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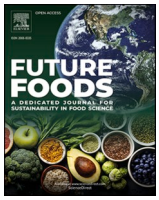

Sensory aspects of products based on the landrace cereal swidden rye (*Secale cereale*)

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ABSTRACT

Consumer trends are shifting toward local and regional produce, particularly those with historical significance, such as landrace cereals. Increasing the production and consumption of landrace cereals has been identified as a key component of sustainable food systems. Furthermore, landrace cereals show promise for the development of healthy and gastronomically appealing products.

Currently, the use of landrace cereals in commercial products is limited, which in turn affects their availability to consumers. By the use of sensory methodology, both analytical sensory and hedonic methods, this study aims to investigate the sensory characteristics of the landrace swidden rye (*Secale cereale*). Swidden rye from various Swedish farms, along with conventional rye, was included in the study and analysed both as flour and as baked sweet goods.

The results revealed significant variations among the flours, primarily in texture and appearance. Overall, all samples exhibited a rye aroma, a grey to golden hue, firm texture, rye flavour, and a slightly bitter taste. The addition of fat and sugar amplified the differences among the samples, particularly in flavour. Consumers evaluated all baked sweet goods positively, with most significant differences in preference observed between the conventional rye and the swidden rye samples.

A focus group provided further insights into preferred attributes, such as buttery, roasted, nutty, and brittle characteristics. Notable sensory differences were found among the samples when evaluated both as flour and as baked goods. The addition of butter and sugar altered the sensory profiles and their intensities. The differences observed among the swidden rye varieties may be attributed to factors such as origin, climate conditions, or agricultural practices.

1. Introduction

The production of food is at the centre of many planetary health issues (Godfray and Garnett, 2014; Rockström et al., 2017; Tilman et al., 2011). A critical aspect is the loss of agrobiodiversity (Jones et al., 2021). That is, the diversity of and within plant species, varieties, animals, and microorganisms that through cultivation, interaction, selection, and care over millennia has come to underpin food cultures and agricultural production systems (Hunter et al., 2017). To shift the trend of declining agrobiodiversity, eating from more diverse food sources, including different varieties of crops and types of foods, that are sustainably produces, can be a way forward (Gordon et al., 2017; Willett et al., 2019). Simultaneously, consumers are becoming more aware of the connection between food and sustainability and are demanding more sustainably produced foods (Aschemann-Witzel et al., 2019; Asioli et al., 2014; Hoek et al., 2017; Petrescu et al., 2019). Sustainability is the practice of meeting current human and non-human needs without compromising future ones and include staying within safe and just earth system boundaries (Bruntland, 1987; Rockström et al., 2023). The evolution of agriculture toward more intensive, standardised, and high-input modes of production has contributed to a decreased agrobiodiversity and an increased vulnerability of production systems toward shocks (FAO, 2018; Li and Siddique, 2018; Wouw et al., 2010). Approximately 60 % of calories consumed daily comes from only five

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staple crops (FAO, 2018) and only 170 species out of 30 000 are produced on commercial scales and are easily available to consumers (Li and Siddique, 2018). Increasing agrobiodiversity could not only make diverse food sources more accessible to consumers, but could also improve the resilience of food production system while keeping traditional ecological knowledge alive and benefit small-scale farming (IPCC, 2022; Jones et al., 2021). The Intergovernmental Panel on Climate Change (IPCC) (2022) has suggested that diversifying crop species produced and consumed ia an integral part of sustainable pathways to the future.

One of the most important crops in food cultures globally is cereal grains. However, with increasing temperatures cereal yields are decreasing at the same time as research shows the need to increase them with 70–100 % until 2050 (Godfray et al., 2010; Ray et al., 2013. Currently, the majority of cereals produced and consumed globally are modern varieties developed for intensive large-scale farming systems (Byerlee, 1996; OECD, 2018; Batur et al., 2021). Given the importance of cereals as staple foods, research has been aimed at finding more sustainable ways of producing them, from continued plant-breeding (Hawkesford et al., 2013), changing land-use and agricultural practices, to reducing waste and promoting dietary changes (Ray et al., 2013). Another option could be a return to landrace cereals, i.e. dynamic, locally adapted and genetically diverse populations of cultivated cereals associated with traditional farming systems, deep historical origins, and with distinct identity (Villa et al., 2005; Batur et al., 2021). Landrace is sometimes used synonymously with the terms ancient, heritage, farmers, and traditional varieties (Villa et al., 2005). It has been suggested that by increasing the share of landrace cereals, food systems can become more adaptable to a changing climate (Boukid et al., 2018; Scherr and McNeely, 2008; Slama et al., 2018), which has led to an increased focus on potential benefits of increasing their production and consumption (Boukid et al., 2018; Longin and Würschum, 2016). Despite lower yields compared to modern cereals, landrace cereals have proven to be more drought-resistant and increase food system agrobiodiversity, which contributes to their adaptability to environmental variability (Boukid et al., 2018; Johansson et al., 2021; Zamaratskaia et al., 2021). Landrace cereals also contribute to healthier diets with higher nutritional values compared to modern varieties, due to their high protein and mineral content (Johansson et al., 2021; Zamaratskaia et al., 2021). They are suited to be cultivated on marginal land, that is land less suited for conventional agricultural production such as hilly landscapes or areas with less fertile soil conditions, and also require less water, energy, and fertilisers compared to modern cereals (Lazzaro et al., 2017; Ortman et al., 2023; Slama et al., 2018).

Landrace cereals offer a greater diversity of ingredients and sensory characteristics which provides potential for gastronomy, product development, and for meeting present and future consumer preferences (Westling et al., 2019; Zamaratskaia et al., 2021). A recent survey found that consumers are becoming more aware of landrace cereals and want to consume them in a variety of food products (Wendin et al., 2020). However, research is needed to identify which characteristics are important for consumers (Longin and Würschum, 2016), given that much knowledge on their qualitative characteristics have been lost in the shift to modern cereals (Leino, 2017). This requires investigations of landrace cereals sensory characteristics, their application in products, and consumers preferences to those (Aschemann-Witzel et al., 2019; Asioli et al., 2014). Prior sensory studies have focused on emmer, spelt, einkorn, millet, and wholemeal wheat, showing that tasty products with high nutritional values can be produced (Zamaratskaia et al., 2021) and that different landrace cereals offer different sensory attributes (Starr et al., 2013). Studies with a focus on comparing conventional and landrace wheat have also shown promising results for landraces in consumer studies with high consumer liking and nutritional benefits (Coda et al., 2010; Serban et al., 2021). Others have focused on combining conventional and landrace cereals with healthier and tastier products as a result (Angioloni and Collar, 2011; Collar et al., 2014). Different preparations and cooking techniques have shown significant impact on sensory descriptions, especially regarding flavours and texture (Kissing Kucek et al., 2017), showing the need and importance of better understanding these aspects in product development and application.

Although studies on landrace cereals have increased, there are species that have received less attention. One of those is rye (*Secale cereale*). In the Nordic region, rye has been of historical importance (Katina et al., 2007) and was up until the beginning of the 18th century the most important cereal cultivated in Sweden (Katina et al., 2007; Persson and Von Bothmer, 2002). Today, rye, has relatively low consumption rates among Swedish consumers (Sandvik et al., 2017), even if it has been highlighted as wonder crop containing essential macromolecules, vitamins, and minerals (El-Mahis et al., 2023; Kaur et al., 2021). Apart from its nutritional and historical value, rye can also be cultivated on marginal land (Larsson et al., 2019). A study identifying barriers to the consumption of alternative staples as rye found the main ones to be a lack of knowledge on usage, low availability, and, unfavourable sensory attributes (Shah et al., 2021). Increasing consumer awareness of landraces, including landrace rye, the availability thereof, and better understand their sensory characteristics are essential steps that could help increase consumer consumption through existing or new products. Landraces of rye, including the swidden rye is grown for its large production of straw, a key resource in smallholder agriculture. The “swidden” landrace rye variety was historically used in swidden agriculture, where forests were burnt and then planted with rye, and from where it has gotten its name (Leino, 2017). In Scandinavia, landraces of rye have been named based on how they are grown but it has yet to be determined if they are genetically different (Hagenblad et al., 2016; Leino, 2017). It is also called “root”, or “bush” rye as it forms large tufts.

Provided that fewer studies have focused on landrace rye, this study sets out to investigate sensory aspects, analytical and hedonic, of rye varieties, and evaluate them in the form of flours and baked sweet goods. It is well known that sensory attributes in cereal products are highly impacted by other ingredients, especially, the impact of fat and sugar (Garvey et al., 2020). Thus, this study show how sensory properties of swidden rye varieties will change with added fat and sugar. In addition, the consumer liking of the baked sweet goods will be evaluated to reach a better overall understanding of its potential. By doing so the study can provide further input to the growing field of research on applications for landrace cereals and their sensory potential as well as consumers’ acceptance. The knowledge gained can be used for future product development.

2. Material and methods

A mixed-methods approach was used with analytical and hedonic sensory evaluations. Quantitative Descriptive Analysis with trained panellists were used to identify the sensory profiles of the included samples, while a consumer panel used the hedonic scale to assess liking of the samples. Both methods outlined by Lawless and Heymann (2010). Additionally, focus group interviews were performed, as described by Braun et al. (2022) and McNeill et al. (2007) to reveal a deeper consumer insight. The study included five varieties of swidden rye and one conventional variety as reference. The rye samples were chosen to geographically cover a large part of Sweden, where swidden rye is grown. All rye varieties were milled into flour and used for all sensory analyses. To be able to evaluate the flours they were mixed with water. The addition of sugar and fat can enhance flavour attributes in products. So, to be better able to assess these attributes of swidden rye the flours were also mixed butter sugar and butter to form baked sweet goods. Analytical analyses were used to generate descriptive vocabularies for the rye flours and baked sweet goods. To understand the potential use of swidden rye in products and consumers liking of these, a hedonic test and a consumer focus group were conducted for the baked sweet goods. Fig. 1 shows an overview of the study.

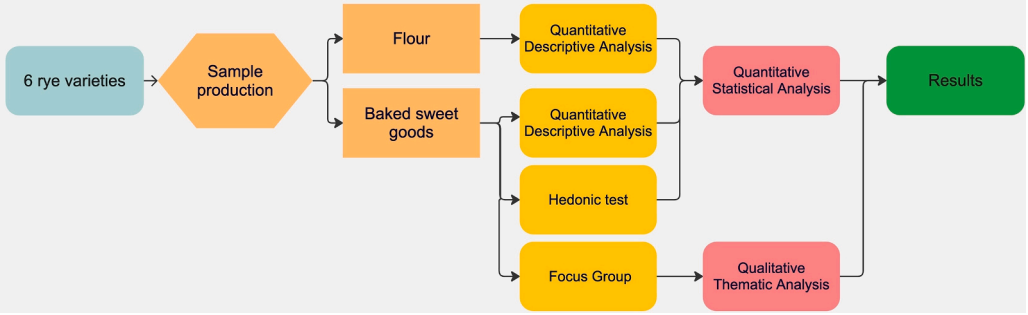


Fig. 1. A flowchart detailing the different steps of the study starting from the material used, sample production, sensory analyses, data analysis, and results.

2.1. Materials

2.1.1. Rye varieties

The study included six varieties of rye: five varieties of swidden rye from five different farms using organic farming methods in Sweden and one conventional variety from Sweden as reference (Kungsörnen, Sweden). Table 1 shows the included varieties, their code used throughout the study, seeding time, agricultural production system, and farm/field location. The five different swidden rye varieties were harvested, dried, stored, and cleaned at each farm. They were stored at room temperature prior to analysis. The conventional variety was purchased from a grocery store. All varieties were milled to flour at the finest setting using Fidibus XL KoMo stone mill (Austria). The unsifted flour used for the hedonic test and focus group was stored in a freezer at −18 °C for a maximum of 1 month until the day of sample production.

2.1.2. Flour samples

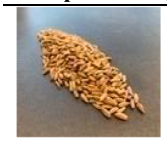
The flour samples were prepared from the six rye varieties in four steps based on a method developed by Starr et al. (2015) with some slight alterations (Table 1). In the first step, boiling water was added to the whole-meal rye flour under constant whisking in a stainless-steel bowl using an electric mixer until homogenised. Boiling water was added in order to deactivate the amylases in the flour to prevent the enzyme from breaking down the starch into sugars during heating. Secondly, a Rational oven (SCC101, Germany) was set at full steam and 130 °C, the samples were covered with aluminium foil and placed in the oven for 25 min. Thirdly, the samples were re-stirred to ensure homogenous samples and prepared in triplicates and put into 10 g servings in plastic cups with lids marked with a three-digit code. In the fourth and final step, the samples were tempered in a heating cabinet set at 40 °C for 90 min before serving. Table 1 provides a recipe summary for producing one sample batch of 30 samples.

2.1.3. Baked sweet goods samples

The baked sweet goods samples were prepared from the six rye varieties in triplicates. Sugar and room tempered butter were mixed in a Bjørn Teddy Varimixer (M0058301Z, Denmark) at the second speed for five minutes. Next, the whole-meal rye flour was added and mixed for four minutes at the second speed. The edges of the mixing bowl were scraped to ensure homogenization and mixed again for four minutes at the second speed. The dough was placed on plastic wrap and rolled to a thickness of 0,7 cm in a rectangular shape and placed in a fridge at 4 °C

Table 1

Field origin, flour processing and cookie formulation for the six Swidden-rye samples. Top block: sample details, visualised by kernel photos, code, seeding time, type of farming system, and geographical location of the farm in Sweden. Middle block: flour-batch production details for approximately 30 test portions per batch, with literature source. Bottom block: cookie recipe derived from each flour—ingredient for a 24-cookie batch, with literature source.

Sample Codes, Seeding System, Sowing Time & Location					
					
D2 Midsummer Organic Skåne	E Autumn Organic Småland	T Midsummer Organic Hälsingland	F1 Spring Organic Dalarna	G Midsummer Organic Uppland	KONV - Conventional Sweden

Flour Sample					
Rye Flour	Water	Milling degree	Oven setting	Tempered	Reference
100g	400g	Fine	130°C 25 min Full steam	40°C 90 min	Starr, 2015

Baked Sweet Good Sample							
Rye Flour	Butter	Sugar	Milling degree	Shape	Weight	Oven settings	Reference
165g	125g	25g	Fine	Circle 4*0,7cm	11-13g	180°C 8 min Reduced wind	Davidov, 2012; Devisetti, 2015

for two hours. After, the baked sweet goods were shaped with a circular cutter (Devisetti et al., 2015). Each batch created 24 samples. To minimize any effect of tray location during baking, a randomised placing was performed. They were baked in a Rational oven (SCC101, Germany) at 180 °C for eight minutes at a reduced wind speed (Davidov-Pardo et al., 2012) and after left to cool to room temperature (21±2 °C) (Devisetti et al., 2015). The samples were placed in plastic bags with butter paper in-between to prevent gain of moisture (Davidov-Pardo et al., 2012) and stored in room temperature (Arifin et al., 2010) for three to five days before serving. For the evaluations one piece of sweet baked goods were placed in a plastic cup with a lid marked with a three-digit code. Table 1 provides a recipe summary for producing one sample batch of 24 samples.

2.2. Methods

2.2.1. Ethical considerations and prior informed consent

The study has followed and considered the Swedish Ethics Review Act, applying to all research carried out in Sweden and to research that gathers sensitive personal data. All participants in the study were provided verbal and written information about; the purpose of the study; how the data was to be used and handled; and that they were free to withdraw their participation at any time without providing a reason. None of the data collected can be used to either identify or trace any participant. The study focused on questions about food opinions that are not classified as sensitive data according to the Data Protection Ordinance.

2.2.2. Analytical sensory assessments: flour & baked sweet goods

Quantitative Descriptive Analysis was used. The first step was to generate a descriptive vocabulary for appearance, aroma, flavour, and texture for both sample groups according to ISO 11132:2021 (Swedish Institute for Standards, 2021). A panel of five trained panellists from Kristianstad University's sensory panel participated, they were selected according to ISO 8586:2023 (Swedish Institute for Standards, 2023) and had undergone sensory training and regularly participated in sensory evaluations. The same procedure described below was used for evaluating both the flour samples and the baked sweet goods samples.

During two training sessions of two hours each, the panel was encouraged to familiarise with the samples and generated a descriptive vocabulary used during the evaluation session (see Table 2). The first session focused on generating a descriptive vocabulary through individual tasting and group discussions to form consensus on terminology, this was done through repeated tastings using three of the flour and baked sweet goods samples as reference. The second session focused on assessing the samples on a scale. The panellists went through all descriptive word generated during the first session and discussions were moderated for certain attributes to ensure a consensus. The session was concluded when a consistent evaluation and consensus of the descriptive vocabulary was achieved.

The sensory evaluations were conducted in a sensory laboratory, equipped according to ISO-8589:2010 (Swedish Institute for Standards, 2010) and situated at Kristianstad University. The analyses were performed using EyeQuestion® (Version 5.0.7.11. The Netherlands). To neutralise the senses neutral crackers and water were served, and for the baked sweet goods evaluation also sliced cucumbers as an additional palate cleanser (Akonor et al., 2017). Each sample was served in a sealed plastic cup marked with a three-digit code. The flour and baked sweet goods samples were served monadically in triplicates in a balanced and randomised order. All attributes were assessed on an unstructured line scale anchored at 10 %=weak to 90 %=strong (Lawless and Heymann, 2010).

2.2.3. Hedonic assessments: baked sweet goods

The hedonic analysis was conducted to investigate the degree of liking of the baked sweet goods. The analysis was conducted in a separate part of a restaurant closed off with curtains after lunch service in Sundsvall, Sweden. The analysis was designed following recommendations about recruitment and execution (ISO 11136:2014; Swedish Institute for Standards, 2014) using a mixed recruitment approach: prior and on-site, that is, either by poster invitations in the building where the restaurant is located and prior booking or by drop-ins during advertised hours with the goal of recruiting 70–80 consumers. The inclusion criteria were being 18 years or older, consuming products containing

Table 2
Descriptive vocabulary generated and used for sensory evaluations of flour and baked sweet goods samples. They are presented according for appearance, aroma, taste/flavour, and texture for both sample groups according to attribute, abbreviation, and definition.

Flour samples	Attribute	Abbreviation	Definition
	Aroma		
	Rye	ARye	Intensity of rye aroma
	Honey	AHoney	Intensity of honey aroma (late summer potent aroma)
	Freshly baked	Afreshly baked	Intensity of a freshly baked whole meal bread aroma
	Almond	AAlmond	Intensity of almond aroma
	Appearance		
	Golden	APGolden	Intensity of golden appearance
	Grey	APGrey	Intensity of grey appearance
	Particles	APpartiples	Intensity of visible particles
	Texture		
	Firmness (Hand)	TexFirmness (Hand)	Intensity of firmness texture when hand scoping sample
	Firmness (Mouth)	TexFirmness (Mouth)	Intensity of firmness in mouthfeel
	Gluey	TexGluey	Intensity of gluey texture
	Gritty	TexGritty	Intensity of gritty texture
	Taste/Flavour		
	Rye	FRye	Intensity of rye flavour
	Sweetness	TSweetness	Intensity of sweetness
	Sourness	TSourness	Intensity of sourness
	Umami	TUmami	Intensity of umami
	Bitterness	TBitterness	Intensity of bitterness
Baked sweet good samples	**Aroma**		
	Rye	ARye	Intensity of rye aroma
	Oats	AOats	Intensity of oat aroma
	Syrup	ASyrup	Intensity of syrup aroma
	Browned butter	ABrowned butter	Intensity of browned butter aroma
	Appearance		
	Grey	APGrey	Intensity of grey appearance
	Golden	APGolden	Intensity of golden appearance
	Cracking	APCracking	Degree of cracking
	Light particles	APLight particles	Amount of light particles
	Taste/Flavour		
	Roasted Nutty	FRoasted Nutty	Intensity of roasted nutty flavour
	Rye	FRye	Intensity of rye flavour
	Oats	FOats	Intensity of oat flavour
	Butter	FButter	Intensity of butter
	Sweetness	TSweetness	Intensity of sweetness
	Salt	TSalt	Intensity of salt
	Texture		
	Degree of milling/ grinding	TexDegree of milling/grinding	Degree of milling/ grinding (finer and coarser particles)
	Oiliness	TexOiliness	Intensity of oiliness (greasy feeling)

gluten and lactose, and regularly consuming baked sweet goods. A 7-point hedonic scale ranging from 1= "Dislike very much" to 7= "Like very much" was used.

The software EyeQuestion (Version 5.0.7.11., the Netherlands) was used for the data collection. The consumers were given instructions on how to conduct the test both verbally and written. The six samples were served simultaneously in a randomised order in sealed plastic cups with a three-digit code along with still water, neutral crackers, and sliced cucumbers. Each consumer answered demographic questions and were asked to indicate their degree of liking for each sample. Table 3 provides the questionnaire used.

2.2.4. Focus group: baked sweet goods

The focus group was conducted to retain deeper insights into consumers' preferences and use of descriptive words, and to bridge any potential gap between the analytical and the hedonic analysis. The focus was on generating descriptors for the samples to increase the understanding of how consumers perceived descriptive words, and which samples and descriptors generated higher or lower liking. Participants were recruited via the hedonic analysis, where they were informed about the focus group and could register their interest. The goal was to recruit six to ten participants recommended for consumer focus groups (O'Sullivan, 2020). In total, six participants were included in the focus group, which was conducted at the same location as the hedonic analysis.

The focus group session was divided into four parts, (1) Introduction, (2) Sample descriptors without tasting, (3) Sample description with tasting, and (4) Sample attribute liking (Supporting Information 1) (McNeill et al., 2007). A flip chart was used to guide the session, direct the participants' attention, and for note taking. After the introduction the participants were encouraged to unaided generate words to describe baked sweet goods and discuss which they perceived as negative versus positive. The participants were then presented with all six samples simultaneously in a randomised order in plastic cups marked with three-digit codes, a pen, paper, still water, neutral crackers, and sliced cucumber. First individually and later in open discussions they were asked to describe the different samples' colour, appearance, and aroma before tasting. After the participants tasted the samples, textures and flavours were discussed. Finally, discussions were focused on which attributes were most and least important, ranking the samples according to liking while discussing which attributes made them rank the samples the way they did. The audio was recorded and the flip chart and participant notes gathered.

Table 3
Questionnaire used for the hedonic assessment of the baked sweet goods.

Questions	Options
Age	18–29, 30–39, 40–49, 50–59, 60+
How often do you consume baked sweet goods?	Daily, Weekly, Monthly, More Rarely
What gender do you identify with?	Male, Female, other, do not want to answer
Please indicate your degree of liking for cereal aroma	1= "Dislike very much" to 7= "Like very much"
… overall aroma	"
… color appearance	"
… overall appearance	"
… nutty taste	"
… cereal taste	"
… overall taste	"
… texture	"
… overall liking considering aroma, appearance, taste, and texture	"
Is there anything you would like to add about the sample you have just tried?	Open-ended non-mandatory

2.2.5. Data analysis

Statistical analyses have been conducted on data gathered from the analytical and hedonic evaluations. The data from the descriptive analysis was converted into numbers, where the scale equalled 0–100. The data from all three evaluations were analysed in EyeOpeneR (Version 5.0.7.11, Eye Question, The Netherlands). Descriptive statistics were calculated, and a two-way ANOVA with Tukey's post-hoc HSD (Honestly Significant Difference) was performed, the significant level was set at $p < 0.05$. For the two Quantitative Descriptive Analyses, a principal component analysis (PCA) was performed using mean values to analyse what attributes related to each sample using EyeOpeneR®. For the hedonic analysis the raw data was first analysed in Microsoft Office Excel to ensure that none of the consumers used the hedonic scale in a repeated manner. Since only a few comments were provided in the open-ended section and since they did not provide further information to what had already been obtained, the section was excluded from the analysis.

The focus group data were analysed through a reflexive thematic analysis with an abductive approach, where interpretations and analysis are shaped by empirical and theoretical reflections (Alvehus, 2019). When conducting a reflexive thematic analysis, the researchers firstly familiarise themselves with the material to interpret what it contains and then formulates codes based on their interpretations of different paragraphs (Braun et al., 2022; Byrne, 2022). Furthermore, these codes are used to construct distinct themes that represent the various narratives present in the material. The purpose of reflexive thematic analysis is not to report what has been said in the focus group, but to interpret and synthesise it, allowing narratives to emerge from the collected material (Clark et al., 2021; Braun et al., 2022).

The data, consisting of the session recording, was transcribed, and the participants and flip-chart notes were compiled. The combined data was read repeatedly to gain a deep understanding of the material. Through rereading, specific segments of the text were marked and assigned an initial code, which represented an interpretative meaning or was more descriptive in nature. When all the data had been coded, 34 codes with corresponding quotations were assembled and assigned an individual colour. The codes that shared a common theme, according to the author's interpretive analysis, were grouped. Similar codes were merged. The process was repeated until 21 codes remained. Following a reflexive thematic analysis, the codes were clustered and grouped to form distinct themes. Three themes were developed and given a clear name to capture their essence. Analytical decisions on which codes were grouped under each theme were based on the authors' interpretations of the codes' meanings.

3. Results

3.1. Descriptive sensory analysis of the flour

As shown in Fig. 2, four out of 16 assessed attributes showed significant differences ($p < 0.05$) between samples: golden appearance, visible particles, the texture of firmness in mouthfeel, and gritty. Further, Fig. 2 shows the mean values and standard deviations for all assessed attributes (Supporting Information 2). The most notable differences were found in appearance and texture. It can be noted that no differences in rye aroma or flavour were noted between samples.

The golden appearance was significantly higher in samples T and G than in KONV. Visible particles were significantly the most notable in samples E, G and F1 in comparison to samples T and KONV. The firmness mouthfeel was significantly the highest in sample G, compared to KONV and D2.r. Sample F1 had a higher firmness than sample KONV but not D2. The texture attribute gritty was assessed as most intense in sample G, significantly more intense than samples T and KONV. The difference was also observed for sample E, which also had a gritty texture.

The PCA Biplot in Fig. 3, explains more than 70 % of the variation in the resulting data. Three clusters were observed, each characterised by

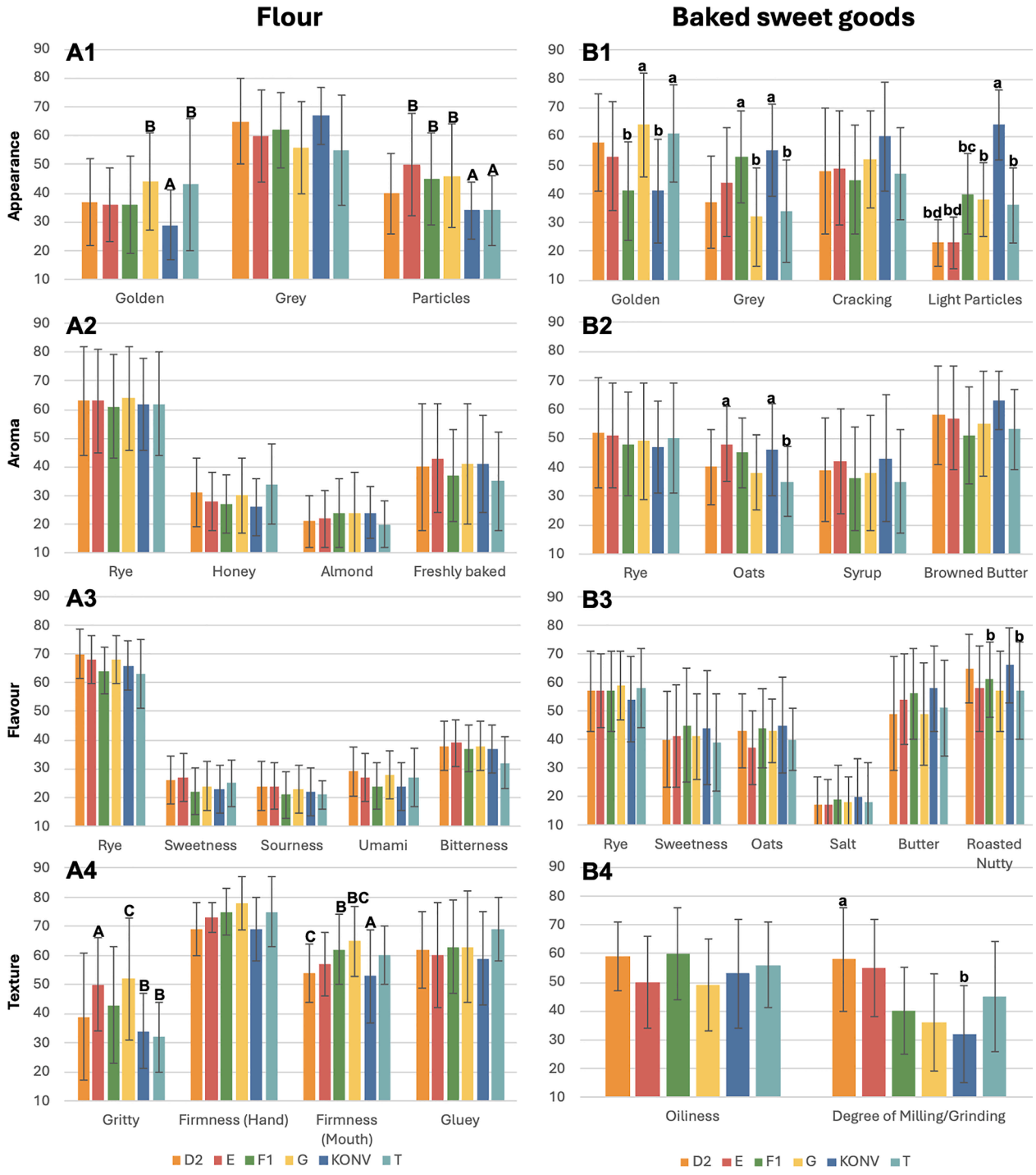


Fig. 2. Sensory profiles of Swidden-rye flour (A1–A4) and baked sweet goods (B1–B4).
Panels are grouped by modality: appearance (1), aroma (2), flavour/taste (3) and texture (4), (A) flour, (B) baked sweet goods. Bars show the mean intensity ($n = 5$ panellists) ± SD on a 10 – 90 scale (10 = weak, 90 = strong). Sample codes (D2, E, T, F1, G, KONV) identify rye sample. Upper-case letters (A–C) indicate homogeneous groups within flour, lower-case letters (a–c) within baked sweet goods; bars sharing at least one letter do not differ significantly (Tukey HSD, $p < 0.05$).

different sensory attributes. The first includes samples G, E, and D2, the second KONV and F1, and the third T. Samples KONV and F1 show a grey appearance and almond aromas. Samples G, E, and D2 are associated with rye and freshly baked aromas, the taste of umami, sweetness, and sourness as well as rye flavour, and a gritty texture with particles. Sample T lies in the upper left quadrant and is associated with a golden appearance and a firmer texture for both hand and mouthfeel as well as a gluey texture.

3.2. *Descriptive sensory analysis of baked sweet goods*

Six out of 16 assessed attributes showed significant differences between the samples: oats-aroma, grey appearance, golden appearance, amount of light particles, nutty flavour, and degree of milling. Fig. 2 shows mean values and standard deviations. The most notable differences were found in appearance, texture, and aroma.

Samples KONV and E had a significant higher intensity of oat aroma than sample T. Further, samples KONV and F1 were perceived to be

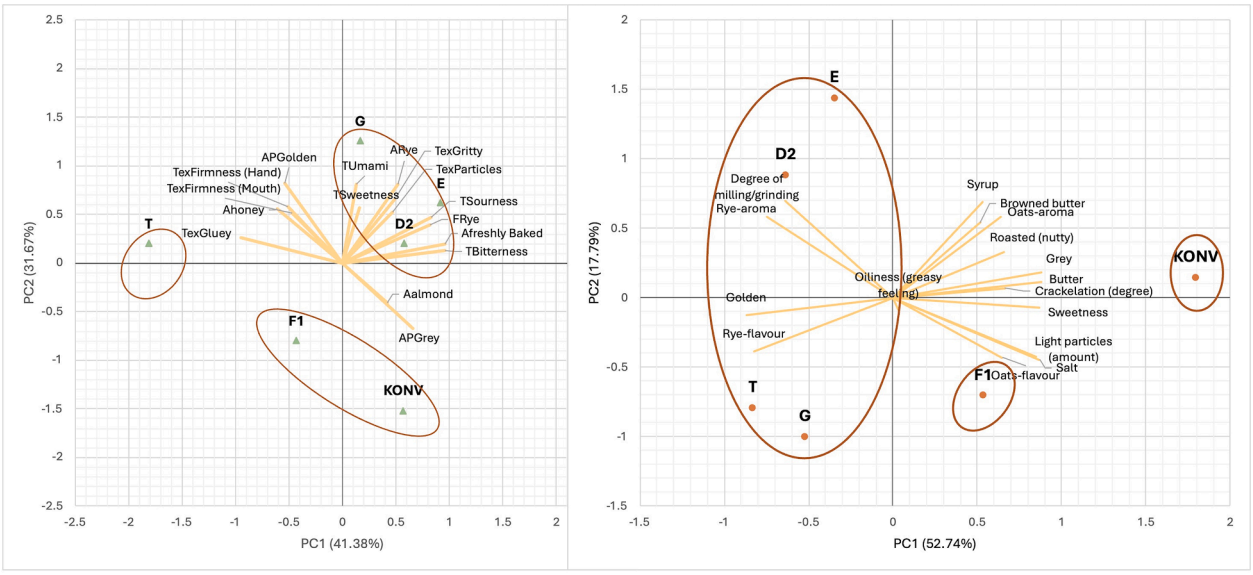


Fig. 3. Principal-component analysis (PCA) of the descriptive-sensory data.
(A) Flour samples (B) Baked sweet goods samples. Sample codes (D2, E, T, F1, G, KONV) are plotted as orange symbols; sensory attributes are shown as yellow loading vectors. Ellipses highlight the natural clustering of samples. The first two principal components (PC1 × PC2) explain 41.38 % + 31.76 % = 73.1 % of the variance for flour (panel A) and 52.74 % + 17.79 % = 70.5 % for baked sweet goods (panel B).

significantly greyer than T and G which were assessed to be more golden. The amount of light particles varied among the samples, and sample KONV had nearly twice the intensity of light particles compared to all other samples. However, light particles also occurred insample F1 whichwas a significantly highet content than what could be found in D2 and E. As for flavour, sample KONV had a significantly higher intensity of roasted nutty taste than T and G. Lastly, for texture and the attribute degree of milling, sample D2 had higher intensities than KONV.

The PCA Biplot in Fig. 3, shows more than 70 % of the variation of data and the samples divided into three clear clusters, the first cluster included samples E, D2, T, and G, the second consisted of KONV, and the third of F1. Sample KONV lies furthest away from the other samples on both PC1 and 2, indicating its uniqueness. However, KONV is closest to sample F1, and both these samples are associated with similar appearance attributes; grey, a higher degree of cracking, and light particles. Samples E, D2, T, and G are associated with the attributes golden, degree of milling, and rye aroma and flavour.

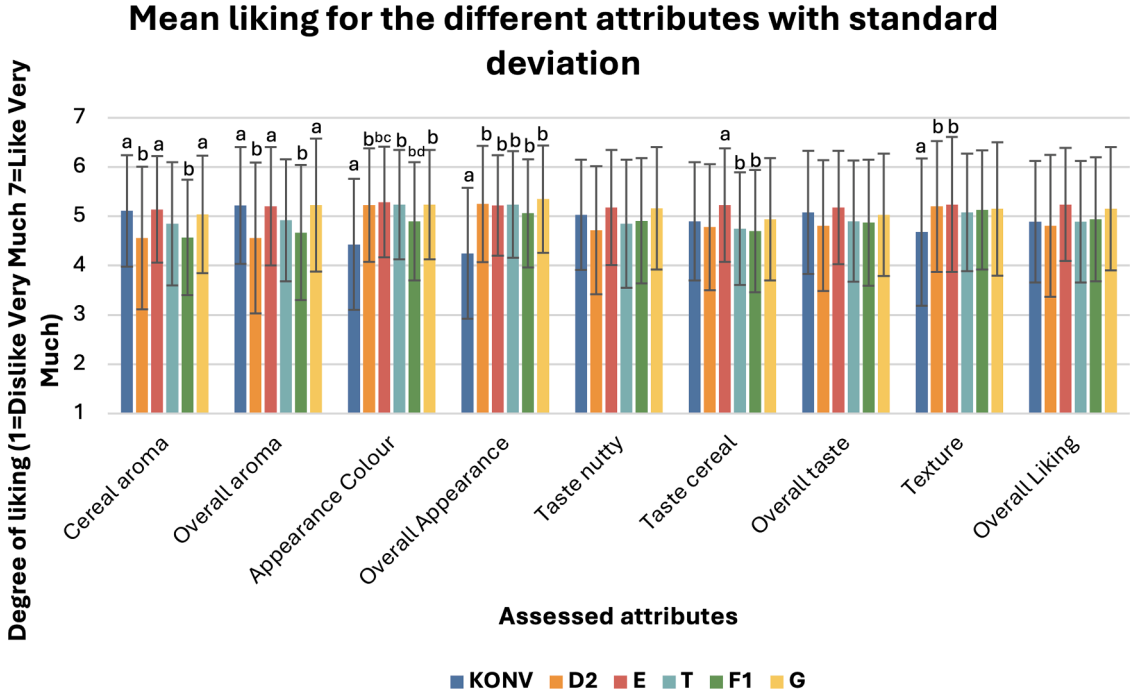


Fig. 4. Mean liking of the assessed attributes for the assessed baked sweet goods samples with bars indicating standard deviation for each sample. With the scale ranging from 1=Dislike very much and 7=Like very much. Lower-case letters (a–d) indicate homogeneous groups within baked sweet goods; bars sharing at least one letter do not differ significantly (Tukey HSD, $p < 0.05$).

3.3. Hedonic analysis of baked sweet goods

For the hedonic analysis 79 out of 82 consumers completed the full questionnaire. Data from uncompleted questionnaires were excluded from the analysis. The distributions of age and gender were even and most consumers ate baked sweet goods on a weekly or monthly basis.

The liking of the baked goods is shown in Fig. 4 as means and standard deviations for each sample. Significant differences between samples were found for the liking of cereal aroma, overall aroma, colour, overall appearance, cereal flavour, and texture. Notable differences in liking were observed between the sample with conventional rye and the swidden rye samples. Also, differences among the samples with swidden rye were found. Overall, all samples scored a mean liking on the positive side of the scale for all attributes, indicating high acceptance among the consumers.

Samples KONV and E attained the significantly the highest liking among the samples for cereal aroma. Sample G also attained a higher mean liking for cereal aroma than D2 and F1. For the attribute overall aroma, samples KONV, E, and G received the highest liking, significantly higher than D2 and F1. Concerning appearance, sample E was ranked to have the highest liking for colour, while KONV was rated for lowest liking for its colour. For overall appearance sample G had the significant highest liking score while KONV had the significantly lowest scores. For cereal flavour, E was significantly higher liked than T and F1. For the liking of texture, samples D2, E, and G received the highest liking and KONV the lowest.

For overall liking, the consumers were asked to consider the whole sample: aroma, appearance, flavour, and texture. Although no statistical differences, samples E and G received the highest mean liking.

3.4. Focus group baked sweet goods

Initially, 34 codes were developed which were later reduced to 21 during the analysis and supported three overarching themes. The three themes *Sensory Experiences, Interplay of attributes and personal preference* and *Meaning of words* are presented in the text below. In Fig. 5, example quotes from each theme are presented. All quotes have been translated from Swedish into English.

The first theme, *Sensory Experiences*, captures descriptive words used by the focus group, which words they perceived as negative or positive for describing baked sweet goods, and their overall liking of them. There were several similarities between the words used by the participants and the descriptive vocabulary developed by the analytical panel. All the baked sweet goods samples were liked by the focus group participants. The sweetness of the samples was not perceived as high, and the samples were overall perceived as buttery, roasted, caramel, and cereal tasting. Participants saw them as a good choice for Swedish "fika" and, by some, also as a small snack. During the session, there was much focus on colour, flavour, and texture attributes where the participants had different opinions, whereas they were more in agreement regarding aroma attributes. Flavours were often described as products, such as sourdough, crispbread brands, or breakfast cereals. It showcases that everyone is affected by previous experiences and references for some flavour characteristics, indicating the importance of using words in sensory descriptions that relate to consumer experiences.

The second theme, *Interplay of attributes and personal preference*, shows how appearance, aroma, texture, and taste interact and that it is highly personal what determines a higher liking for a product. The appearance of the samples provided the consumers with expectations about the texture and was often described with textural attributes. The attributes used to describe textures also created expectations of whether a specific sample would be tasty. Showing that appearance descriptions was important for creating textural expectations and texture descriptions for setting flavour expectations. Regarding aromas, samples described with negative attributes were also expected to be less tasty and vice versa. However, the focus group also highlighted that some negative attributes could be compensated for by other positive ones; for example, a blander sample with a nice texture was seen as a good sample where one attribute compensated for the other. Personal preferences were discussed several times during the session, where the participants preferred certain attributes more than others, and also perceived them slightly differently. Even so, they could, with the help of each other and by using different descriptive words, point them out to each other. Showing that descriptions are vital for expectations and that one can perceive some attributes more clearly if they are described in an accessible way.

The third theme, *Meaning of words*, ties into the two previous themes to some extent but highlights how, and in what context, the words used

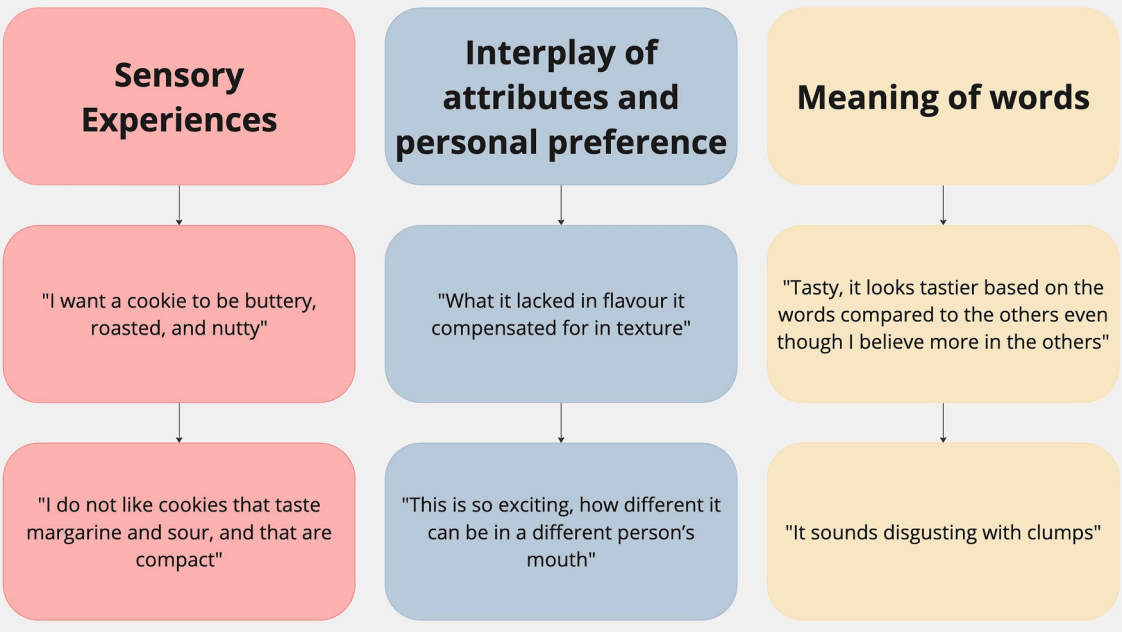


Fig. 5. The three themes derived the reflexive thematic analysis of the focus group are shown in red, blue, and yellow on the first row followed by two example quotes from the consumers corresponding to each theme and shown in the same colour.

influenced the focus group's perceptions. For example, some words were only perceived as positive for describing the samples in this study. The focus group indicated that those words could be perceived as unfavourable in a different context and vice versa. Some words were perceived as negative descriptors, and the participants in the focus group referred from using those, such as vapid and instead suggested words as bland or mild for describing sensory intensities. Clumps was another such word, where synonyms such as spotty and sandy appearance were perceived as more positive. Showing how descriptive vocabularies and accurate sensory descriptions set expectations and creates a positive perception. This could be seen by the end of the session, where more complete descriptions for each sample had been developed, which could almost change the preferences of the focus group participants, since they thought some sounded tastier from the description than they had ranked them according to their overall personal liking.

4. Discussion

4.1. Sensory characteristic of swidden rye flour and baked sweet goods

The results from the descriptive sensory analysis illustrated different sensory profiles of the swidden rye flours. In line with this study, it has previously been shown that different landrace cereals have different sensory qualities (Starr et al., 2013) and this study adds to understanding the complexity and sensory qualities of the landrace swidden rye grown at different sites in Sweden. Broadly all samples could be described as having a rye aroma and flavour, a grey to golden appearance, a firm texture, and a slight bitter taste. When evaluated as flour, significant differences could be detected only among the samples for appearance and texture attributes. However, when adding ingredients such as butter to the baked sweet goods, more attributes were identified and, significant differences for a number of appearance, texture, and aroma attributes were found. The change in perception and aroma intensities can be explained by the change of polarity in the food matrix making more aromas available (Garvey et al., 2020) and is a useful knowledge for the development of products and recipes based on flour from swidden rye. As an example, the flour samples were assessed according to the flavour attribute rye, sweetness, sourness, umami, and bitterness, while the baked sweet goods were evaluated for the flavours of roasted nutty, rye, oats, butter and the tastes sweetness and salt. Indicating that the bitterness, sourness, and umami of the flour samples were muted in the baked sweet goods while butter, oats, and roasted nutty flavours became prominent. Different preparation and cooking techniques may also significantly impact sensory characteristics, especially flavours and texture (Kissing Kucek et al., 2017). For the swidden rye samples the differences in flavour attributes in the descriptive sensory analysis were not significant for the flour samples but for the baked sweet goods samples significant differences were detected in both the analytical and hedonic analysis. This indicates that differences could be connected to the preparation and cooking techniques employed, in this study boiling vs baking which is in line with the findings of Kissing Kissing Kucek et al. (2017).

In previous studies on conventional rye, bitterness is often present and associated with a lower consumer liking (Heinio et al., 2016). In this study the swidden rye landrace varieties were less bitter than the conventional one which seem to have contributed to the higher consumer liking. In the flour samples, bitterness was present in varying degrees in both the conventional and the swidden rye samples. However, for the baked sweet goods, bitterness was not included in the attributes generated during training of the analytical panel, indicating that no bitterness was perceived in the baked goods. One possible explanation is that the added sugar and butter reduced the bitterness found in the flour, in line with Heinio et al. (2016). As mentioned above, both sugar and butter are known for enhancing and changing sensory properties of foods (Goldfein and Slavin, 2015; Rapp et al., 2007). Sugar enhance aromas and contribute to a higher palatability (Goldfein and Slavin, 2015). Butter can both enhance and decrease perception of flavour attributes and affect texture depending on amounts added (Kähkönen et al., 1995; Rapp et al., 2007). Just by adding small amounts of sugar, overall aromas and flavours can be enhanced which seems to be the case for the baked sweet goods (Goldfein and Slavin, 2015) where the bitterness decreased and other flavours were enhanced.

4.2. Consumer liking of baked sweet goods

It has been argued that landrace varieties can contribute with new and exciting gastronomic potential in different products (Westling et al., 2019). Adding to that, our results show swidden rye's rich sensory potential, which can be useful for deciding in which products it can be used and how the characteristics can change in a product. Results from earlier sensory studies on emmer, spelt, and millet have achieved both tasty and liked products with high nutritional values (Zamaratskaia et al., 2021). Our study showed that the swidden rye samples were liked by the consumer group. The participants in the focus group also expressed a high liking of the baked sweet goods, and suggested it to be consumed as "fika" or as smaller snacks. The results further build on those observed by Wendin et al. (2020) who showed that Swedish consumers were interested in consuming landrace cereals in a range of products. From this study it is clear that consumers remain willing and positive toward products with landrace cereals after testing them.

Overall, the hedonic analysis showed a high liking of all attributes assessed across samples. However, the conventional sample used as reference received the lowest liking score observed for appearance and was significantly different from the other samples with a greyer appearance, with more cracks, and more light particles. However, in other assessed attributes, such as cereal aroma and nutty taste, the conventional sample received a similar liking as the swidden rye samples. One could assume that the conventional sample should have gotten a lower overall liking score given that appearance showed to influence expectations and liking of samples. Using other quantitative methods, such as CATA or regression analysis (Lawless and Heymann, 2010), could have uncovered some of these preference relationships. However, according to the insights from the focus group, what a sample lacked in one attribute could be compensated for by others. The conventional sample did receive high likings for aroma attributes, indicating that these might have compensated for appearances and contributed to the overall liking. In an earlier study, one identified barrier for increased consumption among alternative staples as rye were sensory attributes relating to taste, appearance, and aroma (Shah et al., 2021). The high consumer liking for all samples, and most consistently across attributes for the swidden rye samples, shows that swidden rye could possibly be a good option for increasing consumers' willingness to consume rye products.

4.3. Differences among the swidden rye samples and future potential

Although, many differences were found between the conventional rye sample and the swidden rye samples, the results consistently showed significant differences among the swidden rye samples across all performed analyses. Apart from the influence of added ingredients, other studies have shown impact on landrace cereals sensory attributes from harvest year and weather impacts (Korczyk-Szabó and Lacko-Bartošová, 2013). In our study, these aspects could possibly explain the variation found among the swidden rye samples given that they were cultivated at different farms distributed geographically across Sweden. In other studies, on cereals, climatic variations, agricultural practices, place, and genetic diversity have shown to influence the nutritional values (Boukid et al., 2018; Hidalgo and Brandolini, 2016; Miranda et al., 2011). Results from this study indicated that these aspects also could have influenced the sensory attributes in line with the concept of terroir. Terroir is a French concept often applied to wine, which explains the relationship

and influence of environmental, geological, and geographical aspects on sensory attributes.

The cultivation of swidden rye in Sweden has recently been highlighted by Ortman et al. (2023) who showed that is has gained popularity among farmers since farmers associated it with good intercropping capabilities, it has traits that aid weed management, and it requires less fertilisers and ploughing. The study also showed that the motivation for cultivating landrace cereals in Sweden generally related to agronomic traits and that they are well suited for niche markets that provide economic incentives for farmers (Ortman et al., 2023). It connects to the increased interest among consumers for eating landrace cereals (Wendin et al., 2020). Given this, there is a need for further studies on landrace cereals sensory characteristics, their application in products, and consumer preferences to these (Aschemann-Witzel et al., 2019; Asioli et al., 2014). The results from this study provide additional knowledge on one landrace cereal cultivated in Sweden, highlights consumer appreciation, and showcased sensory characteristics that were perceived as positive by focus group participants. This could further strengthen farmers motivations for increased cultivation of swidden rye and other landrace cereals.

5. Conclusion

This study investigated sensory aspects, analytical and hedonic, of swidden rye. Significant differences were found among the samples when evaluated as flours and baked sweet goods. By adding butter and sugar the sensory characteristics and their intensities changed. Enhancing sweetness, nuttiness, and buttery notes and muting the flours' bitterness. A high consumer liking was found for all samples. The differences found among the swidden rye varieties could be explained by their different origins, climatic differences, or agricultural practices.

The results may be beneficial when using swidden rye in food products. The results highlight the sensory potential and consumer liking of swidden rye, and offer further motivation for farmers to increase production. In line with the growing interest in landrace cereals, the study provides valuable insights of swidden rye's sensory aspects that can inform and contribute to future product development. Further, future studies could aim to determine if and how terroir influences and relates to the differences found in sensory attributes.

Ethical statement

According to the Swedish Ethics Review Act (SERA) (Swedish Ethical Review Authority, 2003) ethical approval is not required to conduct a consumer study. Due to this regulation, no human ethics committee was consulted and/or formal documentation process is available. This study includes questions about food perception which, according to the Data Protection Ordinance, are not classified as sensitive personal data. According to the General Data Protection Regulation, none of the responses to the questionnaire used in this study include information that can be traced to or used to identify any individual. All participants received written information about the test and gave their informed consent to participate. Additionally, the participants could withdraw from the survey at any time without giving a reason.

CRediT authorship contribution statement

A. Jonsson: Writing – review & editing, Visualization. **K. Gerhardt:** Writing – review & editing, Project administration, Funding acquisition. **J. Andresen:** Writing – review & editing, Resources, Project administration, Methodology, Conceptualization. **K. Wendin:** Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Investigation, Formal analysis.

Declaration of competing interest

There are no conflicts of interest.

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Data availability

Data will be made available on request.

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