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Historical grains in modern gastronomy: A case study of artisan breads

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ABSTRACT

While modern wheat has been bred for improved yields and baking properties, heritage cereals have recently gained increased recognition for their nutritional profiles and resilience towards climate change. This increased interest in heritage cereals calls for deepened understanding of their sensory attributes and consumer acceptance. Hence, this study evaluated bread based on two heritage wheats (Öland and Källunda) and a modern wheat mix by the means of quantitative descriptive sensory analysis ($n = 8$) and consumer liking ($n = 47$) using a 9-point hedonic scale. The sensory profiles of the three breads were similar, with differences mainly in the crust's brownness, roasted odor, chewiness, and hardness. These differences were not linked to whether the wheat was heritage or modern. Overall, consumers gave positive scores for the crumb and crust of all three bread types: Öland (6.38 and 6.87), Källunda (6.53 and 6.19), and Modern (6.26 and 6.49). Among all participants, 68.1 %–85.1 % gave positive scores for the breads. Öland wheat crust was better liked than crust from Källunda wheat, which related to less roasted odor, brown appearance, chewy and hard textures. The study's implications for gastronomy includes that heritage wheat can be used like modern varieties without impeding sensory quality, making them versatile for various foods and cuisines.

1. Introduction

There is current interest in foods based on heritage grains, and breads baked with these grains are considered as both healthy and sustainable. A study by Wendin et al. (2020) on consumers' awareness, attitudes and preferences towards heritage cereals reported that bread and pasta are the most consumed cereal-based products among Swedish consumers. These products were also regarded as the most potential products to receive consumer acceptance if based on heritage cereals. Among the participants in the study, as many as 98.4 % would consider purchasing bread products based on heritage cereals. Therefore, present study evaluates this interest further by comparing the sensory profiles and consumer acceptance of bread based on heritage (Öland and Källunda) and modern wheat. It has previously been shown that cereal origin and health aspects are of importance, as well as descriptions such as ancient, natural, organic, old variety, heirloom, local or wholegrains have a highly favorable influence on the consumer acceptance (Zamaratskaia et al., 2021). However, the most important attributes for bread acceptance are taste and flavor, followed by freshness and texture.

Hence, the sensory aspects of a food product play a major role in its acceptance. More or less all wheat products can be described by sensory attributes such as sweet, bitter, and oat porridge. However, variations in intensity and perception of taste and aroma attributes are observed within and between different species (Kissing Kucek et al., 2017; Starr et al., 2013). Similar to taste, differences in perceived texture and mouthfeel characteristics may differ both within and between species. These differences can be caused by factors such as genotype, environment, and by milling interactions influencing quality of the wheat (Kissing Kucek et al., 2017). On the other hand, bread based on Kamut® khorasan flour showed sensory properties and loaf volumes very similar to bread made using modern wheat (Pasqualone et al., 2011). More studies on sensory characteristics of heritage cereals in relation to modern varieties are needed to understand consumers' attitudes and the future for heritage cereals in more resilient food production systems.

Today, food production is threatened by climate change, damaged ecosystem services, and loss of wild and domesticated diversity. Six crops (rice, wheat, corn, potato, soybean, and sugarcane) share more than 75 % of total plant-derived energy intake (Singh et al., 2022), where wheat is dominating together with corn and rice. Modern wheat is a result of continued scientific breeding from ancient wheat species,

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which includes emmer, einkorn, Khorasan wheat (Oriental wheat), and spelt. Unlike modern wheat, heritage wheat has not been subjected to breeding processes, and hence comprise the ancient species and their naturally and humanly selected varieties. Landraces (local heritage varieties) are dynamic populations of cultivated plants with historical origin and distinct identities. They have not undergone formal crop improvement, and are typically genetically diverse, adapted to local conditions, and associated with traditional farming practices (Boukid et al., 2018; Camacho Villa et al., 2005). There are many varieties of heritage wheat today.

Food systems that rely on a few crops and heavy external input have low resilience. Modern wheat varieties can produce high yields under optimal conditions, good water supply, high mineral fertilization input and the use of pesticides. But if these conditions change, caused by external factors or climate change, grain production is at risk. In the extreme heat and drought during 2018, wheat production in Sweden was reduced with almost 50 % (Gerhardt et al., 2019). Similarly, in 2023 initial dry weather was followed by heavy rainfall and inundations, causing a 26 % lower wheat production than an average year (Almqvist, 2024). Using a greater number and diversity of crops including heritage varieties of wheat, with greater genetic variation, is one way to increase the resilience of our food system. Heritage grains have generally less requirements for external inputs, with less need for weeding and high-input fertilizing. In addition, heritage cereals manage to grow on slightly poorer soils than the conventional varieties are able to (Ortman, 2024).

Other characteristics of heritage cereals concern their nutritional aspects. Heritage cereals are reported to contain lower contents of dietary fibers than modern wheat, although large differences between heritage cereal species prevails (Zamaratskaia et al., 2021). Table 1 summarizes the macronutrients of the flour from two heritage wheat varieties, Öland and Källunda, and one modern wheat used in the present study. The contents of minerals, especially zinc, iron and selenium, are most commonly higher in heritage cereals and may well contribute to the daily intake of minerals. Also, several studies have further reported higher total content of phenolic compounds, tocol (vitamin E) and carotenoid (pre-vitamin A) in certain heritage species compared to modern varieties (Dinu et al., 2018; Johansson et al., 2021; Zamaratskaia et al., 2021). While ancient wheat species do contain gluten and, just like modern wheat varieties, can trigger hypersensitivity reactions in celiac patients, research has shown that they released fewer immunogenic peptides after human digestion ex vivo (Asledottir et al., 2020). Hence, the authors concluded that a wider adoption of these ancient wheat varieties could potentially lower the incidence of celiac disease.

In an effort to sensorially describe food products in a more objective way, analytical sensory methodology can be used, for example described by Starr et al. (2013). One of the most used methods is the quantitative descriptive analysis (QDA), in which the most characteristic sensory attributes are defined, and their intensities are measured on a scale. To obtain a fuller picture of consumer perceptions and acceptance, the analytical sensory test may be complemented with an affective test, where the consumer liking is studied in relation to the analytically described sensory attributes (Fiorentini et al., 2020).

This study took the starting point in previous consumer research by Wendin et al. (2020), which showed that the most popular product based on heritage cereals was bread. The aim of the present study was to investigate how bread based on two varieties of heritage cereals are organoleptically perceived and described by an analytical sensory panel and accepted by consumers compared to a modern analogue. Hence, the study aimed to answer the following research question: How do bread based on heritage and modern wheat compare in their sensory profiles and consumer liking?

Table 1
Macronutritional content of the wheat varieties included in the present study. Data is based on previous studies and literature and is reported as g/100 g of flour if not specified elsewise.

	Öland[a]	Källunda[a]	Modern[b,c]
Protein	15.1	15.0	8.5–10
where of gluten	*4.9*	*4.8*	*(80–85 % of protein content)*[d]
Carbohydrates	–	–	72–76
where of fiber	*11.0*	*11.2*	*3.6–11.3*
where of sugars	–	–	*0.7–1.5*
where of starch	*63.7*	*63.2*	*63–72* [d]
Lipids	–	–	1.9–2.5
where of saturated	–	–	*0.3*
where of monosaturated	–	–	*0.2–0.4*
where of polyunsaturated	–	–	*0.8–1.1*

[a] Kernels were milled in a centrifugal mill with a 0.5 mm sieve at 18 000 rpm prior to analysis by Andersson (2022).
[b] Vete Helkorn by Limabacka Kvarn (2024a)
[c] Vetemjöl by Limabacka Kvarn (2024b)
[d] Van Der Borght et al. (2005)

2. Material and methods

2.1. Wheat varieties

In this study, artisan bread baked from two heritage wheat varieties (Öland and Källunda) were compared with a modern wheat flour (Modern). Nutritional data is presented in Table 1. Öland wheat is a landrace (local heritage cereal), derived from spelt (*Triticum spelta* L.), which originate from mid-19th century (Ortman et al, submitted). Källunda wheat is an evolutionary landrace mix evolved from a variety of wheat genotypes enabling the crop to genetically adapt over several years to specific soil and climate conditions (Kristofers et al., 2024). Organic Öland wheat was harvested at Ekhaga (59.8305, 17.8083) and Krusenberg (59.7362, 17.6827) in 2019, and organic Källunda wheat was harvested in Häglinge (55.9973, 13.7006) in 2021. Organic modern wheat (*Triticum aestivum* L.), comprising a mix of varieties, was purchased from Limabacka Mill, in which the largest proportion of grains were harvested from Klockrike (58.4652, 15.3248) and packed in 2022. All varieties were obtained as whole kernels.

Both wholegrain and sifted flour were used in the bread baking. Kernels of the three different wheat varieties were stone-milled (KoMo Fidibus XL, Switzerland) inhouse to obtain wholegrain flour. Parts of the wholegrain flour were subsequently sifted through a sieve for bakeries with 0.5 mm mesh to obtain sifted flour. The wholegrain flour includes the husk parts, while for the sifted flour, the innermost core of the grain has been ground into flour while the husk parts were sifted away.

2.2. Bread preparation

Preparation of the artisan breads was performed in several steps: mixing of poolish (starter dough), pre-fermentation, mixing of dough, autolysis, kneading, maturation, folding, fermentation, and baking.

The poolish was prepared by dissolving the yeast in the water and manually mixing in the wholegrain flour according to the amounts in

Table 2
Ingredient list for the production of bread.

Step	Ingredients	Amount (g per 100 g)
Poolish	Wholegrain flour [a]	16.5
	Water	16.5
	Baker's yeast, fresh [b]	0.0137
Dough	Poolish	All
	Water	27.5
	Sifted flour [a]	27.5
	Wholegrain flour [a]	11.0
	Sea salt, flakes [c]	1.17

[a] Öland, Källunda or Modern flour.
[b] KronJäst, Sweden.
[c] Falksalt, Sweden.

Table 2. The bowl with the poolish was covered with plastic wrap and stored in room temperature (approx. 20 °C) over night (16 h 15 min) allowing for pre-fermentation. Thereafter, the ingredients in Table 2 were manually mixed to prepare the final dough, which was let to rest for autolysis to occur for 40 min, then kneaded by hand, and subsequently matured for 2 h. After 40 min of the maturation process, the dough was folded by hand, before continued resting. Thereafter, the dough was cut into 10 pieces and formed into loafs (approx. 720 g each), followed by the final fermentation at room temperature for 2–2.5 h. Baking was performed in an oven (SelfCookingCenter®, Rational, Germany) at 230 °C for 5 min, then in 200 °C with steam for 23 min, and finally in 175 °C for 8 min to reach a final inner temperature of 97 °C. After cooling to room temperature, the bread loafs were packed individually in sealed plastic bags and stored in a step-in freezer room at −20 °C until the analysis occasion.

The frozen breads were prepared for serving by thawing at room temperature (approx. 20 °C) and then revived for 10–15 min at 180 °C. The bread loafs were then cut into 1 cm slices and served once they had cooled to room temperature.

2.3. Descriptive sensory analysis

The quantitative descriptive analysis (QDA), including panel selection, descriptive training, and final sensory assessment, was performed according to international standards (including ISO 6658:2017, ISO 8586:2023, ISO 8589:2007, ISO 13299:2016).

The evaluation was performed at the sensory laboratory at Kristianstad University, Sweden. One-centimeter-thick bread slices were cut in four (Fig. S1a). The upper quadrants were evaluated for crust and the lower for the crumb. Members ($n = 8$) of the trained analytical sensory panel evaluated the bread types based on odor (O), visual appearance (A), texture (Tx), taste (T), and flavor (F), according to attributes in Table 3. These attributes were assigned a value from 0 to 100 on a linear intensity scale by the panelists during the final sensory evaluation. The assessed bread samples ($n = 3$) were encoded with three-digit numbers and served at room temperature (approx. 20 °C) in triplicate in a randomized order.

Table 3
List of descriptive sensory attributes with definitions for the bread crumb and the bread crust. The attributes were translated from Swedish to English by the authors.

Sensory category	Part of bread	Attribute	Description
Odor (O)	Crumb	O-Cereal	Mix of different grain aromas
	Crumb	O-Baker's yeast	Baker's yeast
	Crust/Crumb	O-Bread syrup	Dark malty syrup
	Crust	O-Roasted	Maillard reaction [a]
Appearance (A)	Crust/Crumb	A-Brown	Color saturation (from light to dark)
	Crumb	A-Airiness	Airiness (from compact to airy)
	Crust	A-Thickness	Thickness (from thin to thick)
Texture (Tx)	Crumb	Tx-Chewing resistance	Chewing resistance (after one chew)
	Crumb	Tx-Graininess	Graininess (after five chews)
	Crust	Tx-Chewiness	Chewiness (after one chew)
	Crust	Tx-Hardness	Hardness (after three chews)
Taste (T)	Crust/Crumb	T-Saltiness	Basic taste
	Crust/Crumb	T-Sweetness	Basic taste
	Crust/Crumb	T-Bitterness	Basic taste
	Crumb	T-Sourness	Basic taste
Flavor (F)	Crumb	F-Rye	Rye
	Crumb	F-Baker's yeast	Baker's yeast
	Crust/Crumb	F-Bread syrup	Dark malty syrup

[a] The Maillard reaction, first described in 1912 by Louis Camille Maillard (1912), is a chemical reaction arising from the interaction between amino acids and reducing sugars, creating distinct flavors of browned foods.

2.4. Evaluation of consumers' liking

A hedonic consumer study was designed to evaluate Swedish consumers' degree of liking of breads based on three different wheat flour varieties (Öland, Källunda, and Modern). Half a slice (1 cm thick) divided in two was served as one sample (Fig. S1b) in a 100 mL plastic container with lid at ambient temperature (approx. 20 °C). All participants were served the samples, marked with a three-digit number, in a randomized order. The study was conducted between the 2–10 November 2022 in the sensory laboratory at Kristianstad University, Sweden. The inclusion criterium was an age of 18 years or above.

Participants ($n = 47$) filled out an online questionnaire, designed in the software Eye Question (version 3.9.7, The Netherlands), in Swedish for each product. Among the participants, 72 % identified themselves as women and 28 % as men. The age span among women was 18–78 years (average 50 years) and men was 18–72 years (average 48 years).

The participants' preferences for the products were evaluated using a 9-point hedonic scale, ranging between 1: dislike extremely, 2: dislike very much, 3: dislike moderately, 4: dislike slightly, 5: neither dislike nor like (center point), 6: like slightly, 7: like moderately, 8: like very much, and 9: like extremely. The adoption of the 9-point hedonic scale in this study is attributed to its widespread acceptance as user-friendly approach which provides adequate differentiation of outcomes (Nicolas et al., 2010). Each sample was evaluated based on overall liking of appearance, odor, and taste/flavor as well as liking of crust and crumb. The participants were then encouraged to comment freely on their perceptions of respective bread samples.

2.5. Ethics

In Sweden, any research involving the processing of sensitive personal data falls under the jurisdiction of the Swedish Ethics Review Act. The present study, which explores perceptions of food, does not involve sensitive personal data as defined by the Data Protection Ordinance. All participants received written and oral information about the test and the contents of the assessed products, including allergens, and gave their informed consent to participate. No information from any of the questionnaires can be traced to or used to identify any individual participant, in accordance with the General Data Protection Regulation (GDPR).

2.6. Statistics

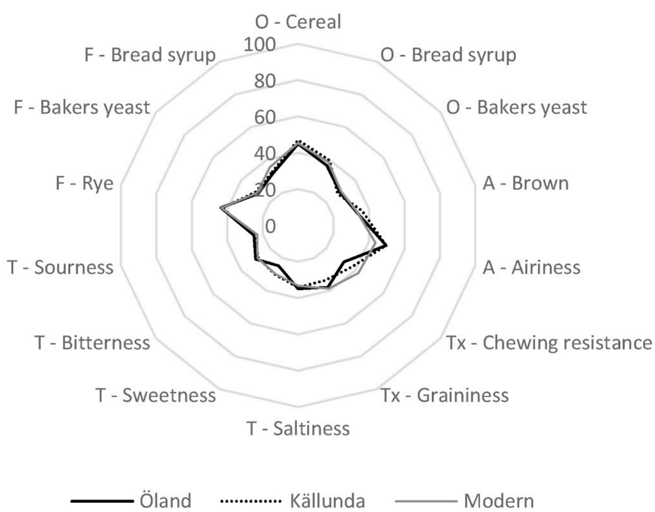
Descriptive statistics were applied to all obtained data, and reported as means ± standard deviation. To determine if any attributes from the descriptive sensory study and consumers' liking test significantly ($p < 0.05$) differed between the products, a two-way analysis of variance (ANOVA) followed by Tukey's *post hoc* test was performed with panelists and products as fixed factors. Different letters or asterisk (*) were used to indicate significant differences between samples. Pearson correlation analysis of average values was carried out to evaluate potential relationship between results from the consumer liking study and the descriptive sensory study. Coefficients larger than 0.7 or smaller than −0.7 ($r \geq |0.7|$) were considered indicative of a strong relationship between two variables (Akoglu, 2018). Microsoft Excel (version 2407, USA), jamovi (version 2.3.28, Australia), and Eye Question (version 3.9.7, The Netherlands) were employed for the statistical analyses.

3. Results

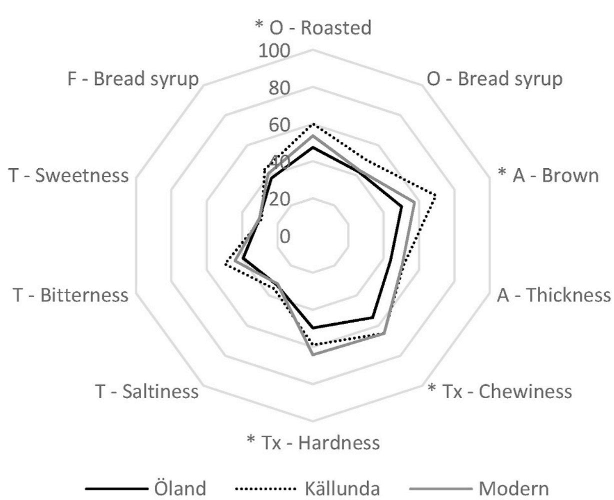
3.1. Sensory profiles of the breads

From the descriptive sensory study, several attributes for the crumb (14 attributes) and crust (10 attributes), were brought forward by the analytical panel. In addition to the basic tastes, the crumb and crust were described in terms of bread syrup, baker's yeast, and brown. The crumb was described by cereal and rye relating to its cereal-based origin, and airiness, chewing resistance, and graininess, relating to the characteristics of bread as a product. The crust in contrast to the crumb, was described in terms of chewiness, hardness, and thickness, as well as roasted which refers to the Maillard reaction.

Overall, the panel's scores for the determined attributes were low to medium high, with scores ranging between 25 and 50 (mean: 35.0, median: 33.5) for crumb and 29–70 (mean: 47.0, median: 47.4) for crust.



a)



b)

Fig. 1. Scores assigned by the analytical sensory panelists ($n = 8$) for each attribute of the a) crumb and b) crust of three breads. Sensory categories include odor (O), visual appearance (A), texture (Tx), taste (T), and flavor (F). Asterisk (*) indicates significant ($p < 0.05$) discrimination between products.

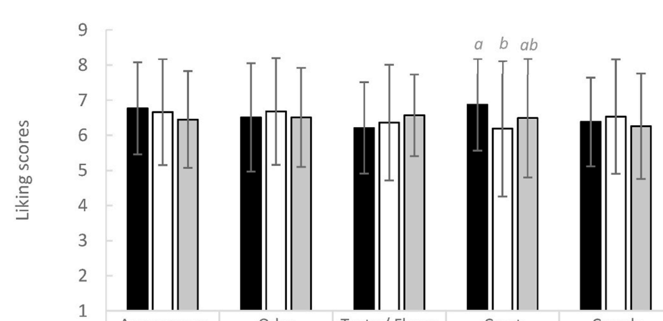
Descriptive evaluation by the analytical sensory panel indicated small or no differences between the three bread products (Fig. 1a and b, Tables S1a–b). While at a higher significance level ($p < 0.10$), it is yet worth noting that differences were observed between the various crumbs' perceived airiness, chewing resistance, and graininess. The two breads based on heritage grains had higher perceived airiness (49.7 ± 15.1 for Öland and 49.7 ± 12.4 for Källunda) and lower chewing resistance (32.3 ± 14.9 for Öland and 37.2 ± 14.7 for Källunda) than bread based on modern flour (43.6 ± 13.3 and 42.3 ± 16.2, respectively). The graininess was higher in Öland (37.9 ± 16.9) and modern (38.7 ± 18.4) wheat breads, than in Källunda (33.7 ± 16.7) wheat bread. All other attributes could not be distinguished between the three breads ($p > 0.10$).

While the crumbs of the three breads were predominantly perceived similar, a few attributes of the crust were significantly discriminated ($p < 0.05$) between the three bread types. The crust of Källunda wheat bread was perceived as more roasted (60.2 ± 17.1) and browner (69.5 ± 11.9) than Öland wheat bread (47.4 ± 14.6 and 50.2 ± 9.1, respectively). Modern wheat bread was similar to both heritage wheat breads in roasting (53.7 ± 16.7) and similar to Öland wheat bread in brownness (57.5 ± 12.4). Modern wheat bread was chewier (65.2 ± 16.6) and harder (64.2 ± 12.0) than Öland wheat bread (54.6 ± 15.8 and 49.8 ± 13.9, respectively), and Källunda wheat bread was similar in chewiness (65.1 ± 12.2) as Modern wheat bread and similar in hardness (58.9 ± 14.9) as both other breads.

Among the descriptive attributes used for the sensory mapping of the breads, a few stood out. To describe the crust, roasted odor, brown appearance, as well as chewy and hard textures received highest scores. Corresponding descriptive attributes for the crumb included visual airiness, followed by cereal odor and rye flavor. However, also attributes with lower intensity can be important to describe the full character of a product.

3.2. Consumers' liking of the breads

The consumer study showed that the scores from the respondents overall had a positive trend towards the three bread products (Fig. 2, Table S2). The fraction of the participants who gave overall positive evaluations (scored >5) for the crust were: 85.1 % for Öland, 68.1 % for Källunda, and 76.6 % for Modern. Corresponding percentages for the crumb were: 74.5 %, 74.5 % and 68.1 % for Öland, Källunda, and Modern, respectively. Overall, the consumers' liking of the three bread products were similar, however significant discrimination ($p < 0.05$) between the crust of the different breads were observed. Consumers



	Appearance	Odor	Taste / Flavor	Crust	Crumb
■ Öland	6.77	6.51	6.21	6.87	6.38
□ Källunda	6.66	6.68	6.36	6.19	6.53
■ Modern	6.45	6.51	6.57	6.49	6.26

Fig. 2. Consumers' ($n = 47$) liking of breads based on the three flours Öland, Källunda, and Modern wheat. The evaluation uses a linear 9-point hedonic scale, ranging from 1: dislike extremely to 9: like extremely. Significant differences ($p < 0.05$, Tukey's) between the products are indicated by letters (a–b).

significantly ($p = 0.044$) liked the crust of bread made from Ölands wheat better than Källunda.

At the end of the questionnaire, the participants were given the possibility to elaborate on their thoughts on the three bread products by free comments. The comments were grouped in "texture", "odor", "taste/flavor", "crust", "crumb", and "overall" in accordance with the categories in Fig. 2. In general, all three breads seemed to have a somewhat neutral taste, with firm/chewy crust and juicy/spongy/sticky crumb (Table S3). There seems to be a discrepancy between consumers' opinion on what constitutes tasty bread.

3.3. Correlation between sensory descriptors and consumer liking

As previously seen in the consumer liking test, only the crust differed significantly between the three breads. The consumers liked the crust of bread baked from Öland wheat better than Källunda wheat (Modern wheat mix scored in between). Therefore, consumers' scores of the crust were correlated (Table 4) with parameters of the crust from the analytical sensory test. Attributes which significantly differed between the products were selected.

The correlation matrix in Table 4 indicated that the consumers liked breads better that had a low score on roasted odor and brown color, which had little chewiness and hardness. Hence, the consumers liked the crust of bread made from Öland wheat better than Källunda wheat. Only the relation between liking of crust and roasted odor was significant ($p < 0.05$).

4. Discussion

This study has investigated the sensory profiles and consumer liking of breads baked from two heritage wheat flours (Öland and Källunda) and compared them to a modern wheat flour. Overall, the results indicated that the breads based on the two heritage wheat varieties were perceived similar as breads baked with a modern wheat flour. Contrarily, previous studies have indicated a variation in sensory properties within and between different wheat species, and even suggested sensory advantages of ancient grains (Roumia et al., 2023; Starr et al., 2013). There are hundreds of heritage wheat varieties in the world and the comparison in this study is limited to two varieties. Hence, more studies of a wider array of heritage wheats are needed to fully understand the sensory properties of these.

The sensory profiles of the three breads included attributes directly relating to the characteristics of cereals in general and bread in particular. The descriptive attributes developed in the present study are similar as in previous research (Mollakhalili-Meybodi et al., 2023). These words covered taste, flavor and texture attributes among the breads which are important for consumer acceptance. Contrarily, freshness of the bread was not directly evaluated, although it is another important attribute according to the consumers (Wendin et al., 2020).

Furthermore, the descriptive attributes determined during the training session later exerted the basis for the evaluation of the breads. The panel's scores for the determined attributes were low to medium high. This may indicate that the breads had neutral sensory attributes. From a culinary perspective, this is useful as these breads might more easily be combined with other food stuffs and products. Additionally, the freezing process is known to influence the volatile profile and sensory characteristics of breads (Fik and Surówka, 2002; Pico et al., 2017). For instance, wheat bread has shown losses of 24 % of their volatile compounds after one week of freezing (Pico et al., 2017). Hence, the freezing process in the present study may have contributed to lower scores for certain sensory attributes.

While the sensory profiles of the breads appeared similar, the nutritional profiles of ancient and heritage wheat varieties are generally known to differ from modern wheat (Zamaratskaia et al., 2021). The content and quality of protein and gluten, which is divided into gliadins and glutenins, are important for the baking performance. Interestingly, breeding of wheat toward improved yields and enhanced baking properties has, as a result, entailed lower protein and gliadin content and higher glutenin levels in modern wheat (Pronin et al., 2020). Glutenin is responsible for the elastic properties of a dough. In the present study, the protein content was higher, while total gluten appears lower, in heritage wheat than in modern wheat. As confirmed in present study, the level of starch is generally high in all wheat varieties, and cereals are a good source of dietary fiber, which we are advised to increase in our daily diet (Zamaratskaia et al., 2021). Today, the average dietary fiber intake ranges from 16 to 26 g/day, while new Nordic recommendations suggest an intake level of 25 g/day for females and 35 g/day for males (Blomhoff et al., 2023). Some studies also suggest that ancient and heritage cereals should have bioactivity beneficial for human health. Although clinical evidence is scarce, available literature indicates that ancient and heritage wheat has different health benefits, including anti-inflammatory and antioxidant proprieties, in relation to modern cultivars (Dinu et al., 2018; Spisni et al., 2019; Valli et al., 2018). All in all, the nutritional profile of these heritage wheat varieties appears promising for increased usability.

Although the nutritional profile differed between the various wheat varieties, the descriptive sensory study could not distinguish the crumbs of the three different breads at a significant ($p < 0.05$) level. However, three attributes – airiness, chewing resistance, and graininess – differed at a higher significant level ($p < 0.10$). While this can provide insights into the differences between the breads, the higher significance level of these observed differences increases the uncertainty of these results. A comparison of sensory scores with nutritional data indicated that higher airiness and lower chewing resistance were associated with higher protein content and lower gluten level of the breads. In contrast, it is commonly known that gluten form strong, cohesive, viscoelastic networks that facilitate the retention of yeast fermentation gases which yield light and aerated baked wheat products (Starr et al., 2013; Van Der Borght et al., 2005). However, bread baking is a complicated task, with several factors, including salt content, water content and baking conditions, affecting the outcomes (Mollakhalili-Meybodi et al., 2023). In addition, gluten consists of gliadins and glutenins, and a perfect ratio between these protein types are essential for good baking properties (Şerban et al., 2021). This ratio is not specified for the wheat varieties in the present study. Moreover, half of the flour used in this study was wholegrain, which contributes to the bread texture and potentially reduces differences induced by gluten that might be more pronounced in white bread. In addition, the small differences in the crumbs' graininess did not associate with any other parameters. While the salt content and baking conditions were designed to be similar, optimizing the water

Table 4
Correlation matrix (Pearson's) with attributes significantly ($p < 0.05$) differentiating between the bread crusts from the descriptive study and consumers' liking study.

	Liking of crust	Roasted odor	Brown appearance	Chewy texture	Hard texture
Liking of crust	–				
Roasted odor	−0.997 *	–			
Brown appearance	−0.979	0.991	–		
Chewy texture	−0.894	0.857	0.783	–	
Hard texture	−0.676	0.618	0.510	0.934	–

Note. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

content for each type of wheat flour could potentially yield different bread characteristics.

From the descriptive study it was further demonstrated that while the crumbs of the three breads were overall perceived as similar, some attributes for the crust differed. These differences appeared to be attributed to each type of wheat flour (Öland, Källunda and Modern) but could not be deduced to a variation between heritage and modern wheat. For instance, it was apparent that the chewiness and hardness of the crust did not differ particularly between heritage and modern wheat although the protein content, and expected gluten level, differed. Among the bread samples, the crust of bread made from Öland wheat was better liked than the crust of Källunda wheat bread. According to the correlation analysis, this is likely related to its lower roasted odor and potentially its lower brownness, chewiness, and hardness. These attributes are typically related to the Maillard reaction which arises when amino acids react with reducing sugars (Maillard, 1912). Hence, the occurrence and degree of this reaction, which is dependent on the constituents of the bread, is important for the overall liking.

As mentioned in the introduction, a previous study (Wendin et al., 2020) investigating the attitudes of consumers towards heritage cereals, demonstrated a willingness to purchase bread based on heritage cereals. Similarly, a majority of the participants in this study gave positive liking scores to all three products. For the crumb, more participants gave positive scores for the breads based on heritage wheat, compared to modern wheat. The consumer scores in all categories for all breads ranged between "like slightly" and "like moderately". The moderate liking can be attributed to the neutral character of the bread as seen in the descriptive analysis and from the free comments. Similar scores and positive sensory characteristics for bread baked on evolutionary wheat flours was also observed by Spaggiari et al. (2022). In addition, Teuber et al. (2016) demonstrated that most participants exhibited a highly favorable attitude towards ancient grain varieties, primarily perceiving them as healthy and environmentally sustainable. Hence, current literature suggests an overall positive attitude and liking towards breads based on ancient and heritage grains.

Whereas the present study provides valuable insights into the liking among Swedish consumers, it is important to acknowledge the limited number of participants in the consumer study as a constraint. The study's reduced participant count diminishes its statistical power but gives a valuable extension to the descriptive test. Another limitation is the lack of comparisons of nutritional content and potential health benefits between the wheat varieties due to the absence of advanced chemical characterizations. However, this study includes data from previous studies of Öland and Källunda wheat and information from the manufacturer of modern wheat. Additionally, this study gives a snapshot of two heritage wheat varieties, which may differ from the many available varieties around the globe.

5. Implications for gastronomy

There is a current and growing interest in foods based on heritage cereals. Today, heritage cereals can be regarded as trendy, however they are in comparison to conventional cereals more of a niche product and often sold from the producer directly to consumers, or to artisanal bakeries, but show great potential for expanded consumer acceptance and usage. This study has demonstrated that although nutritional deviations occur between the wheat varieties, none or few sensorial differences are observed when introduced as breads. Heritage cereals have in addition promising cultivation properties for a more resilient food system. Hence, the implications for gastronomy are that heritage wheats could be used in similar ways as modern varieties without impeding the sensory properties of the products, here illustrated by breads. The neutral sensory profile of all breads further implies that these products have the potential to be combined with a range of different food stuffs and be included in a wide spectrum of products and cuisines.

6. Conclusions

This study has evaluated how breads based on heritage and modern wheat compare in their sensory profiles and consumer liking. Heritage cereals have recently gained increased recognition for their nutritional profiles, contribution to biodiversity, and resilience towards adverse climate change effects. While breeding of modern wheat has focused not only on improved yields and harvest index, but also on enhanced baking properties, the present study suggests that breads based on two heritage wheat varieties have similar sensory profiles as bread based on modern wheat. However, differences between available varieties of heritage wheat varieties may occur. The consumers' liking for all three breads were overall positive, with scores ranging between "like slightly" and "like moderately". A majority of the consumers scored positively for all breads. The neutral sensory profiles of all breads indicate their versatility in pairing with various foods and inclusion in diverse cuisines. Finally, the gastronomic implications of the study suggest that heritage wheat can be utilized similarly to modern varieties without impeding sensory qualities, as demonstrated here with breads.

CRediT authorship contribution statement

Madeleine Jönsson: Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis. **Karin Gerhardt:** Writing – review & editing, Resources, Project administration, Funding acquisition, Conceptualization. **Karin Wendin:** Writing – review & editing, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijgfs.2025.101165.

Data availability

Data will be made available on request.

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