Enriching cereal bread with faba bean concentrate

Effects on taste, protein content and physicochemical parameters

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Abstract

A shift from animal protein towards plant-based sources of protein could, at the same time, help to enhance the nutritional quality of food and reduce negative climate impacts from agriculture. Faba beans (*Vicia Faba*) is a legume crop, rich in protein, fibres and minerals. It can be cultivated in cooler climates, making it especially interesting from a Swedish agricultural perspective. The incorporation of faba beans into bread, a staple in our diet, could make legumes easily accessible and thus ease a shift to plant-based proteins. The current study aims to investigate how faba bean in the form of a concentrate (65% protein) could be incorporated into bread formulas to enhance the protein levels of bread. For this purpose, varying levels of faba bean concentrate (0, 5, 10 and 15%) replaced wheat flour in a white bread formula (refined wheat, water, sugar, oil and salt). The moisture content, specific volume, colour, texture and sensory profile were assessed to examine possible alterations in bread quality.

The bread substituted with 15% faba bean- concentrate was calculated to reach a sufficient level of protein for the health claim “high in protein” (20.5–21.6 E%). Regarding physicochemical parameters, only the crust colour differed significantly ($p<0.05$) from the control bread. A preliminary sensory evaluation involving untrained panellists (n=40) indicated that the faba bean bread was acceptable even at the highest level of substitution (15%). However, the sensory evaluation suggested a reduced overall acceptance and the presence of off-flavours in faba bean enriched bread. In future studies, one could further increase the level of faba beans and investigate how additives could be used to enhance shelf-life, texture and reduce off-flavours.

Keywords: faba bean, bread, protein, protein-shift, sustainable

List of tables

List of figures

Abbreviations

CB	Control bread
FB	Faba bean concentrate
E (%)	Energy percentage
TPA	Texture profile analysis
WF	Wheat flour
BU	Brabender Units
ANF	Antinutritional factors
His	Histidine
Ile	Isoleucine
Leu	Leucine
Lys	Lysine
Phe	Phenylalanine
Tyr	Tyrosine
Met	Methionine
Cys	Cysteine
Thr	Threonine
Trp	Tryptophane
Val	Valine

1. Introduction

High consumption of animal protein has been shown to have a negative effect on the environment (Pimentel & Pimentel 2003). A shift towards a plant-based diet, could not only have positive environmental effects but also provide several positive health effects. Among vegetable protein sources, legumes (fruits of the Fabaceae family, e.g. beans, peas and peanuts), are especially valuable as they both are rich in protein and promote sustainable agricultural practices though the symbiotic nitrogen-fixation (Röös et al. 2020). Western diets are now dominated by animal proteins, but research has shown that consumers may be more willing to choose vegetable proteins, such as legumes, if they are more easily accessible and tasty. (Röös et al. 2022). It has also been demonstrated that introducing new foods can be made easier through incorporating them into existing food items (Schösler et al. 2012).

Bread is a staple food globally, reaching an average consumption of 70 kg per capita each year (Carocho et al. 2020). The popularity of bread could be attributed to its simplicity and variability. Only a few ingredients are required: flour, water, salt and yeast. Additionally, the method and ingredients can be varied depending on local availability and tradition. Western countries have seen a decrease in white bread consumption in favour of healthier breads with increased fibre and gluten-free alternatives, it seems that people are more interested in healthy bread types (Carocho et al. 2020).

Cereals are rich in methionine. Legumes are, on the other hand, rich in the essential amino acid lysine that is low in other cereal-based protein sources. Thus, legumes and grains could complement each other to provide a balanced amino acid profile in foods (Hoehnel et al. 2020). Therefore, incorporating legumes into cereal bread has the potential to enhance the nutritional value of bread and, at the same time make legumes more attractive and accessible.

1.1 Aim

Previous studies have focused on the incorporation of faba bean flour into cereal bread formulas (Benayad et al. 2021; Coda et al. 2017; Maravić et al. 2024). The use of faba bean as a concentrate (65% protein) instead of flour could result in bread that is richer in protein, even at lower levels of wheat flour substitution. This study aims to investigate the effects of enriching wheat bread with faba bean concentrate, in order to enhance the protein level while maintaining its technological and sensory qualities.

2. Background

2.1 Faba bean

Faba beans (*Vicia Faba)* is a legume within the plant family Fabaceae. It is of particular interest within Swedish agriculture, as it withstands Swedish climate. Moreover, this crop is already cultivated to a large extent in Swedish agriculture. The current production is primarily oriented towards production of animal feed but could be shifted towards human consumption in the future (Röös et al. 2020). From a nutritional point of view, the advantage of faba beans is their high protein content (26–33g), mainly consisting of legumin (11S) and vicilin (7S). It also comprises a source of dietary fibres, minerals and vitamins (Multari et al. 2015). Nevertheless, a major concern is the presence of antinutritional factors (ANF), including saponins, lectins, phytates, convicine and vicine, impairing uptake and bioavailability of nutrients. Two main ANFs in faba beans are vicine and convicine, being particularly important as they may trigger haemolytic anaemia in people suffering from the enzyme deficiency called favism (Khazaei et al. 2019). Moreover, convicine and vicine have also been shown to cause bitterness (Tuccillo et al. 2022). The ANF- levels vary notably between different cultivars, but ongoing research on genotypes seek to reduce or eliminate vicine and convicine through breeding programs (Khazaei et al. 2019).

2.2 Bread quality

2.2.1 General aspects

Bread quality is a multivariable characteristic involving several aspects. It is primarily determined by the choice of raw material and the manner in which they are processed (Cauvain 2012).

Bread wheat (*Triticum aestivum*) provides starch, vitamins, minerals, and proteins. The main protein components in wheat flour are glutenin and gliadin (50 and 30% respectively), which form a strong gluten network held together through disulphide bonds (Urade et al. 2017). Proteins need water to become hydrated during kneading, to strengthen the gluten network and thus help to form a viscoelastic dough. Addition of salt (sodium chloride) further tightens the gluten network by balancing repulsive ionic charges (Urade et al. 2017). Moreover, endogenous enzymes (alpha-amylase) present in the wheat are important for the breakdown of starch into simpler fermentable sugars (Zhang et al. 2018). Yeast (*Saccharomyces cerevisiae*) feed on sugars, added and/or degraded from starch that is turned into ethanol and carbon dioxide during fermentation. This process reaches its maximum efficiency at 35–40 °C, the optimum temperature for yeast growth. The final baking at high temperatures causes gas expansion, starch gelatinisation and evaporation of water and volatiles such as alcohols. Maillard-reactions or non-enzymatic browning are responsible for the characteristic colour, aroma and crispiness of the bread crust. The reactions take place between free amino acids or lysine and reducing sugars at elevated temperatures (>115°C) and low moisture conditions on the top of the bread (Cauvain 2012; García-Baños et al. 2004). The freshness of bread reduces rapidly after baking. Bread staling effects result from moisture migration and starch retrogradation, that is an effect of the recrystallisation of gelatinized starch (Wyrwisz et al. 2024).

2.2.2 Protein quality

The amino acid profile of a raw material or a product provides data used to evaluate the levels of certain amino acids, more importantly the indispensable ones (His, Ile, Leu, Lys, Phe, Tyr, Met, Cys, Thr, Trp and Val). When it comes to wheat and faba beans, differences are primarily identified regarding the balance of certain amino acids. Wheat is rich in Met and Cys, while the content of Lys is limited (Arendt & Zannini 2013). The opposite is true for faba beans, which contain relatively high levels of lysine. Thus, a more balanced amino acid profile can be obtained by combining the two.

2.2.3 Protein quantity

In addition to considering protein quality, the quantity of protein is also an important factor. The protein-to-energy ratio, or protein E%, is the proportion of total energy derived from protein. According to EC regulation (No 1924/2006), if a food is to be labelled as "rich in protein", it requires a protein E of 20%. The substitution levels of high-protein ingredients in bread formulations can be calculated to meet the levels required for this claim.

Hoehnel et al. (2020) reported that a 10% substitution of wheat with faba bean protein-flour (61% protein) could increase the protein level to reach a protein-energy value of 24.8%. In comparison, 30% of faba bean flour (36% protein) was needed to reach a protein E of 24% (Coda et al. 2017). This demonstrates that a lower degree of substitution is needed when using protein-dense ingredients. This study, with specific focus on a faba bean concentrate, assesses alterations in energy percentage and is limited to the total amount of protein. The potential impact of antinutritional factors and disruptive reactions on protein quantity and digestibility will not be considered here. Yet, it can be advantageous to include in future studies.

2.3 Analysis

The following section summarises the methods used to prepare the dough and analyse the baked loaves of bread.

2.3.1 Farinograph

The farinograph is used to mix the dough while measuring dough resistance. The dough consistency is measured in Brabender Units (BU) and is dependent on the type of flour used and added water at a specific temperature. The farinograph can be used to monitor the amount of water needed to reach a specific consistency keeping this parameter constant when developing a new formula. Farinograms can provide data on flour characteristics and dough mixing tolerance. In general, high protein flour absorbs more water and is better at resisting overmixing (Finnie & Atwell 2017).

2.3.2 Texture profile analysis

Instrumental textural measurements, including the Texture Profile Analysis (TPA) is a tool used to measure physical parameters during a double compression of a food item, imitating mastication. Textural data regarding the double compression is presented within a force-time graph enabling the determination of hardness, cohesiveness, springiness, chewiness and resilience of items (Szczesniak 2002). The hardness corresponds to the highest peak force of the first compression. Cohesiveness could be described as a positive characteristic in bread and is related to the strength of the internal bonds. It is calculated as the ratio between the area of the first and second compression. Chewiness is the product of springiness, cohesiveness, and hardness. A lower chewiness results in in bread that are easier to disintegrate mouth and may be perceived as softer. Springiness is defined as the ratio of the time needed to reach the highest point in the second compression to that in the first. It measures the ability of the bread crumb to retain its original shape following the first compression. This parameter correlates with bread staling effects; low springiness indicates a less fresh bread. Resilience is a parameter that describes the ability of the bread to regain the ordinary height. This parameter is similar to the springiness parameter, but it could be determined from a single compression cycle. The resilience is equal to the ratio between the upstroke and downstroke area of the first compression (Montemurro & Pontonio 2024).

Significant alterations in the physical parameters of bread measured as a reduced bread volume and an increased crumb hardness was previously observed in bread where over 20% wheat flour were replaced with legume flour (Mohammed et al. 2014). The results were explained as an effect of dilution of the functional gluten proteins (glutenin and gliadin), and disruptive effects of legume-particles on the gas-retention by the gluten network. It is yet to be determined whether similar effects on physicochemical properties are relevant when faba bean concentrate is used as a substitute for legume flour

2.3.3 Sensory evaluation

The acceptance test provides subjective information from a consumer or a focus group. Hedonic rating is one of the most popular among these. The typical setting in this kind of test is large consumer groups, about 100 consumers are often referred to as accurate. Inclusion criteria can be used to match the target group, for example regular consumers of a certain product group (Meilgaard et al. 2007). The 9-point hedonic was introduced in 1952 and includes verbal statements corresponding to the level of liking from “dislike extremely (1)” to “like extremely (9)” (Peryam & Girardot 1952, see Meilgaard et al. 2007). The information from panellists, especially untrained, must be interpreted within its context, with the potential sources of error involved. Untrained panellists tend to estimate values in the middle, score samples in position one higher or adapt to stimuli and may have difficulties in discrimination between stimuli (Meilgaard et al. 2007). Several preventive actions are aimed to counteract these. Participants are offered water to cleanse their palate between samples, intensity-scales are chosen to be large enough for assessors to be able to differentiate between samples and no more than four samples are assessed at the same time. Samples should be anonymized and presented in a randomized order in a balanced design known as a Latin square design (Macfie et al. 1989; Meilgaard et al. 2007).

A “presence/absence or yes/no”- method could be used to assess the quality of a product, to identify any presence off-flavours. The evaluation is qualitative and simple in its design but is developed for trained panellists (Marcazzan et al. 2018). The presence/absence could still be a better method for untrained panellists compared to a quantitative scaling method.

2.3.4 Off-flavour

A pleasant taste and texture are determining factors for consumer’s acceptance towards plant-based food (Wang et al. 2022). However, faba beans are known to be able to impart a bitter aftertaste. An unpleasant “beany aroma” is primarily associated with oxidation products resulting from lipolysis of PUFA. The off taste is both associated with volatiles formed in lipid oxidation of polyunsaturated fatty acids (PUFA) and non-volatile compounds including phenolics, saponins and tannins (Lippolis et al. 2023; Tuccillo et al. 2022). An aversion to bitterness is innate as it may elicit warning sensations (Pierguidi et al. 2023). Thus, sensory aspects and consumers’ opinions may provide useful information during the development of faba bean enriched products.

3. Method and material

3.1 Experimental design

Three doughs with varying levels of faba bean concentrate were prepared. From each dough, two loaves were analysed for volume, colour and moisture content and porosity. For the consumer sensory test, three additional dough batches were prepared, one bread per dough was analysed for textural parameters.

3.2 Material

Wheat flour (Kungsörnen Vetemjöl Special, Lantmännen) and dry yeast (Kronjäst, Jästbolaget, Sollentuna) was purchased in the local market. Faba bean concentrate (FBC) obtained through air classification of dehulled and milled faba beans (Vicia Faba) was purchased from (Vestkorn Milling, Norway). Rapeseed oil, sugar (sucrose) and table salt (NaCl) were purchased from a local grocery store. Raw material nutritional parameters are provided in Table 1.

Table 1. Raw material used in bread formulations

Nutrition value ($100g^{-1}$)	Wheat flour[1]	Faba bean concentrate[2]	Rapeseed oil (refined)[3]	Powdered sugar[4]
Energy (kJ)	1447	1550	3700	1700
Energy (kcal)	346	365	900	400
Total fat	1.6	4.5	100	0
-of which saturated	0.4	1.0	7	0
Carbohydrates	68	10	0	100
-of which sugars	0.3	1.9	0	100
Protein	12	65	0	0
Salt	0	0.04	0	0
Fibres	3.5	14	N/A	0
Ash	N/A	6.5	N/A	N/A
Moisture	N/A	7	N/A	N/A

Nutrition facts from: Lantmännen Cerealia[1], Vestkorn Milling[2], Axfood[3], Coop[4]
N/A (Not Available)

3.3 Bread

3.3.1 Ingredients

The experimental design was adopted to obtain control bread (made with 100% wheat flour) and bread with varying levels of faba bean concentrate, substituting 5%, 10% and 15% of the wheat flour, respectively. The ingredients used and respective proportions are listed in Table 2. The adequate amount of water needed to achieve a final dough consistency of 400 BU was examined in a Farinograph (Duisburg, Germany). To reach the same consistency; 128, 130, 132 and 133 g water (37 °C) was needed in the formulations with 0, 5, 10 and 15% FB respectively, see Table 2.

Table 2. Amount of ingredients in different bread samples, expressed as weight in grams (g) and percentage of flour weight [1]

Bread formula	CB		5% FB		10% FB		15% FB	
	(%)[1]	(g)	(%)[1]	(g)	(%)[1]	(g)	(%)[1]	(g)
Wheat flour	100	225	95	214	90	203	85	191
Faba bean conc.	0	0	4.9	11	10	22.5	15	34
Yeast	1.3	3	1.3	3	1.3	3	1.3	3
Salt	1.5	3.4	1.5	3.4	1.5	3.4	1.5	3.4
Sugar	5	11.3	5	11.3	5	11.3	5	11.3
Rapeseed oil	2.5	5.6	2.5	5.6	2.5	5.6	2.5	5.6
Water (37 °C)	57	128	58	130	59	132	58	133

3.3.2 Baking

Yeast, flour and faba bean concentrate was mixed in the farinograph for 1 min prior to the addition of salt and sugar dissolved in part of the water. The remaining amount of water and the oil was then added to be mixed in the farinograph for 10–12 min. The dough was fermented 2 x 60 min at 37–40 °C in a leavening cupboard. The dough was divided into three pieces (100 ± 1 g), moulded and placed in greased metal pans following the first hour of fermentation. The bread loaves were baked at 250 °C for 10 min. Vapour was injected at the start of baking. The loaves were allowed to cool under baking cloths before being placed into zip-bags.

3.4 Analysis

3.4.1 Moisture

The moisture level was determined using an air-oven method (AACCI method 44-15.02). Bread samples were punched out from 25mm slices of bread and placed in preweighed aluminium forms. The samples were left to dry in a 105 °C air oven for 18–24 hours, thereafter cooled in a vacuum desiccator prior to weighing. The bread moisture, expressed as the percentage of baked bread, was calculated according to equation 1,

$$Moisture\ (\%) = 100 * \frac{W2 - W3}{W2 - W1} \quad (1)$$

where W1 = empty cup, W2 = empty cup + fresh bread and W3 = cup + dry bread.

3.4.2 Colour

Colour determination of bread crust and crumb was performed using a Minolta CR–300 colorimeter (Konica Minolta Inc., Japan). Two spots on the bread top crust and slices were analysed and expressed as L*a*b* (CIE Lab colour space). The values to be analysed included: L* (0 = darkness, 100 = lightness), a* (negative values indicates greenness and positive value indicates redness) and b* (negative value indicates blueness and positive value indicates yellowness) (Konica Minolta 2007). ΔE* was calculated as a measure of difference between control and sample according to equation 2.

$$\Delta E^* = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2} \quad (2)$$

3.4.3 Specific volume

The bread loaves weight and volume were examined the day after baking (12h+). The volume was determined based on a method similar to the rapeseed displacement method AACC 10-05.01, except for the use of Sago pearls instead of rapeseeds.

3.4.4 Dallman porosity

Bread porosity was determined by comparing scanned images of bread crust with the Dallman scale (1–9), see Appendix 1. The porosity was analysed on each side of one slice of bread from two loaves of the same dough batch.

3.4.5 Nutritional characterization

The energy value in the bread was calculated based on the bread formula and the table of nutritional contents provided from the manufacturer. The Atwater conversion factors (4 kcal/g protein, 4 kcal/g carbohydrates, and 9 kcal/g fat) (FAO 2003) were used to assume the available energy in the food derived from each nutrient. The energy percentage (E%) was calculated based on the total amount of energy and the energy proportion derived from protein in the bread formulations. For each bread variety, the baked bread mass was calculated as a mean value of six bread loaf replicates. The percentage wheat flour and faba bean concentrate in the dough is based on the total dough mass and is expressed as % (WF) and % (FB) respectively. The equations used for calculation of total energy is given by equation 3 below,

$$tot.energy = \frac{(\%)\ WF \cdot 346 + (\%)\ FB \cdot 365 + (\%)\ oil\ + (\%)\ sugar \cdot 400}{mass\ baked\ bread} \tag{3}$$

where the total energy is expressed as kilocalories (kcal) in 100 g baked bread. The numbers 346, 365, 900 and 400 correspond to the energy expressed as kcal in 100 g of WF, FB, oil and sugar respectively, as provided by the manufacturer.

The E (%) protein is given by equation 4,

$$E(\%)protein = \frac{\left((\%\ protein\ in\ WF) \cdot (\%)WF + (\%\ protein\ in\ FB) \cdot (\%)\ FB\right)}{mass\ baked\ bread} \cdot \frac{1}{tot.\ energy} \cdot 100 \tag{4}$$

where the proportion of protein is derived from the manufacturers' nutritional information, the total energy expressed as kcal/100g bread is given by equation 3.

The proportion of total carbohydrates in the bread is given by equation 5,

$$(\%)carbohydrates = \frac{\left((\%\ carb.\ WF)\cdot(\%\ WF)+(\%\ carb.FB)\cdot(\%\ FB)+(\%\ carb.sugar)\cdot(\%\ sugar)\right)}{mass\ baked\ bread} \cdot 100 \tag{5}$$

where the total amount of carbohydrates, starch and sugars, is based on the bread formulation and the manufacturers' nutritional information.

3.4.6 Sensory evaluation

For the sensory assessment, 40 untrained panellists, most young or middle aged and a majority females, were recruited which was carried out in a classroom out at the

Swedish university of Agricultural sciences, Uppsala. The participants included non-allergic individuals who consumed bread regularly (≥1/week).

The preparation of bread for the sensory tests followed the same procedure as described in section 3.3, substituting wheat flour with 0 %, 5%, 10% and 15 % FB. The bread loaves were placed in plastic bags and placed in a freezer the same day as baking. The bread was allowed to thaw at room temperature the night before evaluation. The loaves were sliced into 10 mm thick pieces, cut into small squares and put into plastic bags. Each participant was served two pieces of each sample, coded with a random three digits, together with a glass of tap water for mouth rinsing. The samples were presented in a balanced Latin square according to Macfie et al. (1989) in order to reduce positional and carry-over effects. The evaluation questionnaire (Appendix 7) covered a sensory affective test for liking of bread attributes including odour, colour, taste, texture and overall acceptability. The 9-point (1–9) hedonic scale was used for panellists to rate these bread characteristics. A second part of the test included "presence/absence"-questions on bitterness and sweetness in samples. The participants were asked to identify whether bitterness and/or sweetness could be perceived, and in that case in which samples. Moreover, the questionnaire allowed for free comments and a question regarding bread type preferences, white bread or wholemeal bread.

3.5 Texture profile analysis

Textural parameters were evaluated with a texture analyser (Stable Micro Systems, TA–HDi, Surrey, UK), equipped with a maximal load of 500 N. The test was carried out on two 12.5 mm bread-slices, which were cut from the central part of the loaf using a meat slicer. The compression was performed using a 36 mm aluminium probe and a 40% penetration depth. The test speed was 1.7 mm/s with a 5 s gap in between compressions; pre-test speed and post-test speed was set to 1.7 mm/s and 2 mm/s respectively. The analysed properties included hardness, cohesiveness, springiness, and chewiness. A previous section (2.3.2) provides a more detailed description of these properties and the relevant calculations. The test was conducted on one loaf from each batch of dough, approximately 18– 24 hours after baking.

3.6 Statistical analysis

Results were evaluated through ANOVA and Tukey's test for pairwise comparisons with the statistical software Minitab (Minitab Inc., State College, PA, USA). $p<0.05$ was considered statistically significant.

Similarity scores between sensory rating (1–9) conducting a consumer panel (n=40) and instrumental textural attributes was estimated with Pearson's correlation coefficient, providing a value from -1 to 1 where scores close to 1 was considered correlated, 0 uncorrelated and -1 inversely correlated (Berman 2016).

4. Results and discussion

This section presents and discusses the results of the instrumental measurements, calculated nutritional value and sensory evaluation.

4.1 Bread crumb attributes

4.1.1 Specific volume and moisture

The specific value (SV) was calculated from the ratio of the average volume and weight data. As shown in Table 3, mean values reached 3.9 cm^3/g in the control and 4.0 cm^3/g in all FB-bread. However, the difference was not significant at a 0.05 significance level.

The moisture level in the bread crumb was calculated as mass-differences before and after air oven drying. The observed moisture-level was slightly lower in control (40.9 %) compared to the FB-substituted bread, ranging from 41.1% to 41.2%, this was however not significant ($p>0.05$). Previous studies have reported increased moisture levels in legume-enriched bread (Mohammed et al. 2014). The authors suggested a link between the moisture level and an increased water absorption of chickpea protein. Nonetheless, further studies need to consider the hydration of faba bean protein specifically.

Table 3. Specific volume, moisture and porosity of bread crumb of control (CB) and bread with 5,10 and 15% faba bean concentrate (FB)-substitution

	CB	**5% FB**	**10% FB**	**15% FB**
Specific Volume (cm^3/g)	3.95 ± 0.16^a	4.01 ± 0.16^a	3.99 ± 0.17^a	3.96 ± 0.15^a
Moisture (%)	40.9 ± 0.7^a	41.2 ± 0.5^a	41.1 ± 2.6^a	41.2 ± 0.7^a
Porosity (Dallman scale)	6.5 ± 0.5^a	6.5 ± 0.5^a	6.3 ± 0.5^a	6.3 ± 0.8^a

Values in the same row that are assigned the same superscript letters do not differ significantly ($p>0.05$) according to Tukey's test for comparison.

4.1.2 Bread porosity

The bread porosity was examined by comparing scanned images of bread-slices with the Dallman scale for porosity (Appendix 2). An average Dallman score, presented in Table 3, was based on 12 images of each bread. The higher score (6.5) in the bread with none or low level of FB (5%) corresponds to a finer bread pore structure compared to the slightly lower value (6.3) seen in bread with 10–15% FB. Previous observations have shown small or non-significant differences in terms of pore size or structure and gas cell area of enriched bread (Hoehnel et al. 2020; Coda et al. 2017). The findings in this study suggest non-significant differences in pore size (p>0.05). Moreover, a considerable variation was observed, suggesting inconsistency in bread structure among samples, or uncertainties in the evaluation of pore size. The determination is based on visual assessments and thus somewhat subjective. Aiming for more objective data, gas and cell structure could be further analysed using an image processing software following a digital imaging system as described in Hoehnel et al. (2020).

4.2 Texture

Texture profile analysis was carried out on triplicates of each bread variety, obtaining instrumental data for analysis. The findings, as shown in Table 4, and Appendix 3, indicate that the hardness of FB15% exceeds that of CB by approximately 30%. A similar trend was seen for chewiness with elevated values among the FB-samples compared to CB. Conversely, springiness exhibited a reverse trend. No evident alterations in cohesiveness and resilience were observed in response to FB-substitution. Overall, no textural parameter differed significantly from control at a p<0.05 level of significance. However, the ability to draw conclusions is limited by a large degree of variation noted in some of the datasets. Additional replicates could allow for better understanding of the analysed data.

Table 4. Texture profile of control bread (CB), and varying levels of faba bean concentrate (FB); 5,10 and 15%

	CB	5% FB	10% FB	15% FB
Hardness (g)	820 ± 160^a	1090 ± 170^a	1040 ± 120^a	1080 ± 210^a
Springiness (%)	92.3 ± 4.7^a	91.1 ± 4.3^a	91.2 ± 7.7^a	89.1 ± 6.7^a
Cohesiveness	0.695 ± 0.02^a	0.689 ± 0.01^a	0.735 ± 0.10^a	0.682 ± 0.05^a
Resilience	0.386 ± 0.02^a	0.379 ± 0.02^a	0.398 ± 0.08^a	0.372 ± 0.05^a
Chewiness (g)	$5.31 \cdot 10^4 \pm 1.29 \cdot 10^{4\ a}$	$6.83 \cdot 10^4 \pm 8.77 \cdot 10^{3\ a}$	$6.95 \cdot 10^4 \pm 9.95 \cdot 10^{3\ a}$	$6.69 \cdot 10^4 \pm 2.08 \cdot 10^{4\ a}$

Values in the same row that are assigned the same superscript letters do not differ significantly (p>0.05) according to Tukey's test for comparison.

The result suggests that replacing up to 15% wheat flour with faba bean concentrate does not significantly alter the bread texture. As explained in the introductory section, previous findings showed alterations in physicochemical parameters substituted with 30% faba bean flour (Coda et al. 2017). In high protein faba bean flour at 10% substitution level, however, textural parameters differed significantly compared to control (Hoehnel et al. 2020). Interestingly, the differences in hardness between control and enriched bread reduced over time. It was suggested that this was a consequence of a reduced retrogradation rate, associated with a reduced starch level in legume-enriched samples (Hoehnel et al. 2020).

The two main factors determining bread staling rate are the extent of migration of moisture giving crust and dryer crumb, and starch recrystallisation (Young 2012). Loss of crumb moisture can be measured as increased hardness and staling effects can result in loss of springiness. Thus, textural parameters are not only related to the ingredient formulation but also the rate of moisture migration and tendency for retrogradation events (Young 2012). The substation of flour with protein-rich flours seems to counteract the staling due to the lower amount of wheat starches involved in retrogradation. An increased water absorption can further enhance moisture retention and slow down the rate of staling (Salehifar & Shahedi 2007).

Interestingly, a softer texture and a reduced level of staling has been observed in gluten free bread substituted with beta-glucan, a fibre common in oats. (Hager et al. 2011). Kurek et al. (2018) reported that pretreated beta-glucans exhibited greater water holding capacity, resulting in bread with enhanced springiness, a feature associated with bread freshness. Earlier findings by Kurek et al (2017) provided insight into methods for analysing staling kinetics in bread to optimize fibre-levels to prevent staling. Further research into the long-term effects of fibre addition (such as beta-glucans) into legume-enriched bread may provide a deeper insight into the long-term effects on bread and help to develop methods to prevent staling.

4.3 Colour

4.3.1 Observations

L*, a* and b* values of loaf crust and crumb were obtained from the colour analysis and the overall difference ΔE^*, was calculated thereof. Mean values of crust and crumb parameters are demonstrated in Table 5 and 6 respectively. Bar charts are presented in Appendix 5. Significant differences ($p<0.05$) were observed between FB and CB for crust, while no significant differences were found any of the crumb colour parameters, except the significantly lower b*-value in FB5% compared to CB. The less negative a*-values and lower b*-values in FB-crusts compared to control suggests that FB substitution results in less green pigment and more blue pigment formation. However, this was not a tendency for the rest of the observed b*-values and further studies are needed to confirm whether this is an anomaly.
However, inconsistent results were observed in terms of the colour of the crust. The b*-parameter for FB10% and the a*-parameter for FB15%, showed a deviation from the generally observed correlation between colour parameters and FB-levels. This variation could be attributed to the sampling method, the randomly chosen spots on the crust may vary in colour due to an uneven loaf shape. Sampling from multiple spots on the crust at a perpendicular angle to the surface of the instrument

could provide more reliable data for a better understanding of the relationship between FB-addition and CB. (Konica Minolta 2007).

The total difference in colour was evident for crust, even at the lowest level of substitution. Given the moderate differences for crumb colour, the ΔE^* was relatively low 3.2 in FB5% and 3.4 for 10 % FB, a value of 4.6 was however obtained for the highest level of substation (15%). A delta E over 3.5 is regarded as noticeable (Robertson (1990) in Kurek et al. (2018), thus the difference in crumb colour is presumed to be visible between control and 15% FB, while being apparent on the crusts of all samples.

For crust, L* decreased with increasing level of FB, indicating a darker crust in FB-samples compared to control. A similar, but less clear trend was seen for crumb colour. A darker crust-colour in legume-enriched bread has previously been reported and could be attributed to an increase in the levels of lysine. The brown pigments result from Maillard-reactions taking place between the lysine or other free amino acids and reducing sugars. However, this may have potential negative effects on the nutritional value due to destruction of amino acids, and especially losses of lysine (Anjum et al. 2005). Moreover, the formation of acrylamide, a probable carcinogen, correlates with browning in baked goods (Purlis 2010). Strategies, such as a reduced temperature and higher moisture could counteract excessive browning reactions in order to achieve a nutritionally stable and acceptable bread.

*Table 5. Parameters (L*a*b*) and ΔE*from colour measurements on crusts of bread with 5,10 and 15% faba bean concentrate (FB) and control bread (CB) from 0% FB*

Bread crust	parameters			
	L*	**a***	**b***	**ΔE^***
CB	104.2 ± 8.3^{a}	-15.9 ± 2.9^{b}	40.8 ± 4.2^{a}	0
5% FB	84.9 ± 11.5^{b}	-10.8 ± 2.1^{a}	23.3 ± 9.1^{b}	26.7 ± 8.2
10% FB	79.9 ± 7.8^{bc}	-10.0 ± 3.2^{a}	25.5 ± 3.5^{c}	34.9 ± 4.2
15% FB	75.4 ± 6.3^{c}	-12.3 ± 4.0^{a}	9.0 ± 3.5^{d}	43.2 ± 4.7

Values in the same column that are assigned different superscript letters (a–c) differ significantly (p<0.05) according to Tukey's test for comparison.

*Table 6. Parameters (L*a*b) and ΔE*from colour measurements on bread crumb of faba bean bread (FB) and control bread from 0% FB*

Bread crumb	Parameters			
	L*	**a***	**b***	**Δ*E****
CB	78.3 ± 11.9^{a}	-11.0 ± 2.2^{a}	36.2 ± 2.1^{ab}	0
5% FB	77.5 ± 12.7^{a}	-10.2 ± 2.1^{a}	34.6 ± 1.6^{b}	3.2 ± 1.6
10% FB	75.8 ± 12.8^{a}	-9.8 ± 2.1^{a}	35.4 ± 1.3^{ab}	3.4 ± 2.0
15% FB	74.9 ± 13.4^{a}	-9.3 ± 2.2^{a}	36.5 ± 1.1^{a}	4.6 ± 2.0

Values in the same column that are assigned different superscript letters(a–b) differ significantly (p<0.05) according to Tukey's test for comparison.

4.3.2 Nutritional aspects

The nutritional value of the bread is shown in Table 7 and is expressed in relation to the mass of the baked bread. The values are estimates based on the nutritional value information provided from the producers. The calculations indicate almost similar energy values, elevated protein-levels, and a lower proportion of carbohydrates in faba-bean enriched bread.

The energy provided from protein in the bread was calculated to reach 20.5%, thus slightly above the threshold (20%) required for the health claim "high protein bread", according to the European Commission's regulation. This calculation was based on the assumption that all nutrients were constant during the fermentation and baking process. However, at least a part of the added sugar is probably consumed by the yeast during fermentation (Zhang et al. 2018). Two different calculations were performed to find upper and lower boundaries. Assuming that all added sugar (sucrose) were consumed, the protein E(%) would instead reach 21.6 (%). The level is probably somewhere in between. Moreover, both sugars and amino acids participate in caramelization and Maillard reactions (Timmermans et al. 2022). Taking this into consideration, a chemical analysis of the baked bread may be a more reliable way of determining the nutritional value of bread.

Table 7. The nutritional value of control (CB) and bread with increasing levels of faba bean concentrate (FB) 5,10 and 15%, expressed as the mass of the baked bread

	CB	FB5%	FB10%	FB15%
Energy (kcal/100 g)	262	261	261	263
E(%) Protein*	12.4	15	17.7	20.5
Carbohydrates (%)*	49.2	42.1	40.1	43.2
Energy (kcal/100 g)	248	248	247	249
E(%) Protein**	13	15.8	18.7	21.6
Carbohydrates (%)**	45.8	39.1	37.1	39.8

** Assuming all added sucrose (3%) remains in the bread.*

*** Assuming all added sucrose (3%) has been consumed as yeast nutrients.*

This study was limited to the total protein content. However, the amino acid profile provides more information about the balance of amino acid. Previous studies (Coda et al. 2017; Hoehnel et al. 2020) reported more balanced amino acid profiles in high protein formulations with faba beans. The chromatographic methods for amino acid determination, described in the mentioned studies, could be possible methods for better evaluation of the nutritional quality of bread in future studies.

4.3.3 Antinutritional factors

The levels of antinutritional factors (ANF), which might affect nutrient bioavailability was not specifically determined in this study. However, data could be obtained from the manufacturer of the used faba bean concentrate. The reported values suggest high variability between cultivars. As shown in Table 8, convicine ranges from 0.7–7 mg/g while vicine ranges from 1.1–11 mg/g, declared to be dependent on batch and faba bean variety (Vestkorn Milling).

Table 8. Data from Vestkorn Milling. Approximate vicine and convicine levels in faba bean concentrate

Faba bean concentrate* (65% protein)	
Convicine[1]	0.7–7 mg/g
Vicine [1]	1.1–11 mg/g

** Dehulled, finely milled and concentrated through air classification.*

[1] According to data from the supplier (Vestkorn Milling).

The issue of ANFs in bread was discussed by Hoehnel et al. (2020), who suggested only low amounts of ANFs to be present in enriched bread substituted with 10% high protein flour, explaining this as an effect of dilution. Using protein-dense flours or concentrates appears to be beneficial in this regard, as it increases protein quantities even at low substitution levels and potentially reduces the total amount of antinutrients.

Nevertheless, ANF-levels exhibit a considerable variation between cultivars and are also influenced by processing methods (Mayer Labba et al. 2021). Compared to dry methods, such as air-classification, aqueous processed protein isolate has been shown to be lower in antinutrient. The drawbacks from wet methods are impaired solubility and negative climate impact (Vogelsang-O'Dwyer et al. 2020). This highlights the importance of breeding and variety selection to reduce the level of antinutrients.

4.4 Sensory evaluation

4.4.1 Hedonic rating test

The hedonic sensory test with n=40 untrained panellists aimed to estimate whether the degree of liking differed between different bread types. The mean scores are presented in Table 9, while a spider chart (Figure 1) displays how scores are distributed between sensory parameters and bread types. On average, only minor differences were observed in terms of liking between the control and FB-samples. Mean values of all parameters scored around 6–7, corresponding to "slight" and "moderate" liking respectively. The smallest difference was observed for odour/smell and colour, a larger, still non-significant difference was seen for taste/flavour and texture. However, as illustrated in Figure 2, there was a significant difference ($p<0.05$) between FB15% and control for the overall acceptability parameter.

Table 9. Results from the sensory evaluation by consumers (n=40). Hedonic rating scores (1–9) on different sensory attributes of control bread (CB), and varying levels of faba bean concentrate (FB); 5,10 15%

	Odour/Smell	**Colour**	**Taste/Flavour**	**Texture**	**Overall acceptability**
CB	6.4 ± 1.8^{a}	6.7 ± 1.4^{a}	6.6 ± 1.5^{a}	6.6 ± 1.5^{a}	7.0 ± 1.2^{a}
FB5%	6.5 ± 1.7^{a}	6.3 ± 1.4^{a}	6.1 ± 1.6^{a}	5.6 ± 1.7^{a}	6.5 ± 1.3^{a}
FB10%	6.2 ± 1.8^{a}	6.5 ± 1.5^{a}	6.0 ± 1.8^{a}	6.3 ± 1.7^{a}	6.4 ± 1.4^{a}
FB15%	6.1 ± 1.8^{a}	6.5 ± 1.4^{a}	5.8 ± 2.0^{a}	5.8 ± 1.9^{a}	6.0 ± 1.5^{b}

Values in the same column that are assigned different superscript letters (a–b) differ significantly ($p<0.05$) according to Tukey's test for comparison.

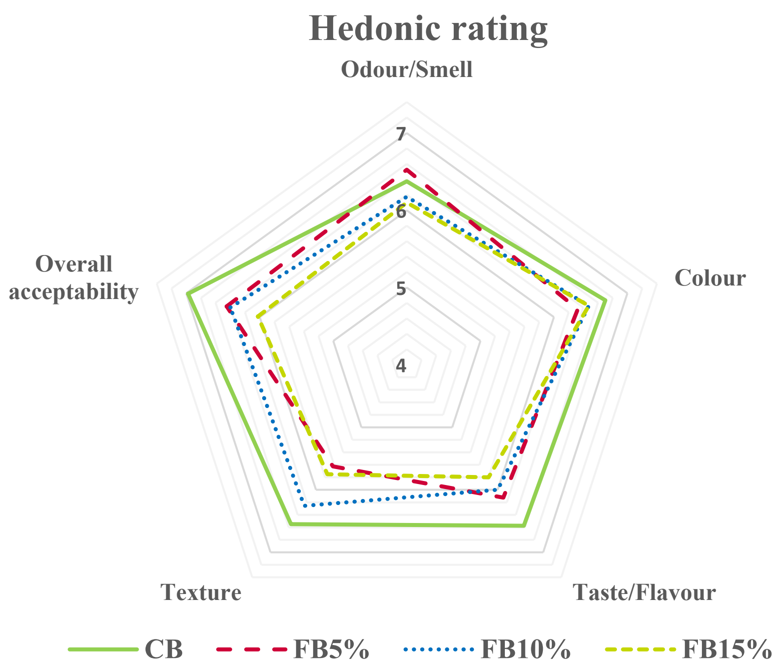

Figure 1. Mean liking scores (1–9) summarized in a spider chart diagram, with axis values ranging from 4 to 7. Based on consumers' evaluation (n=40) of different bread formulations (control bread (CB) and varying levels (5,10,15%) of faba bean concentrate (FB).

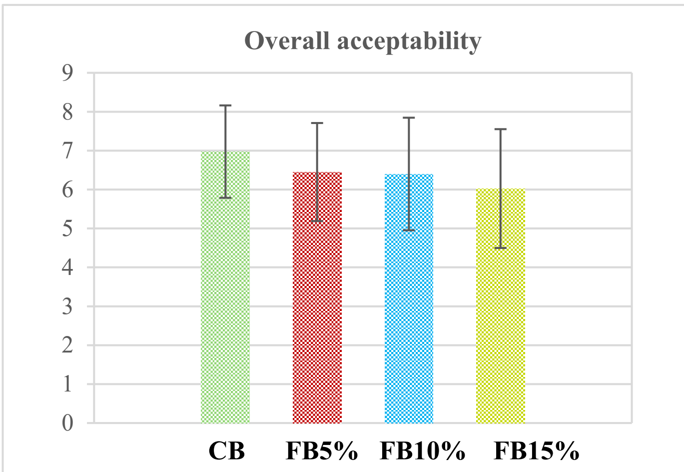

Figure 2. Consumers' (n=40) hedonic liking score (1–9) for "overall acceptability" of different bread types; control (CB) and bread with 5,10 and 15% faba bean concentrate (FB). Error bars show standard deviation.

4.4.2 Attribute test

The consumers were asked to evaluate the presence of bitterness and sweetness in terms of "presence/absence". In the case of "presence", the participant was asked to specify the sample or samples. A majority reported bitterness among the enriched bread, 9 persons noted bitterness in the sample with 15% FB, 10 persons noted bitterness in the sample with 10% FB while 4 and 2 persons noted bitterness in the control and 5%FB respectively. This preliminary test, illustrated in Figure 3 and reported in Table 11, suggest that bitterness could be noticed as a trait in samples with the higher proportions of FB (≥ 10% substitution). However, sweetness was a more prominent trait, 76% reported sweetness. The attribute 'sweetness' was primarily identified in the control bread, with 17 participants noticing it. The lowest degree of substitution (5%) was perceived as sweet by 6 participants. For bread with 10% and 15% FB, the corresponding values were 9 and 6 respectively. According to this, sweetness was identified in all bread but appears to be more prevalent in the control bread.

Keast & Breslin (2003) reported that sweetness and bitterness show mutually suppressive effects. About half of the participants perceived bitterness, a possible explanation is a varying sensitivity or inability to differentiate among different tastes. Consumers are not objective and trained to recognize specific attributes, a trained panel could provide more reliable data.

The control bread was considered as sweet by the largest number of assessors. This may partly be due to its higher levels of carbohydrates (starch), partly due to the absence of masking compounds. To determine whether sweetness reduced bitterness, a parallel test could be performed with bread formulations adjusted for the reduced starch content in faba bean bread.

Figure 3 Percentage of the participants (n=37) who noted bitterness or sweetness in one or more bread samples; control and varying levels of faba bean concentrate; 5, 10 and 15%.

Table 11. The number of votes for a specified bread type among those who identified bitterness(above) and/or sweetness (below) as a feature in one or more bread-types. The test involved a control bread (CB) and bread with varying levels (5,10 and 15%) faba bean concentrate (FB)

Bitterness: n votes/bread-type:	
CB	4
FB5%	2
FB10%	10
FB15%	9

Sweetness: n votes/bread-type:	
CB	17
FB5%	6
FB10%	9
FB15%	6

The large variance in test scores could be attributed to consumers' tendency to express preference rather than observed attributes. Genetic factors appear to influence our perception of bitterness (Feeney et al. 2021). In addition, it appears that personality and attitude towards food influence how we perceive bitterness (Pierguidi et al. 2023). For accurate assessment of taste, trained panels would be desirable in upcoming studies. Furthermore, as Perguidi et al (2023) suggested in their study, the masking of off-flavours could be examined as a way to make plant-based food more appealing.

This sensory test was limited to include only the crumb, and not the crust. The crusts were still affected by the incorporation of faba beans, as demonstrated by the significant reduction in L* and dark (burnt) crusts as demonstrated in photos (Appendix 1). This finding emphasises the importance of refining the baking procedure to overcome obstacles, to attain a more uniform overall bread quality.

The overall liking of the control bread could be attributed to its sweetness, soft structure and low bitterness. However, the overall liking of the FB-substituted bread could still be considered accepted given the very modest difference seen in sensory parameters

4.4.3 Correlation

Pearson's correlation coefficient was calculated to compare textural differences with sensory scores. The strongest correlation was found between the characteristic "texture" in the sensory evaluation and the parameter hardness from the TPA. The negative value (-0.87) indicates that a lower hardness or softer crumb could be a more appreciated trait among consumers. Other parameters seemed to contribute to a lesser extent to consumer liking scores. Correlation between texture scores and TPA-parameters are summarised in Table 10. For a full list of all data contributing to the calculations, see Appendix 4.

Table 10. Correlation between textural and sensory parameters. r= Pearson's correlation coefficient

Characteristic in sensory evaluation	Textural parameter	r
texture	hardness	-0.87
-"-	chewiness	-0.7
-"-	springiness	0.71
-"-	resilience	0.66
-"-	cohesiveness	0.47

4.4.4 Free comments

In addition to the hedonic rating test, consumers were allowed to comment on bread properties, comments are summarized in Appendix 6. In general, the control bread got positive remarks, a “sweet” taste was reported, but considering the high scores for taste, this does not seem to be regarded as a negative attribute by most consumers. Opinions regarding the properties of FB-enriched bread, some commented on “yeasty taste”, aftertastes and acidity as negative attributes, while others who gave higher ratings found the bread to taste “sour” but “nice”. There seemed to be more consistency among the assessors regarding the texture of the FB-bread, commented as “dry” and “crumbly” or “floury”: Overall, aftertaste and dryness seemed to be negative attributes in faba bean bread while the control bread was rated as sweeter, lighter and an overall more accepted for its taste and texture.

5. Conclusion

This study investigated physical, nutritional, and sensory quality aspects of the incorporation of faba bean concentrate (5%, 10%, 15%) into wheat bread. Regarding physical parameters, only colour seemed to be significantly altered. The preliminary sensory evaluation suggests that bread was acceptable even at the highest level of substitution (15%). Nevertheless, the control bread scored higher for all tested attributes in the hedonic sensory evaluation. This underlines the importance of continuous evaluation of sensory aspects in the development of new bread formulations. Regarding nutritional quality, a bread formulation with 15% FB had a calculated protein E(%) between 20.5 and 21.6, just qualifying for the health claim "high in protein".

The level of faba bean concentrate could be increased further to exceed the limit of 20 E% with certainty, however the level must be carefully considered to ensure that the bread maintains acceptable quality standards. A darkened crust in bread with high levels (10–15 %) of faba bean concentrate was identified as a key issue, potentially impairing both flavour and nutritional value. Adjustments of the baking process and ingredients may improve technological and sensory quality properties.

The antinutritional factors were only briefly covered in this thesis. A carefully considered variety selection and a more in-depth analysis of antinutrients could help to develop bread with a high nutritional quality and potentially, reduced off-flavours. Future studies of staling effects in FB breads could help to optimise methods for improving texture and extending shelf life. Investigations into methods for the reduction of off-flavours could also be conducted, including alterations to raw materials and methods, or the addition of masking substances.

In conclusion, faba bean enrichment enhanced the protein content of the bread, but impairments in taste and texture were noticed by consumers. Future studies could focus on additives to improve texture, enhance the shelf-life and potentially improve the flavour of faba bean enriched bread, aiming for a more sustainable and healthy bread for the future.

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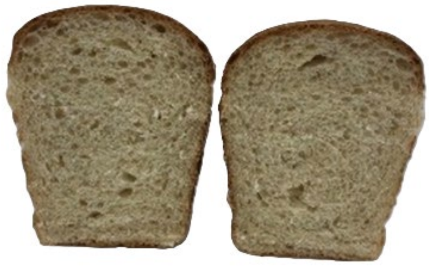
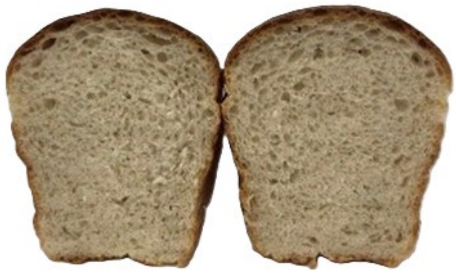
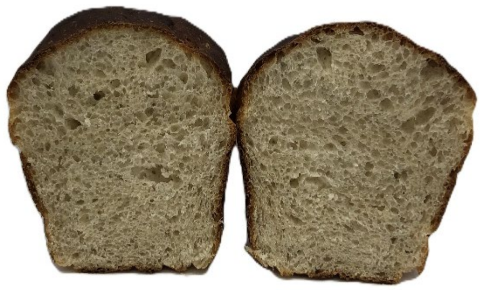
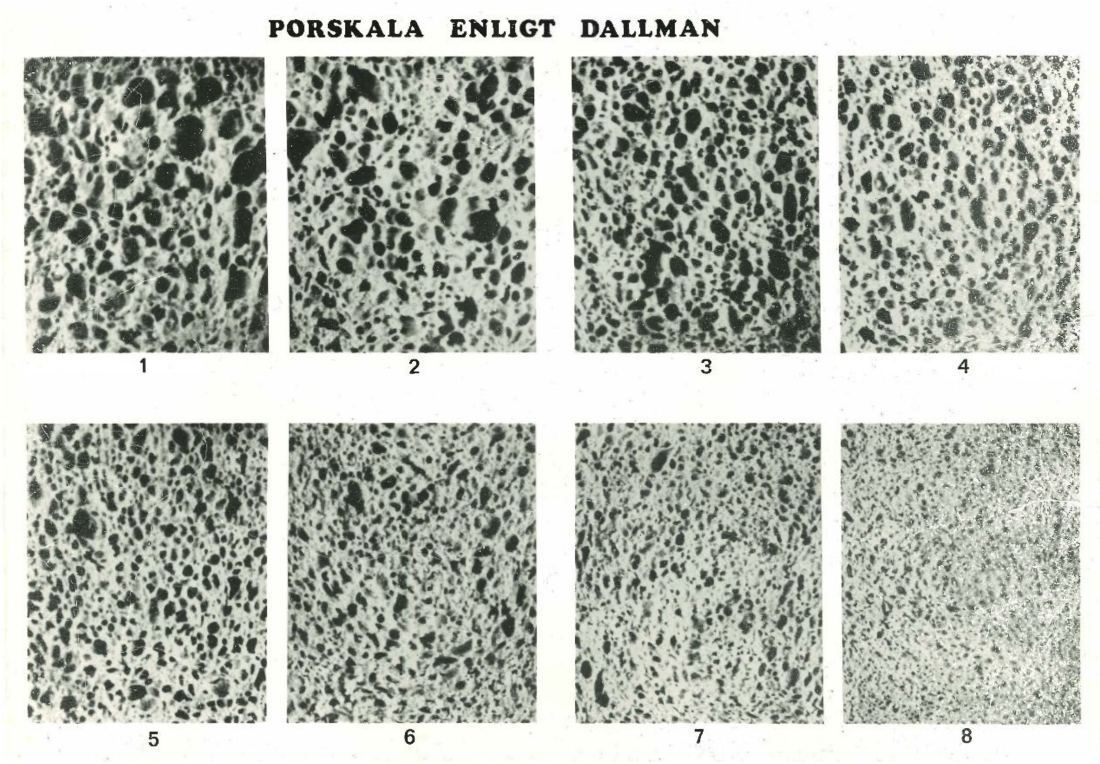
Appendix 1 Photographs on the bread

Photos of bread from different views (top, side, crumb)

	Crust	Side	Crumb
CB			
FB5%			
FB10%			
FB15%			

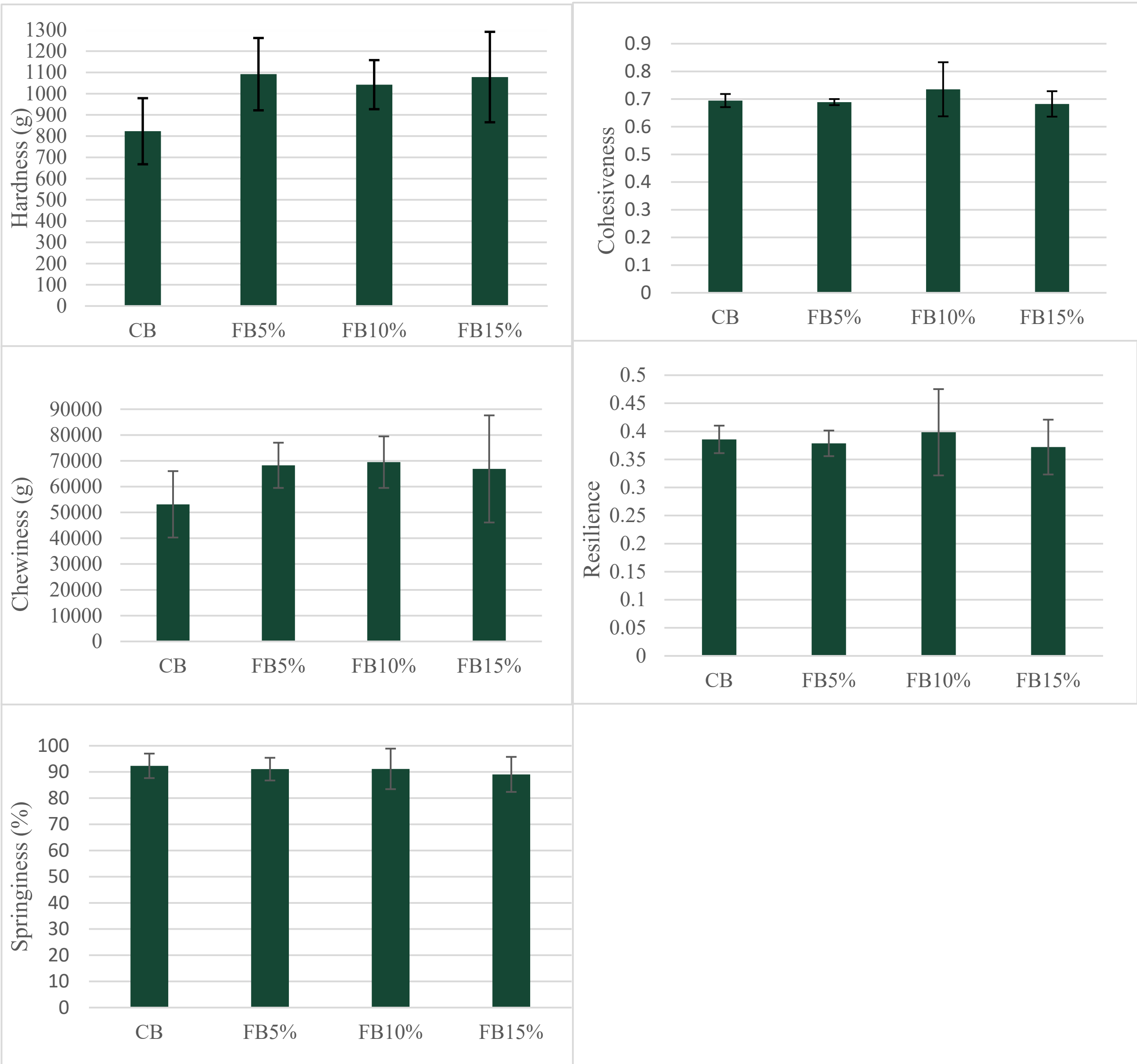
Appendix 2 Dallman scale for porosity



Scale of porosity according to Dallman (1–8) porosity of the bread crumb. This scanned image is a scaled down version of the A4-sized version used for the comparison test.

Scaled down versions of the different bread-types: control bread (CB), and bread with 5–15% faba bean concentrate (FB). 6 slices of each bread type were scanned on both sides, giving a total of 12 images for each formulation.

Appendix 3 Textural parameters



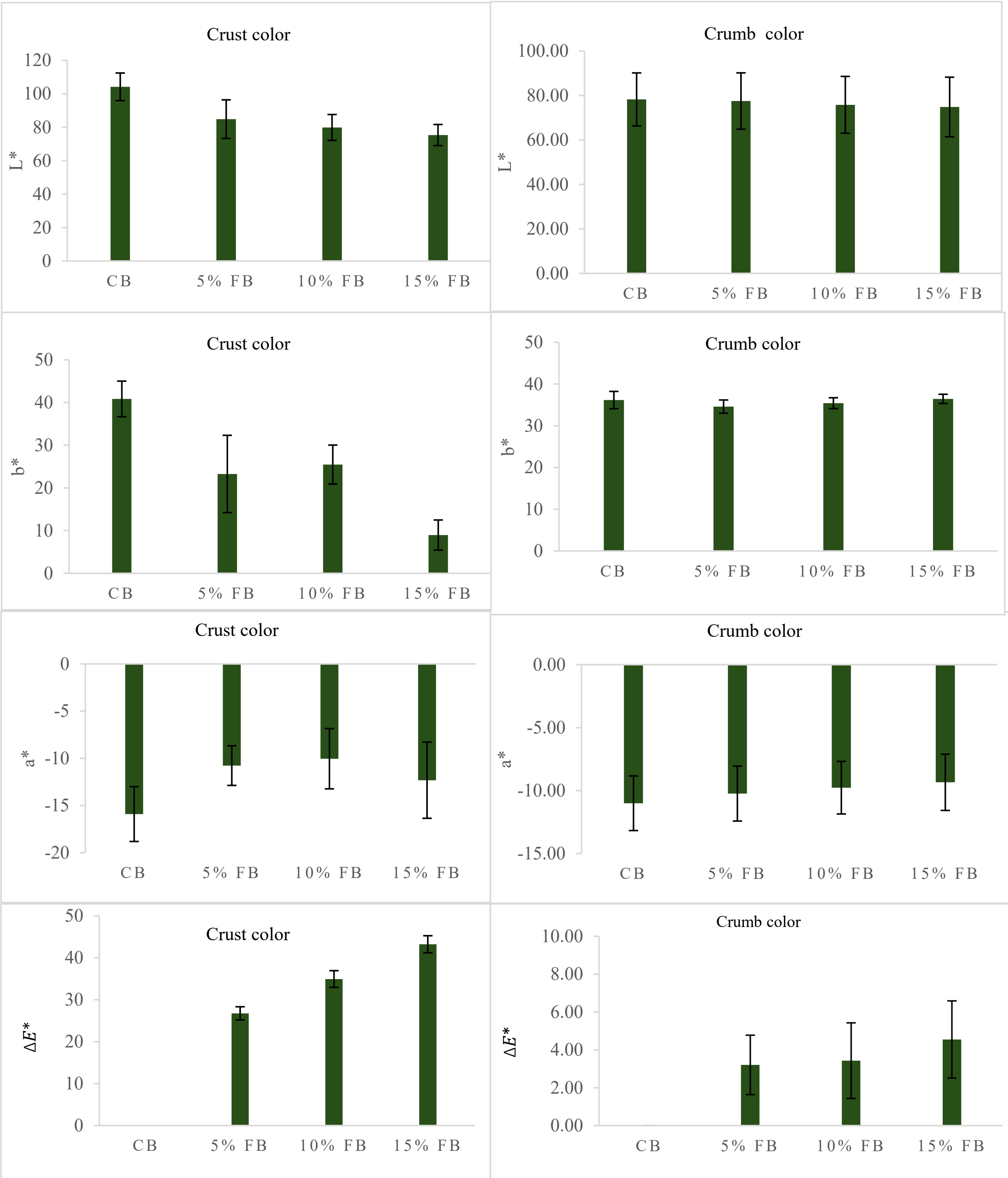
The textural parameters from the TPA-analysis presented as mean values from triplicates. Error bars show the standard deviation.

Appendix 4 Correlation: TPA and sensory attributes

Pearson's correlation coefficient between sensory rating from consumers' sensory evaluation and instrumental parameters (TPA)

(%)FB	Texture score	Hardness(g)	Pearson corr.
0	6.55	823	-0.87
5	5.63	1092	
10	6.26	1042	
15	5.75	1078	
(%)FB	**Texture score**	**Chewiness (g)**	
0	6.55	53143	-0.70
5	5.63	68257	
10	6.26	69485	
15	5.75	66862	
(%)FB	**Texture score**	**Springiness(%)**	
0	6.55	92.34	0.71
5	5.63	91.08	
10	6.26	91.17	
15	5.75	89.07	
(%)FB	**Texture score**	**Resilience**	
0	6.55	0.39	0.66
5	5.63	0.38	
10	6.26	0.40	
15	5.75	0.37	
(%)FB	**Texture score**	**Cohesiveness**	
0	6.55	0.69	0.47
5	5.63	0.69	
10	6.26	0.74	
15	5.75	0.68	

Appendix 5 Colour measurement



Colour characterization is displayed as mean values. Crust and crumb colour parameters (L, a*, b* and ΔE*) to left and right respectively. Error bars show standard deviation.*

Appendix 6 Free comments

Free comments from the bread sensory evaluation are summarised in the table below. Related sensory score in parentheses

	CB	FB5%	FB10%	FB15%
Taste/ smell	“Slightly sweet (taste=8)” “Slightly nutty(taste=7)” “A bit sweeter (taste=9)” good taste (taste=7)” “Sweet (taste=7)” “Slightly beany (taste=6)” “Smells different (smell=5)” “Smells a bit strange(smell=4)”	Tastes “very good” “Good and tasty (taste=8)” “Sour (taste=7)” “Neutral, no such taste (taste=4)” “Slightly rancid smell (smell=4)” “Tasteless (taste=3)” “A little sour aftertaste (taste=3)” “yeast smell (smell=2)”	“Sour (taste=8)” “sandwich bread (smell=7)” “Possibly a bit floury aftertaste (taste=7)” “less flavour (taste=5)” “Bitter (taste=5)” “didn’t taste so much, a little sour (taste=4)” “Slightly rancid smell (smell=4)” “Sour, acidic (taste=2)” “Yeast-smell, a bit sour (smell/taste=1)”	“Nice, like almond (smell=9)” “Little sour, but nice (taste=9)” “Dusty taste (taste=7)” “Smells wholegrain-like (smell=6)” “A bit grassy taste (taste=6)” “Yeast smell (smell=4)” “Off-flavour? (taste=4)” “Floury aftertaste (taste=3)” “Raw aftertaste (taste=2)” “Sharp acidity (taste=2)”
Texture/ colour	“Lighter and less packed, good(texture=7)” “Lighter(texture=7)” “Too fluffy(texture=7)” “Harder to chew (texture = 5)” “Firm (texture=5)”	“Compact (texture=7)” “Dry (texture=7)” “uneven texture (texture=5)” “A little spongy (texture=4)” “White spots (colour =4)”	“Slightly stiffer texture (texture=8)” “Spongy(texture=6)” “Big pores, spongy(texture=4)” “Soft and sticky texture (texture=4)” “Gritty texture, floury (texture=3)”	“Firm (texture=8)” “Dryer? (texture=7)” “Paper-like feeling in the mouth (texture =6)” “Dry (texture=6)” “Softer(texture=5)” “Crumbly(texture=5)” “Spongy (texture=4)” “dry texture(texture=4)” “No bite (texture=3)” “Crumbled apart (texture=1) “Little too much like a sponge (texture=3)”
Overall	“White everyday bread (overall=7)” “Nothing bad to tell (overall=7)” “Best one (overall=8)” “A good bread (overall=8)”	“Probably the worst(overall=6)”	“I like it (overall=9)” “Would buy(overall=7)” “Solid bread (overall=6)”	“I’d be glad to buy this (overall=8)”

Appendix 7 Questionnaire

Bread evaluation 8th May 2025

Information

- **To participate, you need to be at least 18 years old, consume bread on a regular basis (once a week or more often), and have no known intolerance/allergy to gluten-/wheat protein or faba beans.**
- **Please avoid eye contact or discussing with others during this evaluation.**
- **Samples are coded and presented in a specific order, please do not change the order.**
- **This evaluation is divided into two parts. Ensure that you have a piece of bread for the test on page 2.**

Hedonic rating test:

1. You are provided four samples from different breads. Each is labelled with a three-digit code.
2. Evaluate the samples in order, from left to right. Please, rinse your mouth with some water in between samples.
3. Evaluate each sample according to your degree of liking in the following 9-point scale ranging from 1-9 and write a numerical value (1-9) in the table.

***1**: dislike extremely, **2**: dislike very much, **3**: dislike moderately, **4**: dislike slightly,*
***5**: neither dislike or like, **6**: like slightly, **7**: like moderately, **8**: like very much,*
***9**: like extremely*

4. You are welcome to add a short comment on each sample (optional).

Sample code: / **Attributes:**				
Odour/smell				
Colour				
Taste/flavour				
Texture				
Overall acceptability				
Comment:				

Page 1(2)

“Presence/absence” of specific attributes:

Please taste the taste the samples again and answer the following questions:

1. Did you notice **bitterness** in any of the samples? Yes ☐ No ☐

If yes, please specify the code of the sample(s): ______________________________

1. Did you notice **sweetness** in any of the samples? Yes ☐ No ☐

If yes, please specify the code of the sample(s): ______________________________

Participant information (please check one box for each question):

Gender: male ☐ female ☐ other ☐

Age: 18-25 ☐ 25-40 ☐ 41-60 ☐ 60+ ☐

Which of the following breads do you prefer (taste-wise)?

- White bread: ☐
- Wholemeal bread: ☐

Page 2(2)

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Publishing and archiving

☒ YES, I, Moa Gålnander, have read and agree to the agreement for publication and the personal data processing that takes place in connection with this