REVIEW ARTICLE

Functional and Novel Foods

The Role of Barley, Sorghum, Rice, and Maize in North African Cuisine

Fatma Boukid [1] ✉ **Hamza Mameri** [2]

1 ClonBio Group LTD, Fitzwilliam Pl, Dublin, D02 XE61, Ireland fboukid@clonbioeng.com
2 INRAE, UMR 1208 Ingénierie des Agropolymères et Technologies Emergentes (IATE), F-34060 Montpellier, France hamza.mameri@inrae.fr

ABSTRACT

Background: Cereal-based foods have been a cornerstone of North African diets for centuries, with grains such as barley, rice, maize, and sorghum holding significant importance for food security, nutritional well-being, and cultural identity.

Aims: This review systematically catalogs traditional cereal-based dishes prevalent across North Africa, specifically focusing on those derived from barley, rice, maize, and sorghum. The review further explores their profound cultural significance, nutritional value, and contemporary adaptations, thereby highlighting their potential relevance in modern dietary trends.

Methods: A comprehensive literature analysis was conducted across scholarly databases such as PubMed, Scopus, and Web of Science, supplemented by an examination of relevant ethnographic and culinary texts. The search strategy incorporated both keywords and controlled vocabulary terms to identify publications spanning from 2000 to May 2024, with no language restrictions (English, Arabic, and French publications were included). The analysis specifically concentrated on the traditional recipes, cooking methods, nutritional profiles, cultural significance, and historical contexts of traditional cereal-based foods indigenous to North Africa.

Results: The review elucidates the substantial diversity and versatility of traditional cereal-based dishes originating from Algeria, Morocco, Tunisia, Egypt, and Libya. These culinary preparations consistently demonstrate high nutritional value, serving as rich sources of essential nutrients such as dietary fiber, protein, and various vitamins. Furthermore, contemporary adaptations and innovative presentations of these traditional dishes present a viable pathway for their integration into health-conscious trends, making them suitable for contemporary diets.

Conclusions: The findings underscore that the strategic revival and modernization of traditional cereal-based foods offer an opportunity for the dual objectives of cultural preservation and enhanced environmental sustainability.

Keywords: Nutrition; Sustainability; Ethnic Foods, Cereals, Food Security.

ARTICLE INFORMATION

✉ **Corresponding author:** Fatma Boukid
E-mail: fboukid@clonbioeng.com
Tel. +36 (302 769 378)

Received: March 27, 2025
Revised: May 20, 2025
Accepted: June 01, 2025
Published: July 11, 2025

Article edited by:
Prof. Khaled Méghit Boumédiène
Article reviewed by:
Dr. Imene Chentir
Dr. Hela Kchaou

Cite this article as: Boukid, F., & Mameri, H. (2025). The Role of Barley, Sorghum, Rice, and Maize in North African Cuisine. *The North African Journal of Food and Nutrition Research, 9* (20): 31–48. https://doi.org/10.51745/najfnr.9.20.31-48

1 INTRODUCTION

Cereal-based foods have long constituted a fundamental component of North African diets, where grains such as barley, sorghum, maize, and rice forming the foundation of numerous traditional dishes across Algeria, Tunisia, Libya, Morocco, and Egypt (Grote *et al.*, 2021; Melih Secer *et al.*, 2020). These cereals possess profound cultural and social significance, shaping community identities and playing key roles in both ritualistic practices and daily sustenance (Moujabbir *et al.*, 2023; Shaikh *et al.*, 2024). In particular, barley and sorghum are particularly well-adapted to the region's arid and semi-arid environments, thereby enhancing food security amid challenges such as drought and desertification (Guetteche *et al.*, 2022).

This review primarily focuses on traditional cereal-based foods derived from barley, sorghum, maize, and rice within North Africa, highlighting their cultural and nutritional importance. From a nutritional perspective, these grains offer valuable dietary fiber, complex carbohydrates, proteins, and essential micronutrients including iron and magnesium, which are particularly important in communities characterized by limited dietary diversity (Arzani & Ashraf, 2017; Boukid, 2024a). Despite their significance, recent decades have witnessed a decline in their consumption, largely attributed to modernization, urbanization, and the increasing preference for processed and refined wheat products (Noort *et al.*, 2022; Melih Secer *et al.*, 2020; Reardon *et al.*, 2021). This dietary shift not only affects nutritional intake but also poses a risk to the preservation of intangible cultural heritage,

as traditional knowledge is primarily transmitted orally and often remains undocumented (Casari *et al.*, 2022).

Although wheat currently dominates extensive research due to its ubiquitous use, other cereals such as barley, sorghum, maize, and rice hold unique culinary, nutritional, and ecological importance within the North African region (Zhou *et al.*, 2014). Barley and sorghum are highly valued for their drought tolerance and ability to thrive in nutrient-poor soils (Adebo, 2020; Allel *et al.*, 2017; Westengen *et al.*, 2014). Conversely, maize and rice, while less traditionally cultivated due to their higher water requirements, have progressively been incorporated into North African diets through increased imports and evolving culinary practices (Ayyad *et al.*, 2024).

Traditional processing techniques, such as stone milling, hand sifting, and the production of varying granule sizes, are integral to the preparation of these cereals (Fišteš, 2021; Aboubacar *et al.*, 2006; Aboubacar & Hamaker, 1999). Despite being labor-intensive, these methods preserve nutrients such as dietary fiber and vitamins and maintain whole grain integrity, offering benefits such as slower digestion and sustained energy release, despite challenges like uneven particle size (Tagliasco *et al.*, 2024; Cappelli *et al.*, 2020).

Recent global trends favoring sustainable and health-conscious dietary patterns have renewed interest in these cereals due to their nutritional and environmental benefits (Soto-Gómez & Pérez-Rodríguez, 2022). International initiatives, such as the Food and Agriculture Organization's (FAO) support for underutilized crops and PRIMA projects, aim to facilitate the integration of these traditional grains into sustainable agriculture systems and diets in North Africa, thereby supporting food security and cultural preservation (Britwum & Demont, 2022; Ramadan, 1986).

This review addresses a critical knowledge gap by cataloging traditional North African dishes made from barley, sorghum, maize, and rice. It further explores their preparation methods, regional variations, and adaptation to modern health-conscious lifestyles. Ultimately, this work contributes to the preservation and appreciation of these culturally and nutritionally vital grains.

2 Research Methodology

A systematic literature review was conducted using scholarly databases, including PubMed, Scopus, and Web of Science. The search strategy involved a combination of keywords and controlled vocabulary terms to retrieve relevant literature on traditional cereal-based foods in North Africa. Example keywords included "barley AND traditional food", "maize AND North Africa", "rice AND fermented dishes", and "sorghum AND culinary heritage"). The review also examined traditional preparation methods employed in the processing of cereal-based foods across North Africa.

The search focused on peer-reviewed articles, review papers, ethnographic studies, and grey literature (e.g., government reports, academic theses, institutional publications, and traditional recipe books) published between January 2000 and August 2024. Publications in English, Arabic, and French were included to ensure comprehensive coverage of the primary languages in the region. Reference lists from selected articles and books were manually searched to identify additional relevant sources not captured in the initial database searches.

Inclusion criteria encompassed:

- Peer-reviewed articles, ethnographic studies, review papers, and relevant grey literature (e.g., government reports, theses, institutional publications, and traditional recipe books)
- Publications from January 2000 to August 2024.
- Content addressing traditional barley, maize, rice, and sorghum-based foods in North Africa.
- Publications in English, Arabic, or French.

Exclusion criteria eliminated

- Studies unrelated to the specified cereals or the North African region.
- Publications lacking sufficient detail on methodology
- Non-substantive sources such as general commentaries or unpublished abstracts.

The data collected were analyzed using a narrative synthesis approach, enabling the integration of diverse sources to identify thematic patterns related to traditional cereal-based foods in North Africa.

3 Overview of Cereal Crops in North Africa: Historical Legacy and Contemporary Production

3.1 Barley

Barley (*Hordeum vulgare* L.) holds a crucial position in North African agriculture and cuisine, serving as a primary cereal crop within a region characterized by diverse climatic conditions (Dawson *et al.*, 2015; Mohamed *et al.*, 2021). Archaeological evidence suggests that barley has been cultivated in North Africa since the Neolithic period, demonstrating significant historical importance in Morocco, Algeria, Libya, Tunisia, and Egypt (Ben Naceur *et al.*, 2012). The utilization of barley grains dates back approximately 18,300 to 17,000 years ago. Its domestication, which commenced approximately 10,000 years ago in the Fertile

Crescent, led to its gradual adaptation to the specific climatic and soil conditions of North Africa (Mohamed *et al.*, 2021). Recent studies indicate that North Africa could be considered a secondary center of barley diversification. Key traits, such as non-brittle rachis and increased seed size and fertility, were selected during this process, which enhanced barley's agricultural viability (Palmer *et al.*, 2009). Historically, barley has been the cereal of choice for rural populations in North Africa due to its resilience (Allel *et al.*, 2017). Its ability to thrive in drought-prone areas and nutrient-poor soils established it as a staple crop, especially during periods of food scarcity (Achli *et al.*, 2022). Barley was also instrumental in ensuring food security, particularly during periods of urban-rural disparity when wheat was favored in cities, while barley remained a rural reserve (Allel *et al.*, 2017; Salih *et al.*, 2022).

In contemporary North Africa, barley remains the second most important cereal after wheat, fulfilling a dual role in both human food consumption and livestock feed. Approximately 3.8 million hectares of barley are cultivated across the region annually (Salih *et al.*, 2022). Between 2019 and 2023, Morocco led regional production with an average of 1.3 million tons per year, followed by Algeria at 1.2 million tons, and Tunisia with approximately 471,000 tons (USDA, 2024). While Libya and Egypt exhibit lower barley production levels, at 100,000 and 97,000 tons respectively, barley remains a staple in rural areas and contributes to overall food security (USDA, 2024). However, regional barley production often falls short of meeting domestic demand, necessitating imports to bridge the supply gap. Barley's future in North Africa faces challenges from climate change and population growth, yet its adaptability positions it as a vital crop in combating food insecurity (Kertolli *et al.*, 2024).

3.2 Sorghum

Sorghum (*Sorghum bicolor*, (L) Moench) has played a crucial role in the history and agriculture of North Africa, particularly in the Sahel arid region, where it has been significant for food security since the early Holocene (Beldados & Ruiz-Giralt, 2023). Archaeological evidence suggests that sorghum utilization dates back approximately 9,100–8,900 years before the present (B.P.), with notable discoveries near the Egypt-Sudan border (Beldados & Ruiz-Giralt, 2023; Westengen *et al.*, 2014). This period marked a significant shift from hunting and gathering to agropastoralism, as communities adapted to the changing environment during the Sahara's transition to a drier climate. Archaeological discoveries from the 8th millennium BCE in Libya (e.g., Uan Afuda Cave and Takarkori rockshelter) and the 6th to 3rd millennium BCE in Egypt (such as Nabta Playa and Hidden Valley) underscore the ancient and sustained use of wild sorghum in these regions (Wasylikowa *et al.*, 1997; Wasylikowa & Dahlberg, 1999). Sorghum cultivation, alongside cattle herding, emerged as a successful adaptation strategy for the dry grassland ecology, facilitating the spread of these practices across Central Africa as climatic conditions evolved (Fuller & Stevens, 2018).

Between 2019 and 2023, Egypt recorded the highest sorghum production in North Africa, with an average annual output of 768,000 tons. In contrast, Morocco's production was considerably lower, averaging only 5,000 tons over the same period (USDA, 2024). Morocco's lower production and consumption reflect differing agricultural priorities and climatic constraints. Currently, sorghum is primarily utilized for human consumption in North Africa, where it remains a staple food, while a smaller portion is allocated for animal feed (Adebo, 2020). However, domestic production frequently falls short of meeting demand, necessitating imports to cover the deficit, especially in regions heavily reliant on sorghum for food security.

3.3 Rice

Rice (*Oryza sativa*) originated in Asia and spread through trade routes into the Middle East, North Africa, and Europe (Snodgrass & Hufford, 2018). *Oryza glaberrima* developed independently in West Africa, exhibiting high adaptation to local climates and ecosystems (Spengler *et al.*, 2021). The rice cultivated in Egypt belongs to *Oryza sativa*, which was introduced to Egypt through trade, notably as a luxury import by the first century AD (Reed & Leleković, 2019). Over time, rice evolved into a significant crop in Egypt, especially during the Mamluk and Ottoman periods (Shopov, 2019). By the 18th century Ottoman period, rice was largely imported, often from Egypt, and became associated with elite banquets (Spengler *et al.*, 2021).

Today, Egypt remains the largest producer of rice in North Africa, with an average annual production of approximately 6.9 million tons between 2019 and 2023 (USDA, 2024). Egyptian rice cultivation is primarily concentrated in the Nile Delta, where abundant irrigation facilitates high yields (Khodeir *et al.*, 2018). As rice continues to be a staple food in Egypt, its production is essential for ensuring food security in a region increasingly affected by climate variability (Elsadek *et al.*, 2024). In contrast, rice cultivation in Morocco is considerably smaller, with an annual production of 44,000 tons (USDA, 2024). Rice in Morocco is cultivated under irrigation, reflecting the limited water resources available for such a water-intensive crop.

3.4 Maize

Maize (*Zea mays*) originated approximately 10,000 years ago in Mesoamerica. Its domestication involved selecting and breeding teosinte, the wild ancestor of maize, leading to the diverse varieties available today (Spengler *et al.*, 2021). Following Columbus's discovery of the Americas, maize was

introduced to Africa in the seventeenth century by the Portuguese, who initially brought it to supply their trading forts (Bjornlund *et al.*, 2020; Cherniwchan & Moreno-Cruz, 2019). African farmers rapidly adopted the crop due to its high energy yield, low labor requirements, and short growing season. By the early 1700s, historical evidence indicates that maize was cultivated widely across much of the African continent (Cherniwchan & Moreno-Cruz, 2019).

By the early 20th century, maize had become an important crop in the region, contributing to shifts in both dietary and agricultural practices (McCann, 2001). Today, Egypt leads the region in maize production, with an annual average of 7 million tons from 2019 to 2023 (USDA, 2024). This reflects the crop's importance as a staple food and feed for Egypt's expanding poultry and livestock industries. In comparison, Morocco produces 41,000 tons annually, while Algeria's production is notably lower at just 5,000 tons (USDA, 2024). Although maize is not as deeply ingrained in North African culture as wheat or barley, its role in modern agriculture is growing, particularly as climate change alters agricultural viability across the region.

4 Traditional Cereals-Based Foods in North Africa

4.1 Barley

Barley is recognized for its versatility and high nutritional profile (Raj *et al.*, 2023). It serves as a significant source of dietary fiber, particularly β-glucans, which have demonstrated efficacy in regulating blood sugar levels and improving cardiovascular health (Boukid, 2024a; Piechota *et al.*, 2020). Additionally, it provides significant amounts of vitamins (notably B vitamins), minerals (such as magnesium, selenium, and phosphorus), and protein (Boukid & Mefleh, 2024). Barley ingredients, including whole grains, semolina, and flour, have historically been used to create a diverse range of traditional dishes (Table 1).

A. Whole Barley Grain Dishes

Mahrash is a traditional Moroccan bread primarily prepared from barley grits. The preparation commences with soaking the barley grits overnight, which facilitates spontaneous fermentation (Moujabbir *et al.*, 2023). Subsequently, semolina flour, along with spices such as cumin and salt, is incorporated to create a dough. A contemporary variation of this bread includes yeast fermentation. When *Mahrash* is made using barley flour instead of grits, it is referred to as *Mahsrash Shair*.

Chorba shair (barley soup) or *Chorba frik* is a traditional North African soup, frequently prepared during Ramadan fasting month. Its preparation typically involves pre-soaking barley grains, followed by drying, and cracking them into different sizes. This process is usually undertaken during the summer after the harvest, and the prepared *Choba shair* is then stored for year-round use. The soup typically includes *Choba shair*, onions, olive oil, garlic, meat, tomatoes, and spices such as coriander, cumin, and pepper. The use of *Choba shair* imparts a distinctive thickness and texture to the soup, which can also be prepared with similar ingredients (Shaikh *et al.*, 2024).

Bsissa, also called *Dardoura*, *Zomita*, or *Zommita* is a traditional North African mixture prepared with roasting and milling barley grains, roasted chickpea, fenugreek, and spices (e.g., cumin, fenugreek, and coriander) (Boukid, 2024b). Although direct nutritional studies on *Bsissa* are limited, its primary ingredients are well-recognized sources of complex carbohydrates, plant-based protein, dietary fiber, and essential micronutrients, including iron and magnesium. Both barley and chickpeas exhibit low glycemic indices, and fenugreek is renowned for its hypoglycemic and lipid-lowering properties (Saddoud Debbabi *et al.*, 2024). These attributes suggest that *Bsissa* may contribute positively to metabolic health, particularly within dietary strategies aimed at managing type 2 diabetes and obesity. Traditionally, *Bsissa* is consumed by mixing the dry flour with milk or water. During Ramadan, it is commonly prepared with water and sugar as a quick and sustaining option for breaking the fast. A thicker version involves combining the mixture with olive oil and sugar to form a dense batter, often garnished with dates or *Chamia*, a traditional sweet made from sesame paste (Saddoud Debbabi *et al.*, 2024).

Laklouka is a seasonal sweet dish from Sfax and the Kerkennah Islands, primarily prepared during the winter months. The process initiates with dried raisins being boiled in water, filtered, and then re-boiled to concentrate the juice. This concentrated juice is subsequently mixed with flour, *Bsissa*, and boiled olive oil, resulting in a dessert that is typically garnished with almonds. *Laklouka* is often served as a breakfast or snack item (Saddoud Debbabi *et al.*, 2024).

Ourkimn is a traditional Algerian communal dish that consists of a diverse blend of ingredients, including whole wheat grains, decorticated barley, maize cobs, faba beans, peas, sorghum, carob, chickpeas, lentils, and dried turnips, with various spices. The preparation involves slow cooking a leg of veal with these components. This dish typically reinforces social bonds and community spirit, especially during the Ashoura festival. As an ancestral recipe among the Amazigh people, *Ourkimn* serves as a celebratory meal for the Amazigh New Year (Deschane, 2024).

Bouza is a traditional homemade beer from Egypt, primarily made from wheat, although other grains such as barley, millet, sorghum, or maize can also be used. The preparation commences with cleaning and separating the

Table 1. Barley-Based Traditional North African Dishes

Product	Origin	Principal Ingredients	Preparation	Reference
Mahrash	Morocco	Barley grits, yeast, oil	Barley grits are soaked and mixed with barley flour and spices and then baked.	Raj *et al.*, 2023
Chorba Shair	North Africa	Barley grains, onions, olive oil, meat, tomatoes, spices	Pre-soaked barley is cooked with onions, olive oil, meat, tomatoes, and spices, creating a thick soup.	Shaikh *et al.*, 2024
Bsissa	North Africa	Roasted barley, chickpeas, cumin, fenugreek, coriander	Roasted barley and chickpeas are ground with spices into flour, which can be mixed with milk, water, or olive oil.	Saddoud Debbabi *et al.*, 2024
Laklouka	Tunisia (Sfax)	Raisins, flour, *Bsissa*, olive oil, almonds	Prepared by combining concentrated raisin juice with *Bsissa*, a flour made from roasted barley and chickpeas mixed with spices, and boiling olive oil.	Saddoud Debbabi *et al.*, 2024
Ourkimn	Algeria	Barley, wheat, lentils, beans, peas, fava beans, maize, chickpeas, spices, meat, dates	A mixture of grains, legumes, and spices is slow-cooked with meat for several hours to create a porridge-like dish.	Deschane, 2024
Bouza	Egypt	Wheat (or barley, millet, sorghum, maize), water	Grains are partially ground and shaped into loaves, which are lightly baked. The remaining grains are soaked and then combined with the baked loaves and water to ferment.	Morcos *et al.*, 1973
Kesra	North Africa	Barley flour, water, yeast, salt	Barley flour is mixed with water, yeast, and salt to form dough. The dough is left to rise, shaped into flat rounds, and then baked on a griddle or in an oven.	Karous *et al.*, 2021
Bazin	Libya	Barley flour, water, meat, vegetables, sauce	Barley flour is cooked with water until it forms a thick porridge-like consistency.	Swesi *et al.*, 2020
Talbina	Egypt	Barley flour, water or milk	Barley flour is cooked in water or milk to create a smooth porridge, typically consumed for its nutritional benefits.	Badrasawi *et al.*, 2013
Labsis	Morocco	Roasted barley flour, honey, eggs, salt, argan oil, cumin (optional)	Roasted barley flour is mixed with honey, hard-boiled eggs, salt, and argan oil.	El Yamani *et al.*, 2024
Toumit	Morocco	Roasted barley flour, cold water, olive oil	Roasted flour is mixed with cold water and olive oil to create a paste.	El Yamani *et al.*, 2024
Lamris	Morocco	Roasted barley flour, cold water or buttermilk, argan oil	Roasted flour is combined with cold water or buttermilk and argan oil to make a paste-like dish.	Moukal, 2004
Barley Couscous	North Africa	Barley semolina, water	Barley semolina is hydrated by gradually adding water to form small granules. The granules are rolled, dried, and steamed until tender.	Messia *et al.*, 2019
Tagoulla	Morocco	Roasted barley semolina, water, argan oil, fermented milk (optional), dates, almonds	Roasted semolina is stirred into boiling water until a thick consistency is reached.	Barkaoui *et al.*, 2024
Malthouth	Tunisia	Barley semolina, olive oil, vegetables, lamb or octopus, water, salt	Barley semolina is cooked with a broth of olive oil, vegetables, and meat	Lahouar *et al.*, 2017

selected cereal. Three-quarters of the grain is then ground, mixed with water, and formed into loaves that are lightly baked, leaving the centers uncooked. The remaining quarter of the grain is soaked in water to promote malting or sprouting, depending on the specific method employed. After baking, the loaves are crumbled and combined with water and the soaked grain to create a mixture that undergoes fermentation (Morcos *et al.*, 1973). To initiate fermentation, a small amount of previously prepared *Bouza* may be added. Following a minimum fermentation period of one day, the mixture is strained, making it ready for consumption or storage.

B. Flour

Barley flour is obtained through a series of processes that involve cleaning, soaking, and milling (a stone mill) of barley grains into a fine powder (Fišteš, 2021). Roasted flour is a distinct type of flour prepared through a traditional process involving the steaming, drying, roasting, and milling of green grains harvested before full maturity or soaked grains at maturity (Farag *et al.*, 2020). The traditional processing steps for both barley flour and roasted barley flour are illustrated in Figure 1.

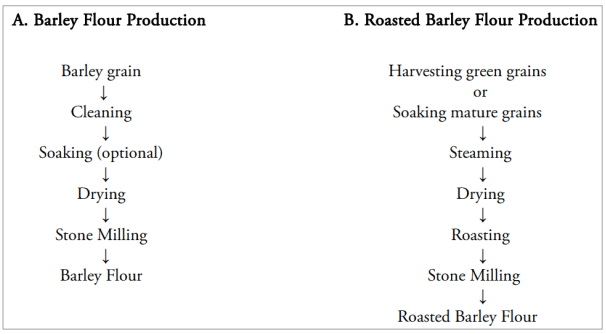

Figure 1. Traditional processing steps for (A) barley flour and (B) roasted barley flour production

Kesra, also called *Kobz Chair*, is a traditional North African flatbread made from barley flour (Karous *et al.*, 2021). This traditional bread is characterized by its dense texture and slightly nutty flavor. The dough, comprising barley flour mixed with water, sourdough (currently replaced by yeast), and salt, undergoes a rising period prior being shaped into flat rounds and baked on a griddle or in an oven. *Khemir Kesra* incorporates a fermentation process utilizing sourdough or yeast, which allows the dough to rise for an extended duration. This fermentation enhances the flavor, texture, and digestibility, yielding a softer, tangier version compared to its unfermented counterpart (Perri *et al.*, 2023). *Kesra* is commonly served as an accompaniment to soups, stews, and tagines (Pasqualone, 2018).

Bazin is a traditional Libyan dish primarily composed of barley flour, which is cooked into a thick porridge. The preparation method involves combining barley flour with water and then cooking the mixture until it achieves a dense, pudding-like consistency. It is typically served with a variety of accompaniments, including meat, vegetables, and sauce, and is often served during communal gatherings and special occasions (Swesi *et al.*, 2020).

Talbina is a traditional Egyptian porridge prepared from whole barley flour (Afzaal *et al.*, 2021). It is prepared by cooking barley flour in water or milk until it reaches a smooth, thickened consistency. This dish is frequently sweetened with honey and occasionally flavored with spices such as cinnamon. Historically, *Talbina* has been consumed during periods of illness or emotional distress, and its use is supported by references in Islamic tradition, where it is noted for its calming and restorative properties (Badrasawi *et al.*, 2013).

Labsis is a traditional Moroccan snack consisting of roasted barley flour, honey, hard-boiled eggs, salt, with the addition of argan oil (Moukal, 2004). The barley flour is roasted to intensify its flavor, then combined with honey, chopped hard-boiled eggs, and salt. Argan oil is incorporated for its nutritional value, particularly its monounsaturated fat content. Optional ingredients, such as cumin, fennel, oregano, or thyme, can be added. *Labsis* is typically prepared for special occasions such as weddings, religious holidays, and Quranic memorization ceremonies (El Yamani *et al.*, 2024).

Toumit is a simple Moroccan dish prepared by mixing roasted barley flour with cold water and olive oil. The roasted flour is combined with cold water to form a smooth paste, and olive oil is added to enhance texture and provide healthy fats. This dish is rapid to prepare and is valued for its simplicity and nutritional benefits (El Yamani *et al.*, 2024).

Lamris is made by mixing roasted barley flour with cold water or buttermilk and argan oil. The barley flour is roasted and then combined with cold water, buttermilk, and argan oil. This dish is commonly consumed for breakfast or as a snack, especially in Quranic schools or among lower-income households, owing to its high energy content and affordability (Moukal, 2004).

C. *Semolina*

Barley couscous, produced from barley semolina follows a process distinct from traditional whole-grain couscous (Messia *et al.*, 2019). Initially, finely milled barley flour is hydrated by gradually incorporating water, which facilitates the agglomeration of the flour into small granules (Chemache *et al.*, 2021). These granules are then manually rolled to achieve uniform size and shape. Subsequently, the granules undergo a drying process to reduce moisture content, which facilitates to preserve their structural integrity during cooking (Boukid, 2021b). The dried granules are subsequently steamed until they reach a tender and fluffy consistency. Barley couscous is commonly served with stews, vegetables, or meat, similar to wheat couscous. Nutritionally, barley couscous is rich in dietary fiber, particularly arabinoxylans and β-glucans, which are recognized for their beneficial effects on cardiovascular health, glycemic control, and gut microbiota diversity (Guarneiri *et al.*, 2024; Kovatcheva-Datchary *et al.*, 2015). Additionally, the lower glycemic index of barley couscous compared to wheat couscous makes it a suitable option for individuals seeking to manage blood sugar levels (Messia *et al.*, 2019).

Tagoulla is a traditional dish of the Amazigh people, prepared by combining roasted barley semolina and maize semolina with boiling water and stirring until a thick consistency is achieved (El Yamani *et al.*, 2024). This dish is typically seasoned with argan oil, though fermented milk is occasionally used. It serves as the primary meal of shepherds and is also consumed at snack time or dinner. During the celebration of *Idh Yennayer*, the Amazigh New Year, *Tagoulla* is usually garnished with dates and almonds (Barkaoui *et al.*, 2024).

Malthouth is a traditional Tunisian dish prepared from barley semolina, which is produced by cleaning, roasting, and then cracking barley grains (Lahouar *et al.*, 2017). The preparation involves dampening the cracked barley and mixing it with salt and barley couscous. This mixture is then placed in the upper part of a couscous pot, while the lower part contains olive oil, vegetables, salt, water, and either lamb or octopus. The dish is simmered for approximately one hour, allowing the flavors to meld. During colder months, *Malthouth* is frequently served with a stew prepared with vegetables and meat. Another variation, *Malthouth bel Besbes*, involves cooking the barley semolina with green fennel leaves and other spices (Lahouar *et al.*, 2017).

4.2 Sorghum

Sorghum is utilized in a variety of traditional dishes across the region, primarily in the form of puddings and pastries (Table 2). Despite its extensive historical presence in the region, sorghum remains among the least developed cereals, likely attributable to limited awareness of its agronomic and nutritional advantages. However, sorghum is a gluten-free cereal abundant in dietary fiber, which supports digestive health and contributes to blood glucose regulation (Aguiar *et al.*, 2023). It also constitutes a valuable source of essential macro and micro-nutrients, including protein, phenolic compounds, vitamins (e.g., B vitamins), and minerals (e.g., iron and magnesium) (Abdelbost *et al.*, 2023). Furthermore, sorghum contains antioxidants that may contribute to overall health and reduce the risk of chronic diseases (D'Almeida *et al.*, 2025).

Couscous can be prepared by substituting barley with sorghum flour in Algeria and Tunisia. This dish involves steaming sorghum couscous, which is then combined with dried fruits, nuts, and occasionally sugar and butter. It is particularly consumed during festive occasions or as a dessert during Ramadan (Galiba *et al.*, 1988).

Sohleb is a sorghum-based pudding widely consumed in Tunisia, Morocco, and Algeria. The preparation involves cooking sorghum flour with water or milk until a soft and creamy consistency is achieved. This porridge is typically sweetened with honey or dates and can be further enriched with ingredients such as nuts, dried fruits, or *Chamia* (Kouki *et al.*, 1989).

Bouza is a traditional Tunisian pudding composed of sorghum flour, sesame paste, and hazelnut flour. The preparation involves blending these ingredients with water to create a smooth mixture. This mixture is then cooked until it thickens. Milk and sugar are then incorporated into cooked base, and the dessert continues to cook while being stirred until a creamy consistency is achieved (Kouki *et al.*, 1989).

Bsissa is a traditional Tunisian and Libyan preparation consisting of roasted grains mixed with spices. A specific variant of *Bsissa* utilizes roasted sorghum grains as its primary base. The roasted sorghum is milled into a fine powder and blended with spices such as cumin, coriander, and fenugreek. This mixture can be consumed as a dry snack or mixed with water or milk to create a paste, often served during Ramadan for its energy-boosting properties (Boukid, 2024b).

Ghraiba, a traditional North African cookie, includes a variant known as "*Dooria*" that is prepared with sorghum flour. This cookie is known for its crumbly texture and rich flavor, usually prepared with the addition of butter, sugar, and spices such as cinnamon (Kouki *et al.*, 1989).

4.3 Rice

Rice (*Oryza sativa*) serves as a staple cereal primarily consumed in Egypt and Libya, though its prevalence is less in Tunisia, Morocco, and Algeria due to limited traditional cultivation in these regions (Table 3). This cereal is predominantly composed of carbohydrates, providing a significant energy source essential for daily activities.

Table 2. Sorghum-Based Traditional North African Dishes

Product	Origin	Principal Ingredients	Preparation	References
Couscous	Algeria, Tunisia	Sorghum flour, dried fruits, nuts, sugar, butter	Steamed sorghum couscous mixed with dried fruits, nuts, and occasionally sugar and butter; often served as a festive dessert.	Galiba *et al.*, 1988
Sohleb	Tunisia, Morocco, Algeria	Sorghum flour, water or milk, honey, nuts	Cooked sorghum flour with water or milk until creamy, sweetened with honey or dates.	Kouki *et al.*, 1989
Bouza	Tunisia	Sorghum flour, sesame paste, hazelnut flour, milk	Ingredients are blended with water, cooked until thickened, then milk and sugar are added and stirred until creamy.	Kouki *et al.*, 1989
Bsissa	Tunisia, Libya	Roasted sorghum grains, spices	Roasted sorghum ground into powder mixed with spices like cumin, consumed dry or mixed with water/milk for a paste.	Boukid, 2024b
Dooria	North Africa	Sorghum flour, butter, sugar, spices	Cookies made with sorghum flour for a crumbly texture, flavored with spices like cinnamon, and baked until golden.	Kouki *et al.*, 1989

Naturally low in fat and gluten-free, rice accommodates various dietary needs, making it suitable for individuals with gluten intolerance (Bani *et al.*, 2024). Additionally, depending on the variety, rice also offers essential vitamins and minerals, including B vitamins, iron, magnesium, and selenium (Fukagawa & Ziska, 2019).

Osbana (or *Osbane*) is a traditional North African dish prepared from lamb offal, including the heart, liver, spleen, and kidneys. The offal is boiled, finely chopped, and then combined with rice, spices, chopped onion, vegetable oil, parsley, and dill. The mixture is stuffed into a cleaned lamb stomach. *Osbana* is often prepared during special occasions such as Aid Al Adha and is served either with couscous or in a sauce (Gagaoua & Boudechicha, 2018).

Rouz or *Riz* or *Roz* is prepared by steaming or cooking rice with chicken or meat or *Osbane* or vegetables, and a blend of spices. *Rouz Bel Fakhia* (rice with nuts) is a variation frequently served at weddings. This dish features rice that is steamed until tender and then combined with a savory sauce including meat, saffron, and turmeric. The dish is garnished with a variety of nuts. *Rouz Jerbi* is a traditional Tunisian dish, particularly popular on the island of Djerba. It is made by steaming white rice combined with various ingredients such as meat (beef, lamb, or chicken), vegetables, and spices (Kouki *et al.*, 1989).

Table 3. Rice-Based Traditional North African Dishes

Product	Origin	Principal Ingredients	Preparation	Reference
Osbana	North Africa	Lamb offal, rice, spices, onion, parsley	Offal is boiled and chopped, mixed with rice and spices, stuffed into a lamb stomach, and cooked.	Gagaoua & Boudechicha, 2018
Warak Enab	Egypt/Libya	Grape leaves, rice, minced meat, herbs	Grape leaves are blanched, filled with a rice and meat mixture, rolled tightly, and cooked in water with olive oil and lemon juice.	Melih Secer *et al.*, 2020
Rouz	North Africa	Rice, meat (or *Osbane*), vegetables, spices	Rice is cooked with chicken or meat and seasoned with spices.	Kouki *et al.*, 1989
Roz Mehammar	Egypt	Rice, milk, butter, cream, chicken stock	Rice is cooked with milk and broth, and then baked in a clay pot.	Mahgoub & Badawy, 2015
Koshary	Egypt	Rice, lentils, pasta, chickpeas, tomato sauce	Rice and lentils are cooked separately, layered with pasta and chickpeas, and topped with a spiced tomato sauce and fried onions.	Halawa, 2023
Fattah	Egypt	Lamb, spices, *Eish baladi* (flatbread)	Rice is used as a key ingredient in the layers of Fattah.	Khodeir *et al.*, 2018
Hamam Mahshi	Egypt	Pigeons, rice or freekeh, herbs, spices	Rice is mixed with meat or vegetables and spices and used as a filling for pigeons.	Mohamed *et al.*, 2024
Roz bil Shareya	Egypt	Rice, vermicelli noodles, oil or butter	Vermicelli is sautéed, then rice is added and cooked with water.	Al-Khusaibi, 2019
Mahalabiya	Middle East	Rice flour, milk, rosewater	Milk is heated and mixed with rice flour to create a smooth dessert.	El-Arab *et al.*, 2004

Stuffed grape leaves, commonly referred to as *Warak Enab* in Egypt, *Abrak* in Libya, and *Dolma* in various Middle Eastern cuisines, are a significant dish characterized by filling wrapped in grape leaves (Melih Secer *et al.*, 2020). The preparation involves blanching fresh grape leaves to enhance their pliability, thereby facilitating easier rolling around the filling. The filling often consists of rice, which may be combined with minced meat (e.g., lamb or beef), herbs such as coriander, and vegetables including tomatoes and onions. After being filled, the grape leaves are tightly rolled and secured at the ends to prevent the filling from escaping during cooking process. The stuffed leaves are then arranged in a pot, often layered with additional grape leaves or vegetables, and cooked slowly in a mixture of water, olive oil, and lemon juice until the rice is tender and fully cooked (Melih Secer *et al.*, 2020).

Roz Mehammar is a traditional baked rice dish in Egypt. The preparation involves cooking rice with milk, butter, and cream, along with chicken stock or broth, followed by baking it in a clay pot. This dish is usually reserved for special occasions or festivals, offering a more indulgent alternative to plain rice. It can also be prepared in a sweet version (Mahgoub & Badawy, 2015).

Koshary is an Egyptian dish characterized by its layered composition of rice, lentils, pasta, and chickpeas, typically topped with a spiced tomato sauce and crispy fried onions. The preparation of *Koshary* typically involves cooking the rice and lentils separately, followed by layering them with boiled pasta and chickpeas, culminating in a tomato sauce and the addition of fried onions for texture (Halawa, 2023).

Fattah is a traditional Egyptian culinary preparation characterized by its layering of flavors and textures. It consists of chunks of lamb, seasoned with bay leaves and a variety of spices, served over crispy *Eish Baladi*, an Egyptian flatbread. The dish is also layered with rice and customarily crowned with a tangy garlic-vinegar sauce. *Fattah* is usually

associated with festive occasions and is emblematic of Egyptian communal dining practices (Khodeir *et al.*, 2018).

Hamam Mahshi, a staple in Egyptian cuisine, involves the stuffing of pigeons with a mixture of rice or freekeh, along with a blend of herbs and spices. The preparation process involves boiling the pigeons until cooked, followed by roasting or grilling (Mohamed *et al.*, 2024).

Roz bil Shareya is a traditional Egyptian rice dish characterized by the incorporation of vermicelli noodles (*Shareya*). Preparation commences by sautéing vermicelli in oil or butter until a golden-brown hue is achieved. Afterward, rinsed long-grain rice is incorporated to the mixture. Water is then added and brought to a boil, whereupon the mixture is covered and allowed to simmer over low heat. This cooking method ensures that the rice absorbs the liquid evenly, yielding a fluffy texture. Once cooked, the dish is typically served as a side to stews or grilled meat (Al-Khusaibi, 2019).

Mahalabiya is a traditional pudding originating from the Middle East, including Egypt. The primary ingredients include rice flour, milk, and rosewater. The preparation involves heating and mixing the milk and the rice flour to achieve a smooth consistency. Once prepared, *Mahalabiya* is commonly garnished with toasted nuts (El-Arab *et al.*, 2004).

4.4 Maize

Maize is a nutrient-dense, gluten-free grain that provides essential vitamins, minerals, proteins, and dietary fiber, contributing to several health benefits (Boukid, 2023). Additionally, it is rich in bioactive components such as ferulic acid, anthocyanin, lutein, and zeaxanthin (Singh *et al.*, 2024). As maize is not as predominant in North African cuisine, traditional dishes incorporating maize are relatively few (Table 4).

Eish Merahrah or *Balady* bread is a traditional Egyptian flatbread prepared from maize flour combined with a sourdough starter, and it is often complemented with wheat flour (Ramadan, 1986). The dough for *Eish Merahrah* is prepared using maize flour, which provides a distinctive flavor and texture. The incorporation of sourdough starters imparts a subtle tanginess to the bread, contributing to its unique taste profile. The dough is rolled out thinly and baked until it achieves a crisp, light texture. While variations exist, some recipes include wheat flour, though there are versions prepared exclusively with maize flour.

Grilled maize is a popular street food, resembling the Mexican *elote* (Abdeldaiem *et al.*, 2023). The preparation involves grilling maize on the cob, which is then typically seasoned with salt. Unlike the Mexican version, where the maize is often slathered in mayonnaise, cotija cheese, and various spices, Egyptian grilled maize is served with minimal seasoning.

Popcorn is another common form of maize consumption in North Africa (Benkhoud *et al.*, 2022). The kernels are heated until they pop, creating a light and crunchy snack. Popcorn is often sold in markets and at street vendors, offering a rapid and economical option for consumers. While not a traditional dish in the context of cooked meals, it remains an important and widely consumed snack that reflects the versatility of maize in North African diets.

5 Modern Adaptations and Globalization

In recent years, traditional North African cereals such as barley, rice, maize, and sorghum have experienced a resurgence in interest, both within the region and internationally. This growing focus has stimulated innovative adaptations in their use, reflecting shifting consumer preferences, health trends, and culinary practices. These grains, once central to the North Africa diet, are now being reimagined in contemporary food products, offering exciting possibilities in gluten-free and health-focused applications.

Rice and maize have become staple ingredients in gluten-free diets, serving as versatile substitutes in baked goods and other products for individuals with gluten intolerance or

Table 4. Maize-Based Traditional North African Dishes

Product	Origin	Principal Ingredients	Preparation	Reference
Eish Merahrah	Egypt	Maize flour, sourdough starter, occasionally wheat flour	Dough is prepared with maize flour and sourdough starter, rolled thin, and baked until crisp.	Ramadan, 1986
Grilled Maize	North Africa	Whole maize cob, salt	Maize grilled on the cob and lightly seasoned with salt.	Abdeldaiem *et al.*, 2023
Popcorn	North Africa	Maize kernels	Kernels are heated until they pop, producing a crunchy snack sold in markets and by street vendors.	Benkhoud *et al.*, 2022

celiac disease (Morreale *et al.*, 2018). While these grains are widely used, their application in gluten-free food products has been constrained by certain functional challenges. Rice flour, for example, tends to yield crumbly textures and lacks the cohesiveness found in wheat-based products (Zhang *et al.*, 2023). Maize, conversely, is frequently incorporated into tortillas, snacks, and extruded products, but its protein quality often remains a limiting factor in several formulations. To address these issues, blending rice and maize with other ingredients, such as legumes or starches, was used to improve texture, stability, and overall acceptability (Boukid *et al.*, 2019; Irondi *et al.*, 2023). Rice and maize-based products are among the most extensively studied, with ongoing research focused on optimizing their functional properties for a broader range of applications (Tiozon *et al.*, 2021).

Sorghum, although less commonly studied and used compared to rice and maize, has also gained attention as a viable gluten-free alternative. Research has explored its potential in bread-making, cakes, snacks, and other baked goods. For instance, incorporating 30–40% of whole-grain red sorghum flour into gluten-free bread can improve both its nutritional and technological characteristics while increasing its appeal to consumers, marking progress in developing functional, health-oriented gluten-free products (Dovi *et al.*, 2024; Hugo *et al.*, 2003). It has been reported that 25% sorghum flour yielded good bread volume and texture without sacrificing quality, while higher inclusion levels reduced bread volume, cohesiveness, springiness, and chewiness (Adzqia *et al.*, 2023). Sourdough fermentation improved the nutritional and physical qualities of gluten-free sorghum bread (Ogunsakin *et al.*, 2015). Similarly, it was suggested that sourdough fermentation enhanced the structure and texture of gluten-free sorghum bread made with 70% sorghum flour and 30% potato starch by minimizing protein aggregation and promoting a robust starch gel matrix, making it a viable solution for improving gluten-free bread formulations (Schober *et al.*, 2007). In their study, Curti *et al.* explored the impact of sorghum flour properties on gluten-free sponge cake quality. By processing white and brown sorghum grains through pearling, milling, and sifting, they obtained flours with varying particle sizes and analyzed their composition, starch damage, water absorption, and pasting viscosity (Curti *et al.*, 2022). Regardless of the sorghum flour type (white or brown), finer flours consistently yielded sponge cakes with higher volume and lower firmness, emphasizing the critical role of flour particle size in optimizing gluten-free baked goods. Extruded snacks have also been developed using blends of defatted soy meal flour (0, 10, and 20%) and sorghum flour (Tadesse *et al.*, 2019). Sensory evaluation indicated that all extruded products were well-received, achieving high scores for color, flavor, crispness, and overall acceptability. Protein-rich extruded snacks were further developed by incorporating whey protein isolate, defatted soy flour, and mixed legume flour, into sorghum/corn flour blends. Sorghum-based snacks with whey protein isolate exhibited the highest expansion ratios and superior microstructure, whereas those with defatted soy flour showed lower expansion and smaller cell diameters. Sensory evaluations indicated that the addition of protein sources improved taste and overall acceptability, with the combination of sorghum/corn flour (5:2) and whey protein isolate-defatted soy flour yielding the highest ratings (Shao *et al.*, 2024).

Sorghum flour is prone to developing rancid off-flavors during storage due to fat oxidation, which limits its shelf life and sensory appeal (Adebowale *et al.*, 2020). This instability is caused by the activity of lipases that release free fatty acids, leading to oxidation. Additionally, the flour's coarse texture and potential bitterness can affect the quality of baked goods or other food products (Meera *et al.*, 2011). These challenges necessitate the application of stabilization techniques to enhance their usability in food applications. Several processes are being employed to overcome these limitations. Microwave treatment of whole grain kernels at 36 and 90 kJ/100 g effectively stabilized wholegrain sorghum flour by reducing fat acidity and free fatty acid oxidation during storage (Adebowale *et al.*, 2020). Heat moisture treatment of white sorghum grains improved functional and antioxidant properties while altering nutritional composition (Perraulta Lavanya *et al.*, 2021). Pre-gelatinization of sorghum flour during the extrusion process at varying temperatures (110 and 160 °C) could modify the texture and moisture retention observed in the sorghum-wheat composite bread (Jafari *et al.*, 2018). By partially cooking the starches, pre-gelatinization enhances water absorption, leading to a softer crumb structure and potentially improving the mouthfeel and sensory experience of the bread. This process could also explain the reduced hardness and enhanced flavor profile of the composite bread. The phosphorylation of sorghum proteins resulted in a reduction in amylose content (13%), a 39% decrease in syneresis, and a 68% reduction in retrogradation compared to native flour (Storck *et al.*, 2021). The phosphorylated flour also exhibited higher swelling power and water solubility, depending on the water temperature used. Sorghum protein extracts had protein contents ranging from 50–67% and lipid contents of 18–26%, with high levels of free fatty acids and tocopherols (Gallo *et al.*, 2024). Applying high-pressure homogenization improved their dispersibility significantly and thus can facilitate their use in food fortification and as an ingredient in high-protein formulations (D'Almeida *et al.*, 2021). Additionally, sorghum starch has garnered attention for its functional properties (Boudries *et al.*, 2009). It is characterized by its high amylose content, which contributes to its firm texture and ability to form gels. Pregelatinized

sorghum starch has improved solubility and disintegration properties, making it ideal for use in instant food products and pharmaceutical tablets (Abdallah *et al.*, 2016). Furthermore, the low gelatinization temperature of sorghum starch makes it a versatile component in gluten-free formulations, enhancing its appeal in health-conscious and specialized diets.

Barley is traditionally associated with alcoholic beverages such as beer (Singh *et al.*, 2024). For food applications, it is now recognized for its health benefits, particularly those derived from its dietary fibers such as β-glucan and arabinoxylan (Boukid, 2024a). These fibers are known for their positive effects on heart health and digestive function (Conte *et al.*, 2024). Additionally, they exhibit high functionality, including water-holding capacity, gelling, and emulsification, making them suitable for a wide range of food products. Beyond fiber, barley protein is gaining recognition for its nutritional and functional benefits. However, barley protein faces limitations in functionality due to its low solubility, poor digestibility, and restricted functional properties, such as gelation, emulsification, and foaming (Broucke *et al.*, 2024; Conte *et al.*, 2024). These challenges currently restrict their widespread use in food products, as soy proteins with superior solubility and functional properties are typically preferred to enhance texture and stability in processed foods (Houde *et al.*, 2018). However, ongoing research aims to improve the functionality of barley proteins through methods such as fermentation, enzymatic treatment, and blending with other proteins, which may expand their application in various food products.

Beyond their cultural and nutritional relevance, traditional North African foods made from barley, maize, sorghum, and rice hold untapped potential for advancing sustainability across local, national, and international scales (Guetteche *et al.*, 2022). Locally, these traditional foods are often produced through low-input agricultural practices adapted to arid and semi-arid conditions, contributing to climate-resilient diets and requiring minimal water and energy inputs compared to more intensive agricultural systems (Beldados & Ruiz-Giralt, 2023). Nationally, the valorization of these foods supports agrobiodiversity, strengthens rural economies, and promotes zero-waste approaches, as various traditional preparation methods emphasize whole-grain use, fermentation, and reuse of by-products (Moujabbir *et al.*, 2023). Internationally, their revival aligns with global efforts to develop circular agro-food systems, offering plant-based, culturally embedded alternatives that respond to growing demand for sustainable and health-oriented diets (Grote *et al.*, 2021; Melih Secer *et al.*, 2020). These contributions are increasingly recognized within the framework of the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land).

6 Conclusion

In conclusion, traditional cereal agriculture and associated food systems play a pivotal role in fostering sustainable food systems by supporting agrobiodiversity, preserving invaluable cultural heritage, and enhancing food security. Initiatives aimed at integrating traditional practices with modern agricultural and culinary approaches contribute to both national and international sustainability objectives, thereby demonstrating the value of traditional knowledge in the development of resilient and sustainable food systems for the future.

Currently, traditional cereals such as barley, rice, maize, and sorghum are finding renewed applications in modern food production. This resurgence is particularly evident in the context of gluten-free diets, functional foods, and plant-based alternatives, which are gaining prominence amidst global challenges such as climate change and rapid population growth. This integration not only ensures the preservation of cultural food practices but also addresses contemporary health and sustainability concerns. As consumer demand for healthier, more sustainable food options continues to escalate, the innovative utilization of traditional cereals in processed foods, snacks, and beverages highlights their persistent relevance.

However, one key area that warrants further research and development is the optimization of grain processing techniques to reduce energy consumption. Identifying more sustainable methods for processing these cereals, both within industrial and traditional contexts, could enhance their environmental and economic viability. By bridging the gap between tradition and innovation, these cereals will continue to contribute to the development of sustainable, nutritious food systems that cater to both local and global needs.

Acknowledgment: not applicable.

Source of funding: not applicable.

Previous submissions: not applicable.

Authors' Contribution: Fatma Boukid: Conceptualization, investigation, methodology, writing - original draft, writing - review and editing. **Hamza Mameri:** methodology, validation, writing - review and editing.

Conflicts of Interest: The author declares no conflict of interest.

Preprint deposit: Authors did not share this manuscript as a preprint deposit.

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