes before being placed in a blast chiller for 20 minutes. When thoroughly frozen, the breads were sorted, and representative samples were bagged and placed in a freezer.

3.2.2 Texture analysis

A texture analyser was used to determine the texture of the bread. This was done using a double compression and double penetration test.

Two breads of each dough from each day were tested for both penetration and compression. The breads were thawed to room temperature two at a time and then subjected to the analysis two by two. For each test the machine was set according to table 2.

Table 2. Compression and penetration settings for the texture analyzer.

Test mode	Pre-test speed	Test speed	Post-test speed	Distance %	Trigger force g
Compression	2	1	2	40	5
Penetration	2	2	10	80	5

The tests were conducted according to figure 1 with three replications of both compression and penetration on each bread.

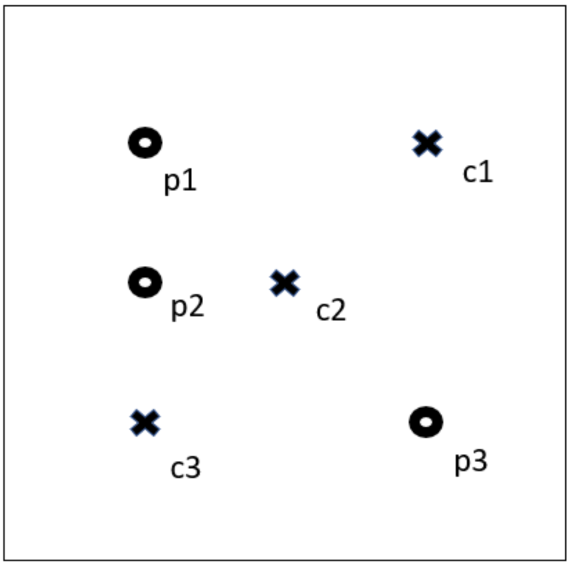

Figure 1. Probe placement map for texture analysis of the bread samples. X represent locations for compression tests (c1-c3) and O represents locations for penetration test (p1-p3).

3.2.3 Colour analysis

The colour analysis was done using a colorimeter and measuring colour coordinates in the L*a*b*- spectrum. As the baking has a bigger influence on the colour of the crust, the breads were sliced and measured on the crumb to get the colour development of the flours. Two breads from each day were measured with four measuring points for each bread. Before measuring, all breads were thawed to room temperature.

3.2.4 Triangle test

The sensory evaluation was conducted through a consumer-focused triangle test. The WG+WR were chosen to be set against breads baked with control flours. Out of 60 participants 57 finished the survey.

Setup

Plates were arranged with a number and 3 bread samples set on spaces marked A, B and C. Samples were set according to even and uneven numbers. Plates of even numbers had two samples of WG+WR placed on a space B and C, and one CW+CR placed on the space A. Uneven numbers had 2 CW+CR placed on space A and C, and one sample of WG+WR placed on space B.

The survey was the conducted at a local supermarket in Örnskoldsvik. A table was set with sample plates and instructions for the taste and the survey in writing. Participants read the instructions and tasted all three samples. They were then asked to scan a QR-code to reach the survey. The survey contained three questions where they were asked to fill in the number on their plate, which sample they identified as the odd one and lastly to rate which bred/breads were the most appealing.

Results

4.1 Dough behaviour

All doughs were mixed to reach 5.5 Wh/kg dough. Difference in mixing time depends on the flour's capacity of water absorption and gluten formation. The average of dough C and 1-5 is shown in table 3. The CW+CR has the lowest average mixing time of 419 seconds while WG+WR has the highest average mixing time of 503 seconds.

Table 3. Average mixing time for dough c and 1-5. CW-control wheat, CR-control rye, WG-white wheat Graham, WV- white wheat Victory, WR- white rye

Dough	**Total mixing time (s)**
C (CW+CR)	419
1 (WG+CR)	421
2 (WV+CR)	476
3 (CW+WR)	491
4 (WG+WR)	493
5 (WV+WR)	503

4.2 Texture analysis

Figure 2 and 3 represents the compression curves from the penetration and compression test. There was a large variance between the samples from each baking day as well as between the different baking days for all recipes.

c

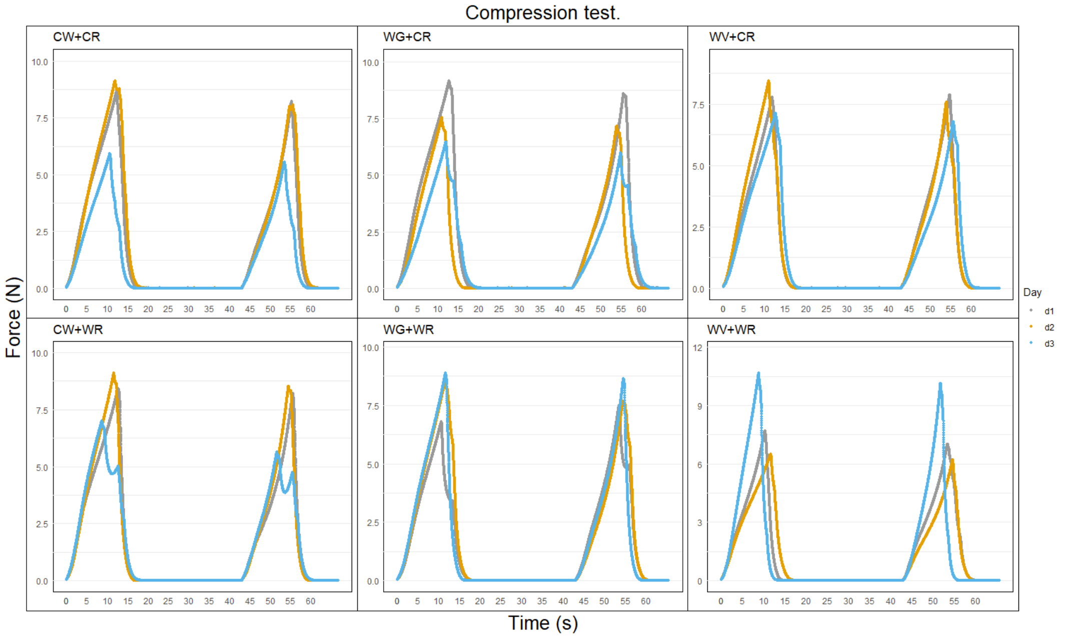

Figure 2: Pressure curves for the double compression test with three curves representing the average curve for each of the three baking days for each dough. CW-control wheat, CR-control rye, WG¨-white wheat Graham, WV- white wheat Victory, WR- white rye.

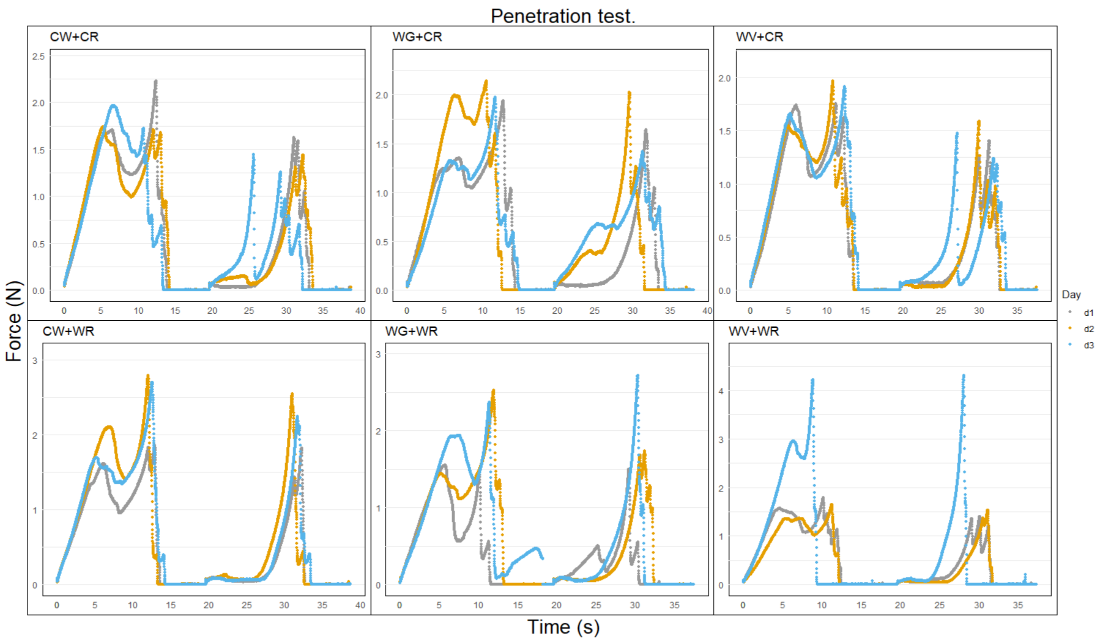

Figure 3: Pressure curves for the double penetration test with three curves representing the average curve for each of the three baking days for each dough. CW-control wheat, CR-control rye, WG-white wheat Graham, WV- white wheat Victory, WR- white rye.

As seen in the figure there is no clear pattern among the curves, and no significant differences were established between the textural attributes of the different samples (table 4).

Table 4: Grouping Information on compression and penetration using the Tukey method and 95% confidence. Means that do not share a letter are significantly different. CW-control wheat, CR-control rye, WG-white wheat Graham, WV- white wheat Victory, WR- white rye.

		Hardness		Cohesiveness		Springiness		Chewiness	
wheat* rye	N	Mean	Group	Mean	Group	Mean	Group	Mean	Group
CW CR	3	8.17	A	0.82	A	0.99	A	7.38	A
WG WR	3	8.26	A	0.87	A	0.99	A	7.17	A
WV WR	3	7.77	A	0.85	A	0.98	A	6.83	A
WV CR	3	8.06	A	0.82	A	0.98	A	6.37	A
WG CR	3	7.91	A	0.89	A	0.98	A	6.25	A
CW WR	3	8.08	A	0.83	A	0.93	A	6.17	A
Penetration		Hardness		Cohesiveness		Springiness		Chewiness	
Wheat* Rye	N	Mean	Group	Mean	Group	Mean	Group	Mean	Group
CW CR	3	2.15	A	0.32	A	0.95	A	3.38	A
WG WR	3	2.45	A	0.37	A	0.96	A	2.57	A
WV WR	3	1.99	A	0.32	A	0.78	A	2.83	A
WV CR	3	2.02	A	0.33	A	1.34	A	3.37	A
WG CR	3	2.38	A	0.37	A	0.83	A	2.25	A
CW WR	3	1.88	A	0.44	A	0.97	A	2.71	A

4.3 Colour analysis

Figure 4 and 5 represents coordinates from the colour analysis. Yellow, orange and purple (figure 4 and 5) represents doughs baked with WR. These doughs had generally more positive values on both the L- and the b-axis compared to the breads baked with CR. The most extreme breads along all axes were WG+WR and CW+CR. The WG+WR was the lightest bread, the mean L-value showed a significant difference compared to the other breads (table 5). No significant difference in lightness could be detected among the other breads. WG+WR had a higher b-value and had the most yellow colour, while CW+CR and WV+CR had the lowest b-value and had the least yellow colour; a significant difference was measured between the samples (table 5).

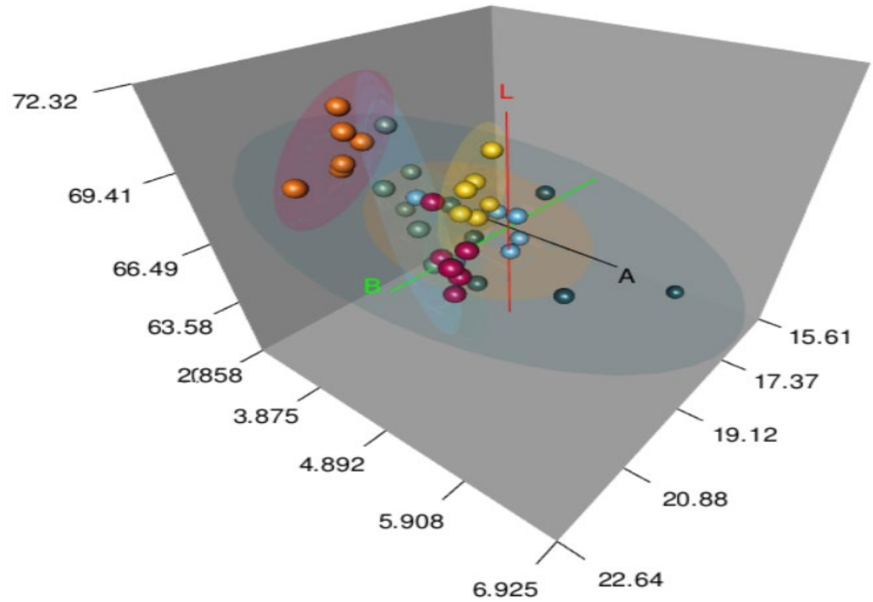

*Figure 4: L*a*b* spectrum with coordinates of two samples of each bread from each baking day figured. Colours are represented by one bread recipe. Teal=CW+CR. Green=WG+CR. Blue=WW+CR. Pink=CW+WR. Orange=WG+WR and Yellow=WW+WR.CW-control wheat, CR-control rye, WG-white wheat Graham, WV- white wheat Victory, WR- white rye.*

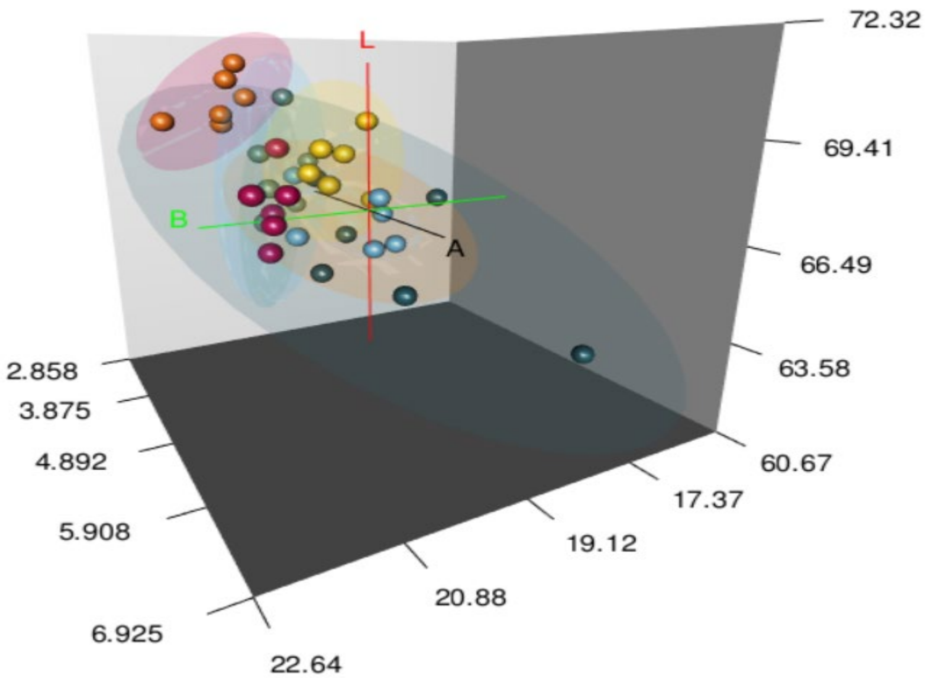

*Figure 5: L*a*b* spectrum with coordinates of two samples of each bread from each baking day figured. Colours are represented by one bread recipe. Teal=CW+CR. Green=WG+CR.*

Blue=WW+CR. Pink=CW+WR. Orange=WG+WR and Yellow=WW+WR.CW-control wheat, CR-control rye, WG-white wheat Graham, WV- white wheat Victory, WR- white rye

Table 5: Grouping Information on colourpoints using the Tukey method and 95% confidence. Means that do not share a letter are significantly different. CW-control wheat, CR-control rye, WG-white wheat graham, WV- white wheat victory, WR- white rye

Wheat*Rye	N	Mean (l)	Grouping	Mean (a)	Grouping	Mean (b)	Grouping
CW CR	3	66.74	B	4.65	A B C	19.62	C
WG CR	3	68.09	B	4.17	B C	20.31	A B C
WV CR	3	66.66	B	4.73	A B	19.56	C
CW WR	3	67.64	B	5.12	A	21.11	A B
WG WR	3	70.29	A	3.99	C	21.17	A
WV WR	3	68.44	A B	4.73	AB	19.78	B C

4.4 Triangle test

In this study WG+WR proved to be more consistent throughout the baking compared to WV+WR and was chosen for the triangle test. The triangle test indicated that there was a detectable difference between breads baked with the CW+WR and WG+WR. Results showed that 62% of all participants managed to detect the odd one out. This was analysed through a two-sample z-test showing that there was a significant difference in the observed proportion of 62% managing to detect a difference and the expected proportion of 33%.

As for what bread participants found to be tastier results showed only a slightly higher preference for the bread baked with WG+WR compared to the control. Results showed that 47% preferred the control bread and 53% preferred the WG+WR bread.

Discussion

5.1 Experimental design

The method for this study was chosen to fit the set time frame and to efficiently collect data for the areas of interest. As the main point was to evaluate the sensory properties of the bread produced, the methods were chosen to evaluate the visual looks of the bread as well as the taste and the texture.

Baking

As the sample flours were from a smaller production only 10 kg of each were available for this experiment. This meant that the batches of each dough had to be calculated to fit the amount of flour available while still being large enough to fit the standards of the dough processer. To minimize the risk of differences in baking conditions, samples were prepared in triplicates and each sample was baked each day. Due to lower amounts of the WR flour than expected, the last replicate of the WV+WR dough had to be replaced by samples from earlier days, which decreased the reliability of the results for this specific combination.

To evaluate the dough behaviour and how the sample flours affected the recipe, the time it took for each dough to reach 5.5 Wh/kg dough was analysed. This also showed that the recipe needed to be adjusted for white Victory and white rye doughs. Despite the alteration of water content, all breads were treated equally in the following experiments.

Further analyses on the baking quality and recipe could have been done by adjusting the amount of sample flour added to the dough and to test the sample flour in difference recipes. However, due to a limited amount of each flour available the tests had to be limited to one recipe and 5x3 batches containing sample flour.

Sensory evaluation

The sensory evaluation combined colour and texture analysis with a triangle test. This was done to evaluate the difference between each sample and to see if the effect of the sample flours provided detectable differences compared to the control flours.

The visual effect is an important factor for food products. When it comes to breads the main visual effects of bread colour is an important factor. Due to manual baking and uneven heat distribution in the oven, the crust of the breads differed too much to be analysed. Instead, the crumb of each bread was analysed for colour as these differences were consistently more visible and comparable.

The texture analysis was conducted to evaluate whether the flour samples affect the texture of the bread and to indicate how well they worked in the recipe. This was done using two different methods. The first was a compression test to evaluate how susceptible each bread was to pressure. This would indicate how they felt to touch for consumers in the store. The second test was a penetrative test that was done to evaluate biting force. These results were to show potential differences to the structure affected by the different composition.

A discrimination method in form of a triangle test was chosen as the taste analysis. These types of tests work well to determine differences between two samples. The triangle method was chosen as it is a time- and cost-effective way to collect data. As the sample pieces were cut to smaller squares, difference between the doughs were harder to decide based on looks alone. Therefore, this test was useful to evaluate how the sample flours affected the taste of the bread and whether the difference was detectable. This test also indicated which bread the consumers found to be more appealing.

The set up was done so that the same amount of each sample were presented. This meant that half of the plates had two samples of WG+WR and half of the samples had two samples of control. To minimize the risk of participants being influenced by each other the plates were numbered so that each plate on the table had a different number.

To further increase the credibility to the sensory profile a trained panel could be used for the triangle test. The test could also be made using all different doughs set against the control. Furthermore, a trained panel could also be used to give each bread a flavour profile. This would give a more detailed picture to the different nuances that the sample flours provide to the final products.

5.2 Baking

The recipe used throughout this experiment was developed to suit the control flours used in Polarbröd’s production. This is seen in the results for the mixing time (table 3). The water content for the dough was calculated to suit the absorption of the control flours. When excessive water is added to the dough, or the flour has a slower absorption rate a longer mixing time is needed to reach the set mixing force. Absorption is connected to the milling and the flour type.

The WV flour had a coarser grinding and differed in absorption giving a need for adjustment in water content. Although the water content was lowered, the mixing time was longer for all doughs containing WV, and the doughs turned out stickier and harder to handle. Sticky doughs can be the result of excessive water or an over worked gluten network. Similar to the WV, WR doughs needed adjustments in water content due to sticky doughs. The mixing time for CW+CR was significantly different from the other doughs. The WG+CR was most similar the control, and the WG flour seems to be most suitable to the recipe used, indicating similarities in absorption to the control wheat. The WG flour had similar texture to the control wholegrain wheat flour and mixing time for WG+CR, 421 s, was closest to the CW+CR, 419 s.

As the water content affects formation of gluten network, dough- and loaf volume, further tests could be done where the absorption for each flour is calculated, and the recipe adjusted to suit each dough. High absorption flours have been showed to increase loaf volume with the same amount of ingredients except higher water content (Puhr & D'Appolonia, 1992). The flours in this experiment that showed signs of lower absorption, mainly WV and WR, may need to be paired with high absorption flour to make a profitable and commercially viable product.

5.3 Sensory evaluation

5.3.1 Texture analysis

There was a great variance between the samples of the same recipe and no patterns were seen in the graphs. Nor were there any significant differences between the textural attributes between the recipes, figure 2&3, table 4. Textural attributes such as hardness of the crust, formation of the gluten network, leavening, are all sensitive to small changes in the baking conditions and during the experiment it was hard to keep the conditions consistent due to the method used. As all the baking were done manually and the baking conditions varied between each baking day and each recipe, more samples would have been needed to get a fair estimate in textural differences. Though, due to limited amounts of flour larger and more batches could not be produced to increase the sample size.

5.3.2 Colour analysis

There was a significant difference for WG+WR, which had a significantly lighter colour compared to WG+CR (table 5). This indicates that the WR indeed provided a lighter colour to the bread compared to the CR. This goes in line with the results by Heiniö et al. (2008), which concluded that rye with lower phenolic content could produce bread with lighter colour.

Comparing the white wheat flours shows that WG has slightly higher values on the L-axis when paired with both CR and WR compared to the WV (fig 4 & 5, table 5). Additionally, colour points for WG showed more yellow colourpoints and less red than for WV. While WG and WV were from the same type of wheat variety, the milling differed between the two flours. Relations between particle size of the flour and colour of breads and baked goods have been examined in previous studies (Vouris et al. 2018), (Protonotariou et al. 2015). These studies suggest that particle size is correlated with lightness and that increased particle size give darker colours in bread. As these flours are made from the same wheat variety and ought to have a similar phenolic profile the difference may be explained by the uniformity and pore size that generally improves with finer particle size. These attributes reduce the light absorption and enhances the ability to reflect light, which in turn increase the lightness of the bread (Pang et al, 2021). WV was coarser and not as finely milled as WG, which could give the appearance of darker colours in the bread baked with WV.

As the breads baked with WG and WR had the lightest and most yellow tone, this flour combination could be suitable to use in wholegrain breads where a lighter colour is desired.

5.3.3 Triangle test

The triangle test showed that WG+WR breads were detectable from the control recipe. This indicates that there is a sensory difference between the white wholegrain flour varieties used in WG+WR and the control flours. White wheat varieties have previously been showed to provide a milder flavour and a lighter colour in wholegrain products (Morris, Engle & Kiszonas, 2020). Studies have also suggested that a low phenolic rye variety may be suitable to wholegrain products where a milder taste is desirable (Heiniö et al, 2008; Liukkonen et al, 2003).

In the recipe used, the wholegrain rye flour is the main flavour provider with a characteristic bitter toned rye flavour. Therefore, the potentially milder white variety used in WG+WR might give this bread a sweeter flavour as the recipe is developed to suit the rich and bitter flavour profile of common wholegrain rye flour. Hence, further studies could be made using the WR in different recipes where the level of sweetness is balanced to a more neutral flavour.

The result regarding which breads participants in the triangle test found more appealing showed little difference between the samples, 47% preferred the control bread and 53% preferred WG+WR. This indicates that there is a market for both types of bread within different consumer groups. Some favour the richer flavour profile of common whole grain flour compared to milder white flours. As most participants in the test were older adults and the bitter flavour profile is more commonly accepted by adults compared to children and adolescents, further tests could be made with a larger and more diverse test group.

5.4 Summary

The aim of this study was to investigate whether it is possible to produce a wholegrain bread with sensory properties more similar those of white bread but with a fibre content of wholegrain bread. The analysis showed that the WG and WR flour has great potential to be used in the production of these types of wholegrain bread.

The combination of WG and WR produced a bread with the desirable colour, lighter with a more yellow tone compared to the typical rye bread. In the triangle test the taste of WG+WR was detectable from the control, and it was favoured by 53% of all participants. This indicates a dual market for both milder breads and breads with a more intense flavour. A milder rye alternative might be a good way for children, adolescents and adults who favours the milder lighter bread types to increase their daily intake of dietary fibres. Although for a better picture of the flavour profile of the WR, which in this recipe should provide most flavour, a trained panel could be used to assess the breads in combination with a larger and more diverse test group to cover more consumer groups.

While the WG flour worked well in the recipe the WR flour needed adjustments in water content. To further improve the recipe the absorption for each flour could have been calculated and adjusted in the recipe.

The textural attributes were hard to assess with the method chosen and no significant difference where established. Lack of differences in the textural attributes could be desirable as the control recipe is based on an established product well-liked by consumers. However, more trials are needed for more consistent results.

Improvements could be made to the method to further increase the reliability of the results. Larger and more batches could be baked in a better controlled and consistent environment to decrease the variance within the samples from each recipe. A more controlled and even baking process would also allow for more consistent crust formation. This would be important to measure and analyse the effect of phenolic content on the coloration of the crust which is one of the most important visual parameters for consumers in the store.

5.4.1 Conclusion

To make it easier for consumers to reach the recommended fibre intake and get the health benefits associated with a fibre rich diet, there is a need for new types of whole grain bread. The result from this study suggests that usage of low phenolic rye and wheat may be an opportunity to create breads with characteristics of refined white bread. A lighter and more yellow tone was measured in the bread baked with WG and WR compared to the control bread, making this combination promising for further research.

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Popular science summary

Bread is one of the most consumed foods throughout history and has always been of great importance in the Nordic diet. Cereals have been cultivated in Sweden since the Stone Age, and historical findings shows bread baked as a staple food since the 800s.

Even today, the tradition of bread as a staple food in Sweden continuous. According to the Swedish national dietary survey Riksmaten from 2011, bread was the largest source of fibre and accounted for 28% of the total intake. It also showed that bread was the largest source of whole grain and concluded that 51% of the total wholegrain intake came from bread.

Most cereals on the market are refined grain products that lacks parts of the original kernel. In classic refining processes the bran and the germ are separated from the starchy endosperm. The endosperm is then further processed through milling to a fine flour. Through this process a fine flour with good baking qualities is produced, though the most nutritional parts of the kernel are lost.

The most common flour for baking is wheat flour, although other cereals such as rye is also popular to add texture, fibre, and flavour to baked goods.

Although the interest for healthy foods and diets are high among many consumer groups, the total intake of dietary fibres and wholegrains are lower than the recommended levels. To make it easier for consumers to reach the recommended fibre intake and get the health benefits associated with a fibre rich diet, there is a need for new types of whole grain bread.

So, is it possible to produce a nutritious bread more appealing to a growing consumers group used to lighter bread made from refined wheat flour?

While all constituents and steps in the baking process contribute to the overall quality of bread, flour is the main ingredient and of great importance for the final product. As flour is a plant-based product, it contains a varying number of phenolic compounds.

Phenols are present in all plant-based food. Their main function within the plant is to protect it, though their presence also affects the plant tissues appearance, taste, and smell. Studies has showed that there is a great potential in using low phenolic wheat varieties when baking wholegrain products to get a milder taste and a lighter colour.

A recent study by SLU in collaboration with Polarbröd have analysed the sensory properties of whole grain breads baked of flour from white wheat and rye varieties. Colour, texture and flavour was analysed as well as the dough properties.

Results showed that a lighter colour could be distinguished when white rye was paired with white graham flour. A consumer's test showed that the taste was also distinguishable from the original recipe. However, a preference test showed that there was no difference in number of participants who preferred the original recipe, compared to the bread baked with white wholegrain flour.

To make it easier for consumers to reach the recommended fibre intake and get the health benefits associated with a fibre rich diet, there is a need for new types of whole grain bread. The result from this study, like the previous studies made on white varieties before, suggests that usage of low phenolic rye and wheat may be an opportunity to create breads with characteristics of refined white bread. A lighter and more yellow tone was measured in the bread baked with white Graham and white rye flour, making this combination promising for further research.

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