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Beyond industrial standards: crafting quality bread with heritage wheat in Walloon alternative bread supply chains

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Echoing a transformative perspective of agroecological transitions, alternative bread supply chains (ABSCs) experiment with technical and social innovations to overcome the limitations of industrial baking through artisanal knowledge. Yet, ABSCs in Wallonia, Belgium, face specific challenges as the heritage wheat varieties they use, while adapted to local conditions, do not meet industry-defined "baking value" standards and are thus deemed unsuitable for bread-making. This study demonstrates that artisanal bakers can effectively use these flours, challenging traditional notions of flour "quality" in terms of nutrition and flavor versus workability. In this study, nine types of flour were analyzed using measures from industrial standards: protein content, water content, α-amylase activity, and baking strength. These flours were sourced from six heritage wheat varieties, two variety mixes (one field-based, one post-harvest), and one modern variety bred for organic agriculture, all grown on the same field and milled under the same conditions. These varieties are used by farmers in Wallonia ABSCs, showing their relevance to the local conditions. Their poor industrial ratings were then put to the test by three artisanal bakers, who baked and assessed each flour using sensory-based evaluation tables before, during, and after baking. Semi-structured interviews provided insight into bakers' strategies for handling these flours and went further in the understanding of why artisanal bakers could even prefer allegedly unsuitable flours from heritage varieties than standard flours, easier to bake. Findings reveal that ABSCs bakers employ complex craft techniques, drawing on sensory awareness and intuitive adaptation to address the variability of heritage flours. This artisanal perspective—viewing raw materials as "living matter"—and its set of related skills should thus be promoted in apprenticeship as they are seen essential for a wider agroecological transition of food systems. These practices contributing to processes of *scaling deep* sustainability initiatives, that aim to reshape values and narratives of the broader system. Such perspectives would indeed contribute to reshaping values and narratives, a dynamic that is crucial to support for amplifying the broader transformative potential of ABSC.

KEYWORDS

agroecological transition, alternative bread supply chains, baking value, artisanal knowledge and know-how, relocalization, wheat heritage varieties

1 Introduction

Wheat is the most extensively cultivated crop worldwide by land area (Food and Agriculture Organization of the United Nations, 2025). Today, wheat is predominantly grown in monocultures using high-yielding varieties (HYVs), commonly referred to as modern varieties. Wheat is embedded in globalized and industrialized supply chains increasingly dominated by the milling industry, which imposes its standards (Hills et al., 2013; Astier, 2016). This system has led to several significant consequences: a loss of genetic diversity in wheat (Bordoni et al., 2017; Cheng, 2018), a depletion of nutritional elements in the grain (Fardet, 2014; Bordoni et al., 2017), biodiversity loss in soils and beyond (Hills et al., 2013; Sacchi et al., 2019), as well as a concentration of added value downstream from the farm, at the expense of farmers and small-scale millers and bakers (Galli et al., 2015; Howard, 2016; Sacchi et al., 2019).

Since the end of WWII, efforts to lower selling prices have spurred the production of wheat grain, flour, and bread. Grain was selected primarily for yield, supported by a wide range of chemical inputs used in the field (Guarda et al., 2004; Baltazar et al., 2019; Sacchi et al., 2019). Certain types of gluten protein were also prioritized, to provide the elasticity and tenacity needed for dough to withstand increasingly industrialized baking processes (Gélinas et al., 2009). These fundamental changes depleted bread of its nutritional value (Fan et al., 2008; Rémésy and Leenhardt, 2009; David et al., 2013; Jones et al., 2015). With these modern varieties, while the yield capacity increased, the nutritional density of wheat hence decreased; a phenomenon called "the dilution effect" (Garvin et al., 2006; Murphy et al., 2008). Nowadays, new breeding efforts are deployed to enhance the nutritional quality of modern wheat (Castellari et al., 2023). Still, the value of grain is currently assessed by standards set by the industrial baking and as Jones and Econopouly put it (2018, p. 715), it seems that we are somewhat "stuck in a single definition of wheat quality, and it can only become more and more refined, and thus less and less nutritious." This general dynamic is also detrimental to the nutritional quality of bread, which depends, in addition to the nutritional quality of grain, on the milling technique and the fermentation process (Jones et al., 2015; Cappelli et al., 2020; Ribet et al., 2023).

Given these drawbacks and the central role of grain-to-bread supply chains in Western food systems, rethinking this system is essential. The agroecological paradigm offers a promising perspective to this respect, calling for a profound transformation of food systems (Holt-Giménez and Altieri, 2012; Duru et al., 2015; Lamine and Chiffoleau, 2016; Hazard et al., 2017; Lamine et al., 2021; Plateau et al., 2021). Agroecological transitions are understood in different ways, broadly divided between two paths: one driven by large-scale, expert-led, technology-focused interventions, and another rooted in local-scale, community-based, and knowledge-intensive processes (Anderson et al., 2019). This study aligns with the second approach, drawing on a systemic vision of agroecology as a transformative paradigm aimed at redesigning food systems to promote ecological, economic, and social sustainability (Anderson et al., 2019; Gliessman, 2020; Savels et al., 2024).

Such transitions rely on the active involvement of diverse actors—farmers, citizens, and scientists—whose collaboration fosters the integration of multiple forms of knowledge and promotes place-based, action-oriented learning (Gliessman, 2020). This participatory dynamic contributes to what Sachet et al. (2021) describe as a "fundamental shift in knowledge production." In this context, Giraldo and Rosset (2023) refer to *emancipatory agroecologies*—approaches that deeply transform how we relate to agri-food systems. Following these authors, Adriaensens et al. (2025) argue that agroecology, often used as a buzzword, only constitutes a true paradigm shift if it radically reimagines not only agricultural practices but also the social, cultural, economic, and political dimensions of agriculture, as well as the role of science itself. This transformative vision requires knowledge producers in agroecology to operate within fundamentally different frameworks than those underpinning industrial agriculture (Sachet et al., 2021; Munoz-Araya et al., 2024; Adriaensens et al., 2025). Consequently, agroecological transitions emphasize cultural, sensitive, and even spiritual values over productivist logics in shaping food systems (Giraldo and Rosset, 2023).

The grain-to-bread supply chains investigated in this paper align with this agroecological perspective. We refer to them as alternative bread supply chains (ABSCs), as they offer a distinct and emancipating alternative to the dominant industrial organization of grain-to-bread systems. ABSCs have been flourishing since the past few decades in Western countries (Galli et al., 2015; Barbier and Moity-Maïzi, 2019; Chiffoleau et al., 2021), including Wallonia, Belgium (Demeulenaere and Goulet, 2012; Baltazar et al., 2019). Operating on a local scale, ABSCs foster technical and social innovations specifically intended to overcome the pitfalls of industrial chains (Demeulenaere and Goulet, 2012; Galli et al., 2015; Chiffoleau et al., 2021; Meyer et al., 2024). For instance, actors in ABSCs often prefer heritage wheat varieties because they are better suited to local agroecological practices. Although they tend to display lower yields and an increased sensitivity to lodging due to their longer straw (Dinu et al., 2018; Beaugendre et al., 2024), heritage varieties typically show better tillering and weed competitiveness than modern varieties, making them more suitable for practices that avoid chemical pesticides and excessive mechanization for weed control (Beaugendre, 2024). Heritage varieties are also increasingly popular for their stronger flavor and higher nutrient content (minerals, essential amino acids, vitamins) (Dinu et al., 2018; Vindras-Fouillet et al., 2021).

Nevertheless, Walloon ABSCs face several challenges. One challenge this study focuses on is the definition of baking value. Within the incumbent systems, only wheat selected for an industrial use passes the quality tests and is therefore considered as "bread grain" (Dewalque, 2021). Conversely, grain that fails to meet these criteria is deemed unsuitable for bread-making due to its low baking value. One possible consequence is that wheat can be downgraded to animal feed, thereby losing much of its financial value (La Spina and Roda, 2019). This poses a particular challenge for heritage wheat since, despite a protein content that is usually higher than in modern varieties, the type of proteins that they display are of a lesser quality for the purpose of industrial baking. This is exacerbated by a rainy weather around harvest time, which causes a high enzymatic activity resulting to poor dough workability (Oger et al., 2003; Wilson et al., 2008). Weaker gluten structures, high amylase activity and seasonal variability in batch quality are indeed difficult to accommodate in mechanized and standardized baking processes (Vindras-Fouillet et al., 2021). Instead, baking flour made from heritage wheat rather requires flexibility and adaptation. A characteristic of many agroecological initiatives is the reappropriation of artisanal knowledge by field practitioners as a form of social innovation, and ABSCs are no exception to that (Chiffoleau et al., 2021). Craftsmanship is central the identity of local food chains

(Schmitt et al., 2018), and ABSCs indeed emphasize artisanal knowledge and techniques. Artisanal processes foster greater adaptability and resilience in addressing diverse challenges while being better suited to local specificities (Demeulenaere and Goulet, 2012; Galli et al., 2015; Barbier and Moity-Maïzi, 2019; Guerrini et al., 2019; Chiffoleau et al., 2021). In practice, within ABSC networks, it is recognized that artisanal bakers, unlike industrial machinery, can adjust their techniques and gestures on a daily basis to accommodate flour with variable properties.

In this context, it becomes necessary to critically examine the extent to which the alleged low "baking value" of heritage wheat varieties constitutes a barrier to the further development of ABSCs. From our observations in the field, a noteworthy aspect indeed emerges within ABSCs: bakers involved in these chains appear to be able to produce bread using heritage wheat flours. Similar findings have been reported in field studies from Italy and France (Guerrini et al., 2019; Vindras-Fouillet et al., 2021). Yet, despite these promising examples, research on this topic remains limited. This paper therefore aims to contribute to a more thorough understanding of what enables these bakers to work with such variable raw materials.

One explanatory hypothesis is that the artisanal nature of baking that prevails in ABSCs leads the bakers to rely on their senses and feelings more strongly, as craft techniques have been shown to rest on sensory perception and intuition (Sennett, 2008). This reliance may help them better navigate the variability and specific characteristics of heritage wheat flours.

In light of these observations, the objective of this study is three-fold:

(1) to assess the baking quality of several heritage wheat varieties that are agronomically adapted to Walloon soil and climate conditions, using the most common industrial tests;
(2) to determine whether artisanal bakers can produce marketable bread from the flours made from the tested varieties;
(3) to explore, through qualitative interviews, how artisanal bakers experience and work with heritage wheat flours, and what meanings or value they attribute to them in their practice.

These inquiries are critical for understanding the motivations of ABSCs actors, and for facilitating the development of these chains in alignment with their needs, both locally and on a broader scale.

The present paper is structured as follows. First, (2.1) a contextual outline is drawn. Then (2.2.), the research approach is presented as well as the set of inter-related methods used for this research: (2.3.) the laboratory analysis of the sampled flour, (2.4.) the artisanal testing, assessment tables set up with the participating bakers, and general outcomes of the tasting event (2.5) the qualitative interviews. In a third part (3), the result of each method is presented in separated sections (3.1, 3.2, 3.3). In the discussion (4), the links between the methods and the results of each method are scrutinized. Section (5) concludes the paper.

2 Materials and methods

2.1 Contextual outline

In Wallonia, cereals occupy an important place in agriculture: 24% of the Useful Agricultural Area is devoted to cereal cultivation and 69% of this area goes to winter wheat (Lahon, 2020). However, only 9% of the wheat harvested in Wallonia in 2010 was intended for human consumption (Delcour et al., 2014). Most of the bread grain (91%) is imported, particularly from France and Germany, but also from Ukraine (Collège des Producteurs, 2025). This high level of dependence on imported wheat is quite risky as illustrated by the recent war in Ukraine which put in jeopardy the global grain supply (Bentley et al., 2022; Hellegers, 2022; Mottaleb et al., 2022), thereby exposing the fragility of globalized agri-food systems.

As mentioned in the introduction, the baking value of wheat is driven by the requirements of industrial baking for a protein content with strong and elastic gluten as well as low enzymatic activity so that the starch chains remain intact (Oger et al., 2003; Wilson et al., 2008; Gélinas et al., 2009). The value of a given batch of wheat regarding these criteria depends as much on the wheat variety as on growing conditions (Kiær et al., 2009; Dinu et al., 2018; La Spina and Roda, 2019). In Wallonia, wheat cultivation faces the additional challenge of frequent rainfall, even in summer, which often lower the baking value of grain (La Spina and Roda, 2019). Extra nitrogen supply could allow the protein content to catch up with the standard required rate, but it would contradict the will of ABSCs actors to reduce or even ban the use chemical inputs in their wheat growing practices. All this explains why Wallonia, and Belgium in general, currently imports a considerable proportion of its bread grain even in ABSCs (Collège des Producteurs, 2025).

Despite these challenges, several ABSCs actors in Wallonia claim that redesigning grain-to-bread chains at each step of the process is relevant, in particular from a nutritive standpoint. Building on studies showing that heritage varieties have superior nutritional qualities (Dinu et al., 2018), Walloon ABSCs actors also point out that having strong working interrelations with millers is a keystone as the milling of grain will also determine the nutritional quality and the workability of a flour. Stone milling is often viewed by ABSCs actors as better than industrial roller milling in that it preserves the wheat germ (i.e., rich in vitamins, and minerals) and enhances flour nutritive quality (Rémésy and Leenhardt, 2009). However, also the milling speed, and not just the tool itself, affects nutritional quality. Bad settings of the grinding wheels or cylinders such as clamping or speed can indeed damage starch (Gélinas et al., 2009; Cappelli et al., 2020). Further down the chain, artisanal baking with sourdough and long fermentation can also boost nutritional value (Gobbetti et al., 2019; Dewalque, 2021).

The will to further test the relevance of such an interrelated grain-to-bread chain is what lies behind the research collaboration with an agroecological farmers network called Farm For Good (FFG),[1] which is involved in the relocalization of agri-food chains in Wallonia. The flour samples used in this study (see the details in Table 1 below) come from the harvest of a wheat producer who is a member of FFG. The varieties tested were selected by FFG for their interesting agronomical qualities in the soil and weather context of their member farms. The

1 FFG is an active cooperative network of farmers in Wallonia who is promoting agroecology through soil regeneration, territorial cooperation and solidarity economy. Led by people who are farmers and academics at the same time, FFG invites regularly researchers to get involved. For more information, see: http://farmforgood.org/.

participating bakers were also contacted through the FFG network. In other words, FFG took an active part on selecting the varieties to test, the mill to use and the bakers to choose, so they could use the results for their own purposes. In line with our research objective, these bakers can be considered artisanal. They primarily use sourdough, avoid additives, and engage in craft practices such as slow kneading. These elements form the foundation of what we consider artisanal baking in this context. They also enjoy experimentation and were eager to take part in the study. This first experiment was kept at a modest scale, in order to refine the process for larger studies. Accordingly, a small sample of three bakers suited our time and resource constraints while allowing the comparison needed for the analysis.

2.2 Research approach and methods

To investigate our research questions, we adopted a transdisciplinarity-inspired approach (Fernández González et al., 2021). However, the sanitary measures for COVID-19 pandemic happening at the time limited the possibilities of collaboration with the field actors. We combined different approaches and we used quantitative and qualitative methods to answer our research questions. Each method is more precisely described in the following paragraphs. First, the criteria of baking value and the history of their implementation were defined through an overview of the scientific literature. Secondly, nine flours milled from eight heritage variety or heritage variety mixes, and one modern wheat variety for comparison (see Table 1), were analyzed by a specialized laboratory to analyze the baking value of their flours, from an industrial point of view. Third, the three participating bakers had to make bread from these flours, in the form of a blind test. Along this test, they filled up assessment grids with criteria chosen from the literature and slightly adapted following discussion with the bakers. Fourth, semi-structured interviews were conducted with the bakers to gain an in-depth understanding of their perception of flour quality, their approach to working with different flours, and, more broadly, their bread-making practices.

In addition, FFG intended to organize a tasting event with the loaves coming from this test, inviting members of the network, to strengthen the social links and to invite farmers to try bread coming from the wheat they grew. This paper does not describe or analyze the tasting event in detail; only the final outcomes are presented to support that the breads made from the tested flours were appreciated by consumers. A more thorough analysis can be found in Baijot (2021).

TABLE 1 Names of the wheat varieties analyzed in this study.

Variety	Milling date
Alauda*	24.03.2021
Blanc des Flandres	16.03.2021
Blanc des Flandres X Chiddam Rouge	29.03.2021
Bon Moulin	25.03.2021
Chiddam Rouge	25.03.2021
Victoria d'Automne	16.03.2021
Vilmorin 27	16.03.2021
Vilmorin 27 X Vilmorin 29	26.03.2021
Vilmorin 29	16.03.2021

Blanc des Flandres X Chiddam Rouge is a field mix, Vilmorin 27 X Vilmorin 29 is a post-harvest mix.
*Alauda is a modern variety bred for organic agriculture.

2.3 Laboratory analysis

2.3.1 Grains and flours processes

The sample tested in this research consisted of seven wheat varieties, one field mix and one post-harvest mix: nine objects in total. In the present sample, all the different varieties were cultivated by one FFG farmer in the same field. Varieties and milling dates are listed in the following Table 1.

Each of these varieties is characterized as "heritage wheat" (breeding before 1930), except the modern variety Alauda (bred in 2011, specifically for organic agriculture) which is a "modern wheat" used by the FFG network. The seeds come from the Réseau Semences Paysannes (RSP) in France (for a further description of the role of this network see Mazé et al., 2021). The seeds were sown during the 2019 autumn and harvested in the summer of 2020. That summer was exceptionally dry, and the harvest happened early and well, with little or no problems of lodging. The grains were sorted in a FFG farm in Namur Province. The Bon Moulin and Chiddam Rouge were stored in this farm and the others in Agribio[2]'s granary (Namur Province). All the grain was milled at Agribio, on an Astrié stone mill with an extraction rate of 87%. This extraction rate, typical of stone mill, is a classic French and Waloon compromise between whole grain flour and white flour. It is still very rich in fiber but a little easier to work with than whole grain. 75 kg of wheat was milled of each variety and packed in 10 kg bags. The bakers received 10 kg of each flour the 30th of March 2020. Prior to sending, each object was sampled for testing by the Laboratory of Cereal Technology[3] of the Walloon Agricultural Research Center (CRA-W).

2.3.2 Measures

The analysis at the CRA-W took place between the 20th and the 28th of May 2021, about 2 months after milling (milling dates in Table 1).

Table 2 presents the measures commonly used in the Belgian milling industry to assess flour quality. It also details the limits and thresholds that flour must meet to be considered suitable for breadmaking. The analysis conducted on our flour samples were the milling moisture (% dry matter), protein content (% dry matter), Hagberg falling number (s), baking strength W (J), dough elasticity as measured by P (Nm^{-2}), dough extensibility as measured by L (s) and P/L balance (in blue in Table 2). Zeleny number on white flour and grain density could not be analyzed, because the grain was already milled upon reception at the laboratory. On the other hand, even more sophisticated parameters such as the Chopin Mixolab set were obtained from these flour samples. However, we do not present these here as this deeper analysis did not further differentiate the different

2 Agribio is an organic grain cooperative providing stocking, milling, baking and commercialization.

3 Laboratory accredited ISO 17025.

TABLE 2 Description of the different analyses used to determine the baking value of the grain in Belgian industry.

Measure/Explanation	Name	Measure	Lower (-upper) limit
Direct measure (systematically used by the industry)	Weight per hectolitre	Grain density	76 $kg.hl^{-1}$
	Protein content	Protein content of the grain	11.5% dry matter
	Grain/milling moisture	Water content	14.5%
	Hardness	Behavior of the kernel during crushing	(classification from soft to hard)
Indirect measure (frequently used by the industry)	Zeleny index	**Flour protein quality**. The analysis measures the volume of the swelling of wheat protein in a standardized acid solution. A high volume indicates a good quality.	> 35 mL
	Falling number (Hagberg number)	**α-amylase activity**. Cereal kernels contain α-amylase in variable quantities, but what is more important is their activity. The analysis consists of the time it takes for an object to reach the bottom of a container filled with a flour suspension. The quicker the object falls through the suspension, the lesser its viscosity, the lower the Hagberg falling number, the shorter starch chains have become as a result of prior activity of the enzyme α-amylase in the intact kernel. Too much α-**amylase** activity breaks down too much starch. Too little activity (high Hagberg falling number) fails to release enough sugars for fermentation during breadmaking. Hence a lower and upper limit.	220–300 s
	Chopin alveograph	**Baking strength.** Deducted from rheological characteristics of the dough. A standardized dough ball receives a standardized pressure to inflate it. The pressure needed to start inflating the dough ball is **P** (Nm^{-2}), the inflation time before the created bubble bursts is **L** (s). The area under the (pressure, time) curve is **W** (10^{-4} Jm^{-2}). For good breadmaking potential, **P** (tenacity) ought to be in balance with **L** (extensibility).	$75 < L < 110$ $W > 170$ $0.3 < P/L < 0.7$

In blue, the measures used for our study.
Source: Oger et al. (2003), Roussel et al. (2010) and Godin (2021).

samples. Nevertheless, detailed analyses and results are available in Baijot (2021).

2.4 Artisanal testing, assessment tables, and tasting event

The nine flours tested in the laboratory were given to the three artisanal bakers participating in the research. Each baker received 10 kg of flour of each variety. The flours were coded so the bakers did not know which flour they were testing, to avoid them being influenced in the case they already knew the tested variety. The bakers had to bake several loaves from the different flours and then had to fill in the assessment grid. It was decided not to limit the bakers to one strict method, as artisan's adaptability seems to be a key factor explaining their ability to bake allegedly unsuitable flour. Still, to secure a certain degree of comparability, the bakers had the sourdough leaven for more than 12 h and chose slow kneading to work the dough.

Within the setting of this study, the three participating bakers were required to test the sample flours during their spare time, which is very little in artisanal baking. Therefore, each baker tested as many flour types as they could. As a result, while one baker was able to bake bread from the nine flour types, the other two could only tested five and four flour samples, respectively. The comparison remains possible as 4 samples were common to all three participating bakers. In addition, they were asked to bake a second time at least five loaves of their three favorite samples for the tasting event.

The assessment grid was inspired from Roussel et al. (2010) and Marion Dewaele (2010). In their work, Roussel et al. (2010) presented a system to characterize the flour, the dough, and the bread in the baking process, to assist decision-making of the actors in the ABSCs. They crossed the vocabularies used by the different professional bodies composing the chain through research and literature review. To present a standardized grid, they used the bread AFNOR ranking method. The AFNOR, "Association française de la normalisation," is the French National Organisation for Standardisation and is a member of the International Organization for Standardization. The aim of this organization is to set standards for products of different sectors, including baking industry. The grid in the present study was presented and explained to each baker ahead of the baking test. Researchers collected their comments about it. They were then taken into account to improve the first grid, leading to slight readjustments to be as close

as possible to the habits but also needs of the bakers (final assessment table).

This final grid used in this study allowed the bakers to rate the flours on a range of criteria, from "insufficient" to "excessive." The criteria concerned each step of the baking process from the first mixing to the final bread. The grids were compiled to have the largest possible coverage of terms and steps in the baking process.

Due to COVID-19 restrictions, the grid was filled in by the bakers themselves, without the presence of researchers, during their baking tests. The grid allowed the bakers to sort the flours according to their weaknesses and strengths. The bakers could also report detailed information about the behavior of the flour during the baking process.

Finally, the last sequence of this bread-making test consisted of a tasting event. This event was important for FFG as their coordinators saw it as an opportunity to invite people from the cooperative and beyond to meet and reinforce the network. It was also a possibility to test whether these actors, as consumers, would appreciate the bread baked with heritage wheat varieties, grown by the farmers of the cooperative. For the scientific team, the event revealed how consumers react upon testing bread made with potentially unsuitable flours. Coping with the COVID-19 restrictions of the time, 20 people gathered for the event. Each baker chose three flours to re-bake for the event and were asked to bring four loaves per flour. All loaves from all the bakers were tested by all the participants. Everyone had to rate each loaf according to their own preferences of the organoleptic characteristics, e.g., taste, smell, visual aspect, texture…. More concretely, each participant had a A2 paper with an axis to sort the loaves. For further details on the organoleptic test see Baijot (2021).

2.5 Qualitative interviews

The participating bakers are Edda,[4] who is running a family bakery in Namur (Wallonia), Marie who is working in the bakery of a municipal mill in the Huy region (Wallonia) and Ihsan who recently opened his bakery in Brussels.

In order to fully understand how artisanal bakers apprehend "baking value," a researcher conducted semi-structured interviews with them after the baking tests. These interviews aimed to explore what enables and motivates these bakers to make bread using flours often considered unsuitable, by examining both the life paths and career choices that led them to their current bread-making practices, and their own definitions of what constitutes a quality flour.

The interviews were recorded and fully transcribed afterwards. Thematic coding was applied to identify similarities and differences in the responses of the interviewees, allowing the grouping of shared perspectives on their work. These recurring themes provide insight into the view of artisanal bakers on their practices and thereby to grasp what makes bakers in ABSCs able to work with flours that are considered less prone to baking. The findings were then put in perspective with insights from relevant studies, here about artisanal work in general and within alternative bread chains in particular.

Qualitative interviews are used to understand "the sense actors give to their practices" and the «value systems and normative benchmarks through which they orient and determine themselves » and permit "access [to] embodied ideas" (Blanchet and Gotman, 2010, p. 24). In our case the interview guide focused on the baking process undertaken with the FFG flours. Qualitative interviews can indeed be used to find out the "processing strategies" put in place by the bakers to manage the supposedly poor workability of the heritage wheat flours (Guerrini et al., 2019). In complement, interviews also covered the bakers' values and principles they follow to give meaning to their practice. Artisans always adapt their way of working to the matter they have at hand and the environment in which they work (Sennett, 2008). Their skills and their working conditions cannot be standardized nor measured so only qualitative research can look deeply into their needs and aspirations.

3 Results

3.1 Laboratory analysis

Table 3 presents the results of the different analysis conducted on flour after milling. The red boxes show the values for which the flours would have been disqualified in the industrial baking chain. The laboratory analysis disqualified all nine flours according to the industrial criteria. Only the moisture content is acceptable for all the varieties. The protein rate (%MS) is too low for all the varieties tested. The Hagberg falling number (s) is too high for Blanc des Flandres, Vilmorin 29, Vilmorin 27 et Chiddam Rouge. The baking strength (W) is far below the acceptability threshold for all the varieties. The dough balance (P/L) index is far above the acceptability threshold. Therefore, none of the flours tested would have been accepted for an industrial outlet, even Alauda (the reference modern variety) did not satisfy these criteria.

However, the results of this analysis must be considered carefully. Indeed, the alveograph should test T55 milling grade (white flour) and can be precise up to T75 milling. But the milling grade used in this analysis was a 87% extraction rate (whole grain flour). Bran and coarse particles reduce the resistance of the dough under air pressure. This could explain the exceptionally low L, and thus high P/L as well as the very low W values.

Table 3 also shows that the Vilmorin 27 X Vilmorin 29 mix has the best baking values as expressed in values of P and W, followed by Bon Moulin as well as Blanc des Flandres X Chiddam Rouge. Vilmorin 27 takes the fourth position. The five remaining flours are of a considerably lower baking value, at least according to these industrial criteria. Even Alauda, a modern variety, belongs to these five.

3.2 Assessment tables and tasting event

The assessment tables allowed the bakers to write down their appreciation of the different flours, before the work, during and after the baking process. As outlined in the previous section, the assessment table was discussed collaboratively by researchers and bakers to determine how it should be completed and to clarify the meaning of each criterion. However, due to COVID-19 restrictions, each baker conducted their test independently, without the presence of peers or researchers. This constitutes a clear limitation of the study, as the completion of the assessment tables was ultimately based on individual

4 Names were changed.

TABLE 3 Baking quality parameters as measured on the different sampled flours.

	Moisture	Hagberg falling number	Protein content	Baking strength W	Tenacity P	Extensibility L	Dough balance P/L
	% FM	s	%DM	10^{-4} Jm^{-2}	Nm^{-2}	s	Nm^{-2} s^{-1}
Acceptability threshold in industry	**<14,5**	**220–300**	**>11.5**	**>170**	**–**	**75–110**	**0.3–0.7**
Vilmorin 27 X Vilmorin 29	12.74	292	10.14	67	65	27	2.41
Blanc des Flandres X Chiddam Rouge	12.87	295	10.12	63	61	29	2.10
Bon Moulin	12.43	229	10.42	66	57	31	1.84
Vilmorin 27	12.72	304	10.10	56	57	26	2.19
Blanc des Flandres	12.74	311	10.15	47	49	29	1.69
Alauda	12.48	271	9.06	43	46	30	1.53
Chiddam Rouge	12.35	314	10.68	43	46	28	1.64
Vilmorin 29	12.60	338	8.86	43	45	29	1.55
Victoria d'Automne	12.48	280	8.98	40	45	27	1.67

In Yellow, the values that do not meet the industrial standards. Bold value means acceptability threshold in industry.

interpretation. After testing as many flours out of the sample as they could, the bakers chose their favorite three flours to bake them a second time for the tasting event with the FFG network.

At first all the bakers said their first impression was that all flours seemed quite similar. However, the assessment tables enabled the artisans to dig into their sensory experience and become more precise on which criteria the flour was easy or not to work with. The support provided by the assessment table thus helped move beyond the limitation of relying solely on subjective impressions, enabling a more detailed and structured evaluation. Overall, they reckoned the flours to have a low "baking strength," as the laboratory analysis showed. But it did not appear as a major challenge for the bakers. To counter the general frailty, the three artisans adapted their whole baking process. For instance, they chose a low kneading speed on their dough mixers and adapted the amount of water to be added according to the dough texture, adjusted the amount of sourdough and proofing time, adapted overall their gestures for kneading and shaping.

Concerning the ranking, the appreciations somewhat diverge and only one baker, Ihsan, tested the entire sample. Nevertheless, some interesting findings can be pointed out. The variety Vilmorin 29 was tested by all the participants and was perceived as one of the best flours. Yet Table 3 shows this variety was the lowest in protein content and had the "worst" Hagberg falling number according to the industrial standards. All three bakers chose this variety to bake for the tasting event. Bon Moulin was not baked by Marie but was very much appreciated by Ihsan and Edda, especially for its taste. An interesting divergence in appreciation can be highlighted: some flours were the favorites of Marie but belonged to the worst ones of Ihsan (Chiddam Rouge and Blanc des Flandres). This underlines the fact that in artisanal work, and thus the appreciation of the raw material, seems to be linked, at least partly, to personal judgment.

A remarkable point is that all the bakers were able to make bread with any of the flours they tested in the sample, thereby further confirming findings from prior studies in Italy and France (Guerrini et al., 2019; Vindras-Fouillet et al., 2021), but here with varieties relevant in the Walloon soil and climate context. Yet, it is worth mentioning that this study benefited from an exceptionally good harvest, thanks to the unusually dry and sunny Walloon summer of 2020. Hagberg values are thus exceptionally high (and even too high for several of the tested flours). This contrasts strongly with the usual harvest conditions in Wallonia, where the Hagberg falling number of the grain of heritage varieties is generally too low, as these varieties are generally sensitive to lodging and thus to germination in the spike, triggering excessive alpha-amylase activity.

The tasting event mentioned in section 2.4 showed one interesting outcome: all the different loaves were positively appreciated by the participants. This is striking compared to the poor results obtained in the laboratory, where all the flours are considered as unsuitable for baking. Furthermore, it was difficult to provide a ranking of the baked flours since what seems to have driven the reported preferences is rather a "baker effect" than the quality of the tested flours: bread baked by the same baker was similar despite the varietal differences and tasters showed preferences linked with the baker, not the variety (i.e., the interested reader can turn to Baijot (2021) for further details of this assessment). Further studies should look deeper into this (artisan) baker effect.

3.3 Qualitative interviews

Given that they were able to make bread with flours that would not satisfy industrial criteria and would thus be downgraded, the qualitative interviews were used to go deeper into the practice of the bakers. More precisely, the interviews seek to understand how the bakers work and how they define the value of a flour. Based on the questions asked during the interviews and subsequent thematic coding of the responses, to identify recurring patterns in the interview data, several key themes emerged: how interviewees define a 'quality flour'; their views on the role of the baker; the importance they attribute to know-how and creativity in artisanal practices; and their perception of working with living matter and the spiritual dimension

of handcraft. These themes occurring in all the discourses are the ones detailed below.

Overall, it is striking that the participating bakers do not choose flour according to its technical advantages as attested by the laboratory analysis. Rather, they put other criteria first and then they adapt to the technical challenges of the flour. They all claim to look for good quality flour, but it is interesting to note that what lies behind "quality" differs from one baker to the other. Overall, they all identify as artisan bakers, which is reflected in the values that emerge from their discourse, as developed hereafter.

3.3.1 A quality flour

Artisanal techniques can preserve, if not enhance, the nutritional properties of the raw food (Ruiz-Cano et al., 2013; Lingham et al., 2022). For Edda, nutrition is the main criteria in her choice of flour. Many of her clients are drawn to the high nutritional quality that her bakery guarantees, achieved through careful selection of wheat varieties and the farmers they collaborate with, based on their agricultural practices. As she explains, "*even some doctors send their patients here.*" For instance, she prioritizes certain varieties for their protein content and glycemic index, focusing on nutritional aspects rather than workability. She avoids strong gluten to ensure her bread is easy to digest. Edda emphasizes that personally knowing the farmers she works with strengthens her trust in the quality of the grain, as she is aware of its origin and the agricultural practices behind its cultivation. Her family also opts for stone milling and maintains close communication with their miller, believing that only a skilled miller can preserve the nutritional quality of the grain. Then the artisan bakers do not just preserve but enhance these qualities maximally through their practices (using sourdough, slow kneading, long fermentation…).

> *"There are now documentaries that show that it is not the gluten level that is important, but it is the quality of the climate and the way you will work the dough. […] According to how you work, you can help the pre-digestion [by the sourdough] to give good nutritional quality to the bread."*[5] *(Edda)*

Edda values nutrition above all. Nutrition always comes back in the interview: on how she chooses her wheat and flour, the reason why she chooses certain baking techniques and when she is asked to give a definition of the "*quality*" of a bread. In the present study, the nutritional quality of the sample was not analyzed. But it does not matter for Edda. It is interesting to notice that for her, heritage varieties *are* more nutritious than modern ones, and that certain milling and baking techniques *are* better to preserve and to add to the nutritional quality of the grain. Edda prefers to work on what she considers as the nutritional quality of her bread because, as she points out, *"people have their own taste."* Taste is indeed difficult to grasp as it is embodied in cultural and subjective aspects.

Still, in contrast, taste is the main motivation for Ihsan and Marie in the flour selection process, and it is even what drove their interest toward heritage varieties. When they are asked about the "*quality*" of bread, the organoleptic values come first, but it is also because they are the sensitive signs of a high nutritional value according to Marie and Ihsan.

> *"It is really in Italy where I worked with Gentil Rosso and the Senatore Capelli, which are very ancient varieties, that I really found the taste of the cereal in the bread. And it was awesome! There, I told myself: "this is this kind of cereals I want to work with"." (Marie)*

Ihsan especially shows enthusiasm in testing different raw materials. Re-centering the tasting pleasure in eating is the core of his project, like a contribution to wellbeing.

> *"Relationship to food is emotional. We eat for emotion and pleasure. We need wheat that can transmit this emotion, otherwise it's useless. […] If you don't enjoy your food when you eat it, your body is not going to receive it the same way." (Ihsan)*

One of the main skills and thrills of the artisanal baker is the ability to bring out the taste of the cereal in the bread. For the interviewed bakers, the taste is the most obvious way to distinguish between artisanal and industrial bread.

> *"We [bakers]don't create, we transform. You don't create taste: you enhance what's already there." (Ihsan)*

> *"Beyond [organic], it is how you bring the taste. In an artisanal practice, there is something. […]. You can see it, you can smell it. You are feeling, you are touching… You can't be tricked". (Edda)*

This echoes some other studies on alternative food initiatives such as Sage (2003, p. 50) who argues that "embodied characteristics of the product—its taste, appearance, and other sensual attributes—[…] give […] it distinction" (i.e., compared to industrial food).

3.3.2 Role of the baker

From the analysis of the interviews, it appears that the role of the baker has different facets, and this multiplicity is at the heart of the meaning of their profession. We can find this state of mind in different people working in alternative bakeries (Demeulenaere and Bonneuil, 2010; Barbier and Moity-Maïzi, 2019). For the present artisans, the baker is responsible for the quality of the bread: ecological, fair, nutritious, healthy, and of course tasty.

> *"Bakers are asked to be kind of a guarantor of the quality of the food that people eat." (Ihsan)*

> *"We have a reputation. Doctors (nutritionists and cancerologists) recommend us to their patients, for the digestibility of our bread. Like Hippocrates said, 'let your food be your first medicine' and we come back to that, nowadays." (Edda)*

Ihsan enhances this with the ongoing multiplicity of labels, supposedly guaranteeing quality but which he considers hollow, and even so fake they become dangerous. Trust between the producer and the consumer is an asset strongly advocated in alternative food networks (Sage, 2003; McKitterick et al., 2016; Lanzi and Maréchal, 2022; Lingham et al., 2022) and also in grain-to-bread chains in

5 All the quotes from the interviews are translated by the authors from French to English.

particular (Masson and Bubendorff, 2022; Meyer et al., 2024). For the interviewed bakers, knowing where the product comes from and how the raw material was grown, but also how it was milled is part of the role of the bakers. The baker has to select carefully the wheat varieties according to their nutritional qualities and their flavors, thanks to this link with the beginning of the chain and to knowledge acquired on the different wheat varieties.

> *« We must be wary of a label of a mercantile system. We must know our products. This is the most important ». (Ihsan)*

For Ihsan, a label is not enough to transcribe the craft of the bakers, including their effort to base their products on a good and truly fair wheat, but also their creativity and their ability to adapt. For the interviewees, particularly Edda and Marie, personally knowing the farmers and millers allows them to better adapt their work to the variability of the raw product, as they can trace the source of any challenges encountered. Moreover, for the interviewed bakers, knowing the consumers seems to be the best way to explain the breadth of their work. This know-how, on how to make *good* bread is at the core of the artisanal practice. Yet, this know-how and knowledge mostly based on experience is hard to grasp with precise criteria, as will be further touched upon in the discussion.

3.3.3 Know-how and creativity of artisans

Despite the use of different terms such as "artisanal," or "craft food," this kind of production differs from the industrial one, in that it rests on skills and know-how of the craftspeople (Autio et al., 2013; Lingham et al., 2022). Our findings corroborate this: the narratives of the bakers strongly evoke the value of artisanal skill and knowledge. As the present research shows, thanks to the artisanal know-how and the handcraft practices, the supposed vagaries of the heritage wheat flour become not so untameable. The early stages of the grain-to-bread chains also draw on craft-expertise. Varieties are chosen carefully by farmers (another kind of craftspeople) grown with awareness and milled with attention (Demeulenaere and Goulet, 2012). The advantage of the alternative bread supply chains lies in the handcraft. As discussed earlier, in the industrial grain system, heavy machines that are limited in their adaptability need flours presenting a "high baking value" to resist the strong kneading they undergo. In the artisanal bread chains, the bakers use small kneaders, or even hand-kneading. Therefore, they can adapt the speed, the strength, of the kneading, and they can add flour or water according to the behavior of the flour. Even though some bakers prefer stable flour, the bakers interviewed in this study, are thrilled by the challenge of having flour to which they have to adapt.

> *"I worked in some bakeries where the work was the same every day. All the flours had a disconcerting stability. Oh, that's so boring! […] I think that any flour can be baked but not by any baker." (Marie)*

As the interviewed bakers explain, the craft skills, the creativity of artisanal work and the will to work with unstable flours, enable the transformation of any kind of flour into a loaf of bread. This creativity, the desire to better understand the flour, the sourdough, the influence of atmospheric pressure, and the necessity of using their senses is what gives meaning to their work.

> *"We are artisans before anything else." (Edda)*

And it is because they are artisans that they constantly try to improve their crafts, seeking for perfection, as Sennett (2008) points out. This is what the interviewed bakers uphold.

> *"We are artisans you know! We are perpetually dissatisfied; we will never be happy with our products. Well, we like them, but we would like to improve them." (Edda)*

> *"I am always researching. I always want to do better. And I am always dissatisfied, which leads me to always look for the rare gem. And I tell you, this is my real job. This is my mission." (Ihsan)*

The main working qualities they underline regarding being an artisanal baker is to take time, to observe, to be flexible. For instance, the bakers have to feel the atmosphere to adapt their practice:

> *"We also work depending on the weather: if it's sunny, if it's stormy, if it's heavy, high or low atmospheric pressure… When the weather is upset, the bread is upset." (Edda)*

This attention to the gesture at any moment expresses a form of "spirituality" that clearly appears in the narrative of some bakers as described below.

3.3.4 Working with the living matter and spirituality in the handcraft practice

Spirituality can be understood as the quality of being concerned with deep, often transcendent values and meanings, distinct from material concerns with a sacred dimension, but separated from (or not especially linked to) religious institutions (Collins English Online Dictionary, 2025). Spirituality is one of the principles of transformative agroecologies, as underlined in Giraldo and Rosset (2023, pp. 838–839): "*transformative agroecology is a way of being, living, feeling, understanding life, acting, and living that far exceeds the economistic understanding that dominates institutions. […] There is something deeper, more enigmatic, more elusive that builds a deep relationship with the land, which must be understood from an esthetic, spiritual, poetic, and sensitive dimension, a mode or way of life.*"

Some artisanal bakers, here Edda and Ihsan, show a certain spirituality when they talk about how they bake, especially during the kneading. This relationship to their handcraft and matter is an essential component behind the reason *why* they are driven toward their work, i.e., artisanal bakery. It gives a strong sense of meaning, through enjoyment, experimentation and connection (Sennett, 2008). For the interviewed bakers, there is a very organic link between the rhythm of the dough and the body rhythm of the baker. The craftsperson learns through their practice how to listen to these rhythms and how to tune them in unison.

> *"This spiritual intention is fully a part of our artisanal know-how. The dough leads you to slow down. Your heartbeat tunes in with this slow rhythm, of these sacred gestures of bread-making." (Edda)*

> *"The sourdough is a central element. It is like the heart of the dough, what is going to give the heartbeat, what is allowing the dough to live". (Ihsan)*

According to the interviewed bakers, this need to be attentive stems from the agency of the matter they are working with, mainly the flour and the sourdough.

> *"We have to try everything to fulfil the flour's expectations." (Ihsan)*

The raw material is seen as a living material, that can change unexpectedly. And it is precisely this dynamic of the material that is giving enjoyment and sense in the artisanal practice. The craftsperson must constantly adapt to the raw material, which is the core of art of baking.

As Edda summarizes, the craft practices are not only a job, but a way of living, because of the intensity of commitment the baker puts in it.

> *"I can say that baking is not a job. Baking is our life." (Edda)*

4 Discussion

4.1 Industrial baking value versus artisanal baking value

The globalized industrial grain-to-bread chain has significant drawbacks, highlighting the urgent need for transformation through their agroecological relocalization (Galli et al., 2015; Barbier and Moity-Maïzi, 2019; Chiffoleau et al., 2021). According to ABSCs actors, one aspect of their agroecological transformation is the use of heritage varieties because they are ecologically sound and nutritionally rich, alongside the fostering of artisanal knowledge and practices suited to these varieties (Demeulenaere and Goulet, 2012; Dinu et al., 2018; Vindras-Fouillet et al., 2021). A challenge remains: heritage varieties produce a weaker dough, and current industrial standards classify them as unsuitable for bread-making (Vindras-Fouillet et al., 2021). Yet, this study confirms that artisanal bakers can use these heritage flours, suited to Walloon soil and climate conditions, to make marketable bread. The qualitative interviews provide insight into the perspectives of artisanal bakers, shedding light on how and why they succeed in working with flours often considered unsuitable, and why they may even prefer them. A key finding of this study is that the notion of "quality" as valued within alternative bread supply chains differs significantly from the one that prevails in industrial baking. This distinction is particularly important: interviewees emphasize taste and perceived nutritional benefits and describe experimentation with diverse flours as a meaningful and integral part of their craft. Furthermore, it appears that the identity of a bread is shaped more by the baker than by the grain variety. Consumers tend to recognize breads by their bakers, as illustrated during the tasting event and supported by existing research (Bracke et al., 2024), highlighting the significance of the baker's expertise and skills. Further research is needed to explore this influence more systematically. This raises important considerations for the co-design of ABSCs: if the perceived quality of bread depends considerably on the baker's handling, this could offer greater flexibility to farmers in selecting grains based on agronomic performance and local growing conditions, rather than attempting to anticipate consumer preferences in taste. However, supplementary studies would be needed to understand how far this baker-led identity dynamic extends across different contexts.

As the results from this study suggest, a Hagberg value > 300 is not a problem for artisanal baking and the explanation is straightforward: the long fermentation times and the work with sourdough rather than yeast still allow the dough to release enough sugars over time because there is always some alpha-amylase which will do the job if given enough time. However, too low Hagberg values are much more difficult to correct. Too much alpha-amylase activity cannot be mitigated by any artisanal means, and it leads to dense, flat, and hard loaves because the fermentation gases are not withheld by the dough (Godin, 2021, oral communication). As such, it might be the only parameter of relevance for the ABSCs in wheat-growing areas with already wet and increasingly unpredictable summers because of climate breakdown. However, there is much scope to adapt cut-off values to the realities of ABSCs. Informal discussions with other bakers from the Walloon ABSCs arena suggest this artisanal cut-off value could be as low as 120, rather than 220 as set by the industry today.

4.2 Artisan's skills can be trained

Given these considerations, one might question whether the currently prevailing industrial criteria truly create barriers for the further deployment of ABSCs. As revealed by the interviewed artisanal bakers, working with flours allegedly unsuitable for bread making is indeed a challenge, requiring time and dedication. It is made possible only through the acquisition of complex craft skills which have been shown to rely on sensory perception as well as intuitive adaptation (Sennett, 2008). Yet, factors such as time constraints, economic considerations, and the need for advanced craft skills must be duly considered when discussing the broader adoption of flours made from heritage wheat varieties in commercial bakeries. Although the participating bakers did not report any difficulty in selling their products at prices they consider fair (i.e., capturing a niche market with consumers willing to pay for artisanal bread), economic considerations and price-related barriers remain a potentially important issue to be addressed in further research (Jenatton, 2023).

Given the importance of craft skills for adapting to heritage flours that this study underscored, training programs emphasizing artisanal techniques appear critical. Climate change is increasingly disrupting wheat cultivation, both globally, affecting Belgium's supply; and locally, through more erratic weather. Modern varieties, which are widely used, tend to be more sensitive to these vagaries and often require agricultural practices that contribute to climate change. This reinforces the relevance of reintroducing locally adapted cereals with heritage varieties, and also the importance of supporting craft-based sensory skills in trainings, such as those practiced in ABSC, to better manage flour variability under uncertain conditions. Currently, baking education in Belgium aligns with industrial practices, focusing on machinery and standards (Plateau et al., 2016). However, many bakers express a need for training in artisanal methods. Integrating artisanal techniques into current programs, along with education on the benefits of heritage varieties for sustainability, health, and local resilience, seems necessary. Courses on artisanal methods, such as the use sourdough and slow kneading, overall adaptable gestures during the whole baking process, e.g.: folding the dough instead of kneading, proofing and shaping, alongside internships

with artisanal bakers, are crucial for apprentices to develop the sensory skills required to work with heritage flours. In craftsmanship, sensory techniques are learned through apprenticeship with professionals (Sennett, 2008). Such trainings should also enhance the understanding of the challenges of farmers and millers (Plateau et al., 2016), resulting in a greater willingness to adapt to a flour that might be a bit harder to work with. In addition, this interconnection also facilitates the crucial role of bakers in ABSCs, who see themselves as responsible for sharing a distinct and alternative storytelling around wheat with consumers (Hills et al., 2013). Artisanal bakers generally demonstrate a strong willingness to share their practices, knowledge, and values widely—both to support the growth of artisanal baking and to raise consumer awareness. However, a key barrier lies in the scarcity of opportunities for such knowledge exchange. Beyond structural challenges, such as the absence of robust networks and formal training programs, the sensitive and experience-based nature of this knowledge makes it difficult to transmit effectively in practical contexts. A participatory action research project was carried out to explore how this kind of knowledge could be shared—most notably through a podcast series, which is now complete and has been well received within the Walloon ABSC community (Chaussebourg et al., 2025).

4.3 The importance of sensitivity in craft skills

The interviews further reveal that the work of bakers is a considerable part of their personal identity. Beyond their will to strengthen the links with wheat growers, millers, and consumers, this is also reflected in their perception of the raw material as *living* matter. The apparent value attributed to the craftwork is indeed rooted in and through a specific *attention* to the raw material (Barbier and Moity-Maïzi, 2019). As artisans identify with their work, they also identify with their product. The bakers are not only using their practical knowledge to put in place 'good practices' to enhance the positive effects on environment and health that heritage wheats provide (Guerrini et al., 2019). They also deploy a particular responsiveness to the *living* raw material that is opening doors for a distinctive way of perceiving their work. Through the interviews, we can clearly notice the attachment of the bakers to the matter they work with, mostly the flour and the sourdough. The matter is not only living matter, but it is also taking an active part in the craftwork. Upstream in the chain, farmers feel the same for seeds and wheat as shown in some studies (Demeulenaere and Bonneuil, 2010; Magda et al., 2022).

This perception of a nonhuman having agency echoes the ideas of Latour (2010), Haraway (2003, 2008), Tsing (2015), Despret (2006, 2019). Through their work, these authors explore the different forms of collaboration that can exist between humans and nonhumans and how the joint actions lead to a common result. In complement to previous findings described in Barbier and Moity-Maïzi (2019), the interviewed bakers show a form of respect toward the basic ingredients. More specifically, they talk about their enjoyment to *work with* the enzymes of flour and sourdough, and they evoke a certain form of spirituality when they bake, through a "connection" to the raw material and their movements. They value a form of sensitivity, assigning a space for their emotions, allowing themselves to be partly guided by them. This sensitivity establishes an openness to the other, allowing them to recognize a form of *agency* in the matter. The flour not passing the industrial tests is deemed "unstable" by the industrial bakery, but considered as *living* for the artisanal bakers, alongside the sourdough made of bacteria and yeasts (Barbier and Moity-Maïzi, 2019).

This sensitive knowledge can be learned through daily practice but also during apprenticeship with other bakers. This form of knowledge is crucial for craftspeople but is challenging to formalize, leading this knowledge to be overlooked in grain-to-bread chains relocalization efforts. Moreover, these considerations are certainly far removed from those attached to the more industrial chains. We could thus legitimately wonder whether this approach of artisanal baking could lead to a paradigm shift. Indeed, moving away from the standard practices in agri-food systems requires no less than a change of *ethos* in our society (Illich, 1973; Gorz, 1974). Allowing sensitivity to be a way of creating knowledge, relating to non-human beings in significant relationships, are radical postures (Arora and Van Dyck, 2021). This radical change of mindsets leads to imagine new paradigms, which is an essential component for a deep agroecological transition (Magda et al., 2022; Munoz-Araya et al., 2024), moving far away from a paradigm based on the *exploitation* of living beings. Therefore, Walloon ABSCs are essential to support, not only to strengthen territorial resilience and to promote more sustainable forms of agriculture but also to move toward a paradigm shift.

4.4 Scaling deep ABSCs

The agroecological paradigm is very insightful when it comes to analyzing the issues at stake within alternative grain-to-bread chains documented in the present study. It indeed provides a promising basis for apprehending the transformation of food systems, stressing the need for systemic redesign toward ecological, economic, and social resilience, and supporting multiple knowledge-rich transitions anchored in local realities (Holt-Giménez and Altieri, 2012; Anderson et al., 2019; Gliessman, 2020; Savels et al., 2024). Conceived as a transformative framework, agroecology requires not only new food and farming practices but also a profound rethinking of agriculture's social, cultural, economic, and political aspects, as well as a reexamination of the ways in which science engages with agricultural and food challenges and how, by who and for who the knowledge is produced (Sachet et al., 2021; Adriaensens et al., 2025). Bringing about such a shift calls for the creation of holistic and transdisciplinary approaches, supported by sensitive and adaptive methodologies, along with a philosophical stance that moves beyond productivist paradigms to acknowledge the cultural and spiritual foundations of food systems (Sachet et al., 2021; Giraldo and Rosset, 2023).

Actors involved in ABSCs are advocating for and to some extent already enacting—transformative changes in grain-to-bread systems. These efforts can be understood through the lens of amplification processes: strategies used by sustainability initiatives, often in collaboration with other stakeholders, to extend their transformative impact (Lam et al., 2020). Among these, Walloon ABSCs appear to participate and give rise to a form of "*scaling deep*," a process aimed at reshaping cultural norms and mindsets by reframing dominant narratives, fostering learning communities (Moore et al., 2015). In our case study, ABSCs are cultivating sensitive, embodied knowledge as a new way of working. A nascent informal network of bakers has emerged to exchange practices and co-produce knowledge. Our research team, involved in the network, launched a participatory podcast created with field actors (for a detailed analysis of this project, see Chaussebourg et al.,

2025, in revision). This podcast initiative aims not only to strengthen field-level knowledge sharing but also to draw the attention of local policymakers to ABSCs as a political issue. Discussions have begun within the network around formalizing artisanal baking training, revealing a tension between maintaining informality and engaging in more explicit forms of political advocacy. At the same time, regional training institutions have started integrating artisanal baking and milling modules into official curricula—a potential sign of *stabilization* (Lam et al., 2020), where initiatives are strengthened through professionalization and institutional recognition. Such developments point toward a possible "*scaling up*" process (Moore et al., 2015; Lam et al., 2020), where ABSCs might begin to influence policy more directly. However, this requires new, often separately structured, initiatives focused on political engagement and collective movement-building (Moore et al., 2015).

In Wallonia, the dynamic of amplification is supported not only by ABSC actors but also by some regional authorities and researchers, including those involved in this study. While these developments are promising, the transformative potential of ABSCs remains only partially realized. Current efforts tend to focus on practical aspects—such as training, skill recognition, and reframing quality—which carry political significance but do not yet amount to a broader, coordinated strategy for transformative change. Links with other agroecological movements and sustained engagement with policymaking remain limited. These gaps may reflect strategic choices, limited resources, or the early stage of collective organization. Strengthening the contribution of ABSCs to agroecological transitions will likely require clearer political positioning, stronger alliances, and continued support for inclusive, systemic approaches.

5 Conclusion

This study demonstrated that: (1) Heritage wheat varieties adapted to Walloon soil and climate conditions do not meet industrial standards for "quality flour" and would thus be considered unsuitable for bread-making in an industrial context. (2) Despite this alleged unsuitability, artisanal bakers can successfully adapt their techniques to work with these flours, producing marketable bread. Further studies are planned to explore more deeply the skillset artisanal bakers use, through baking tests conducted in the presence of researchers and targeted interviews. (3) For the artisanal bakers interviewed, "quality" has a different meaning than in industrial contexts: rather than ease of use (extensibility, elasticity, etc.), they prioritize flavor and nutritional value through grain, milling techniques and their own baking work. The interviews further highlight how these bakers view themselves as guarantors of bread quality, focusing on ecological, fair, nutritious, and flavorful bread. They all take pride in their artisan's skills, combining knowledge with precise skills and an adaptive intuition. Some also emphasize their personal relationships with the producers (farmers) and processors (millers) of their raw materials as a guarantee of quality. Some bakers even describe a connection to their raw materials, like flour and sourdough, which brings a sense of spirituality to their daily practice. All these values are central to their craft and give their work deeper meaning. This sense of purpose appears essential for the viability and further development of ABSCs initiatives, as it fosters resilience and commitment within the community as well as the transmission of strong narratives for the adhesion of consumers.

However insightful, these findings must be taken very cautiously as this study only is a first exploration into the realities of Walloon artisanal bakers and ABSCs dynamics. Although it builds on a long-held prior knowledge of the field, it still has some limitations, notably in terms of scale and year-to-year climate variation. The whole experiment only involved a small sample of bakers and only a small sample of the produced flours was tested by all of them. Still, the qualitative perspective enabled an in-depth exploration of the mindsets of the participants. Additionally, certain external factors restricted the full potential for transdisciplinary research: for instance, COVID-19 restrictions prevented the research team from attending the baking tests in person. As adaptability of baking techniques stands out as a crucial aspect in ABSCs, complementary studies have been launched to more thoroughly explore the skillset artisanal bakers specifically use. The impossibility of observing and interviewing bakers while they were working with their raw material indeed constitutes one important limitation. Furthermore, providing bakers with monetary or practical compensation to ensure that all flour samples would be tested was not feasible within the scope of this study. Another limitation is that this study did not address the time and economic constraints bakers face in accessing and testing heritage flours, nor the potential barriers consumers willing to purchase high-quality artisanal bread could face. These issues thus require future research.

According to our findings, it can reasonably be claimed that the "unsuitability for bread making" of heritage wheat varieties does not really constitute a major obstacle to the deployment of ABSCs if the bakers have artisanal skills. One of the challenges for ABSCs would not be the workability of the flours themselves, but rather the lack of skills to address the unpredictability of the flour. In fact, the absence of apprenticeship in artisanal baking appears to be a more serious barrier to the agroecological transformation of grain-to-bread chains. Conversely, a rethought apprenticeship, along the lines outlined by our findings regarding the importance of sensitivity, notably toward the raw material, is critical for a wider uptake of ABSCs. More importantly, favoring sensitivity may also participate to a distinct perspective on the relationship to living beings and thus offers a promising way forward for a deeper agroecological transition. This would contribute to a shift in cultural imaginaries, an essential dimension of a *scaling deep* process to amplify sustainability transitions, where transformation occurs through changing shared values, cultivating new narratives, and nurturing communities of practice. While such dynamics are already emerging in Wallonia, their consolidation will depend on the capacity to sustain, interconnect, and embed them within institutional support and participatory approaches.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

LC: Writing – original draft, Writing – review and editing, Conceptualization, Investigation, Data curation. FB: Writing

- original draft, Investigation, Data curation. NM: Writing – original drafting, Data curation. MV: Writing – original draft, Writing – review and editing, Supervision. KM: Writing – original draft, Writing – review and editing, Supervision, Funding aquisition.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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