Food Barley in North Africa: state of art and opportunities for development

Salih Ghizlane [(1)], Jilal Abderrazek [(1)], Garcia Miguel Sanchez [(2)] and Visioni Andrea [(2)]

ghizlane.salih@inra.ma

1: Institut National de la Recherche Agronomique, Maroc ; Avenue la victoire BP 415 Rabat
2: International Center for Agricultural Research in the Dry Areas; Avenue Mohamed Belarbi alaoui, BO 6356 Rabat

Abstract

North Africa is facing multiple challenges that threaten food security of their main staple food such as cereals. Being the old basic food cereal of North African countries, barley has shown its prominence for areas with limited resources, for the nutritional security and for the prevention of the century's diet-related diseases. Based on literature data (from 1921 to 2020) and FAO statistical data (from 1961 to 2019), it was shown that barley is the ancient staple cereal of the North African population and its importance for resource-limited regions. This paper is a detailed analysis about the evolution of food barley in North African countries for the last six decades, focusing on how the trends of different barley elements have been changed and the current opportunities of this resilient crop to be part of the production system and the healthy diet of the North African future generations.

Keywords: Food barley, North Africa, state-of-art, opportunities, challenges

L’orge alimentaire en Afrique du nord : Etat des connaissances et opportunités de développement

Résumé

L'Afrique du Nord est confrontée à de multiples défis qui menacent la sécurité alimentaire de leurs principales denrées de base telles que les céréales. Étant l'ancienne céréale alimentaire de base des pays d'Afrique du Nord, l'orge a montré sa proéminence dans les zones aux ressources limitées, pour la sécurité nutritionnelle et pour la prévention des maladies liées à l'alimentation du siècle. En se basant sur les données de la littérature (de 1921 à 2020) et sur les données statistiques de la FAO (de 1961 à 2019) on a montré que l'orge constituait l'ancienne céréale de base de la population de l'Afrique du Nord ainsi que son importance pour les régions aux ressources limitées. Cet article est une analyse détaillée de l'évolution de l'orge alimentaire dans les pays d'Afrique du Nord au cours des six dernières décennies, en se concentrant sur la façon dont les tendances des différents éléments de l'orge ont été modifiées et les opportunités actuelles de cette culture résiliente pour faire partie du système de production et du régime alimentaire sain des générations futures d'Afrique du Nord.

Mots-clés : Orge alimentaire, Afrique du Nord, état de l’art, opportunités, défis.

الشعير الغذائي في شمال أفريقيا: مستوى التقدم الجاري وفرص التنمية

غزلان صالح، عبد الرازق جلال، أندريا فيجني و ميجيل سانشيز جارسيا

ملخص:

تواجه دول شمال أفريقيا تحديات متعددة تهدد الأمن الغذائي لغذائها الرئيسي مثل الحبوب. ونظرا لأن الشعير يعتبر من الحبوب الغذائية الأساسية القديمة في بلدان شمال أفريقيا ، فقد أظهر مكانته البارزة في المناطق ذات الموارد المحدودة لتوفير الأمن الغذائي والوقاية من أمراض القرن المرتبطة بالغذاء.

استنادًا إلى البيانات المرجعية (من 1921 إلى 2020) والبيانات الإحصائية لمنظمة الأغذية والزراعة (من 1961 إلى 2019) ، تبين أن الشعير من الحبوب الأساسية القديمة لسكان شمال إفريقيا وذو أهمية كبيرة للمناطق محدودة الموارد . تمثل هذه الورقة تحليلا مفصلا عن تطور الشعير الغذائي في بلدان شمال أفريقيا على مدى العقود الستة الماضية، مع التركيز على كيفية تغيير اتجاهات مختلف عناصر الشعير والفرص الحالية لهذه الزراعة المرنة لكي يكون جزءا من نظام إنتاج صحي للأجيال المقبلة في شمال أفريقيا.

الكلمات المفتاحية: الشعير الغذائي، شمال أفريقيا، التقدم الجاري، الفرص، التحديات.

Introduction

Barley has a rich history during the evolution of humankind, first as a wild plant then domesticated crop dating from about 10000 years ago. The wild progenitor of Barley (*Hordeum spontaneum*) is still colonizing its primary habitats in the Fertile Crescent, central Asia including Afghanistan and the Himalayan region (Badr et al, 2000; Morrell and Clegg, 2007). This barley relative is also reported in Greece, southwestern Asia, Ethiopia, Somalia, Eritrea and North Africa (Morocco, Algeria, Tunisia and Egypt) (Ben Naceur et al, 2012).

Throughout the years, the man has begun to discover the health benefits and medical applications of barley foods and it has been reported in different civilizations, for example, the Romans gladiators were known by the name of "hordearii" or "barley men" recognized the advantage of eating barley for health by given them a greater strength (Percival, 1921), also in Islamic civilization, barley soup made with milk called "Talbinah" is recommended, the prophet's statement that the soup brings strength to the body and make it able to rid itself of sadness and grief (Al-Jauziya, 1999).

Barley has been the largely adapted cereal grain species to diverse environments and has tolerance to cold and saline conditions and extreme climates that let it extends from Sub-Arctic to Sub-Tropical (Li, Zhang & Lance, 2007). This distinctive feature has made barley a principal food source in different countries around the world (Pastor, et al, 2015); and many studies have been conducted to determine the chemical composition (Idehen, Tang, & Sang, 2017), its functional properties (Sourki, Koocheki, & Elahi, 2017) (Houde et al, 2018) and its health implications (Wang et al, 2017). Previous and recent studies have proved that barley has been related to several positives health effects and has great potential for the prevention of non-communicable diseases due to its valuable bioactive components (Idehen, Tang, & Sang, 2017).

Compared to wheat, the cultivation of barley in North Africa would be as old as the agricultural activity itself. Indeed, barley would have been used since the Neolithic, in human and animal food (El felah et al, 2015). In Egypt, barley grains have been recovered from typical Late Paleolithic archaeological sites and are firmly dated between 18,300 and 17,000 years ago. They appear to represent a very early use of ground grain in the Nile Valley, and evidence is presented for its continued use over the next 6,000 years (Wendorf et al, 2007). Apart from these uses as a food source, barley was used in therapeutic applications. Indeed, barley was widely used in medicinal applications in ancient Egypt and was prescribed in different forms for various diseases (Newman and Newman, 2006).

In North African countries (Morocco, Algeria, Tunisia, Libya and Egypt), barley ranks the second most important cultivated crop after wheat with 3.8 million hectares (FAO, 2017). In the past, barley was used for human consumption (what about now?). In Morocco, for example, barley was stored by the rural population, while wheat was stored by the urban population (wheat is also mostly stored by rural families), creating

two distinct but important systems for famine protection that contributed greatly to the popularity and stability of the ruling dynasty (Newman & Newman, 2008). Qualified as a strategic crop for Algeria, barley until a certain period (1900) was at the top of the crops and was intended for human self-consumption (Rahal-Bouziane, 2005; Rahal-Bouziane, 2016). This review focuses on the evolution of barley cultivation in North African countries since the 1960s, driving the urgent need of promoting this crop in this region characterized by its vulnerability to several challenges (climate change, population growth, cereal import dependency, preponderance of diet-related chronic diseases).

Main results

Barley evolution in North Africa

Prior to the 1960s, barley was the main cereal grown in North Africa and was sometimes the leading one in some countries of the region, notably Morocco. During the period 1933-1937, barley acreage in North Africa was 3 million hectares, whereas it hardly exceeded 0.04 million hectares in Europe (Miège, 1950). The production for the same period was estimated at 2.2 million tons with an average yield hardly exceed 0.5 to 0.6 tons/ha.

After the 1960s, barley cultivation has evolved in all North African countries in terms of cultivated area, production and utilization. In fact, the areas dedicated to barley were very variable from one country to another (Figure1). Indeed, Morocco is the first in terms of barley acreage recording a positive trend from the 1960s to the 1980s. The current trend is towards a decline in barley area. Algeria shows negative fluctuations in barley area from the 1960s to 2006, following a progressive improvement in the area devoted to barley. For Tunisia, Libya and Egypt, the areas occupied by barley stagnated throughout the period analysed (1961-2019).

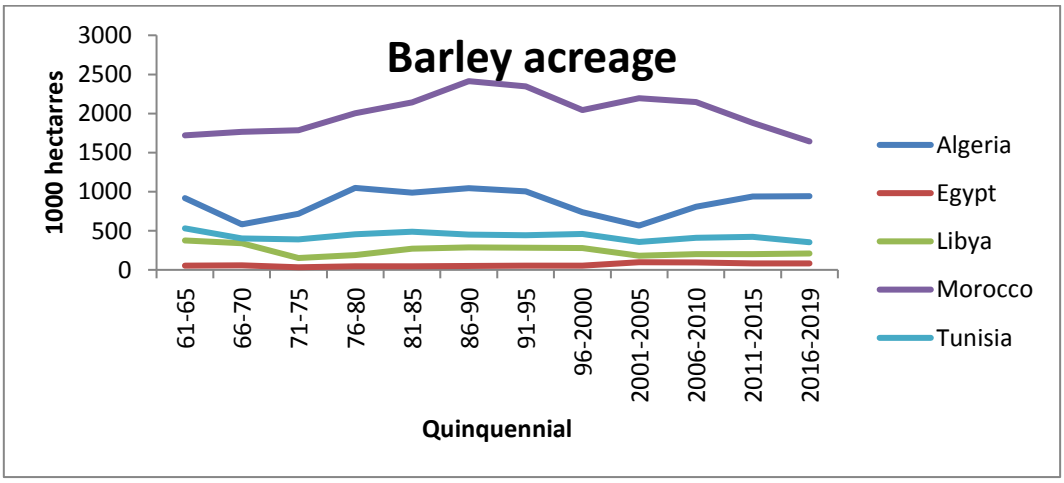

Figure 1. Three decades evolution of barley acreage in North African countries (USDA database, 2020)

As depicted in Figure2, barley grain yield trends in North African countries varies between the countries studied. In fact, Egypt had by far the highest yield (3.1 tons/ha) during the period (1961-2000) due to barley cultivation in the irrigated areas, then its yield dropped considerably and does not currently exceed 1.8 tons/ha due to water scarcity as Egypt is currently below the U.N.'s threshold of water poverty (U.N. World Water Development report, 2018). Tunisia has considerably improved its barley grain yield from 0.25 tons/ha in 1961-65 to 1.1 tons/ha in 2015-2019. Algeria also shows a positive trend, its output has increased from 0.6 to 1.5 tons/ha to 1.5 tons/ha. Morocco has also improved while Libya has the lowest yield compared to all North African countries.

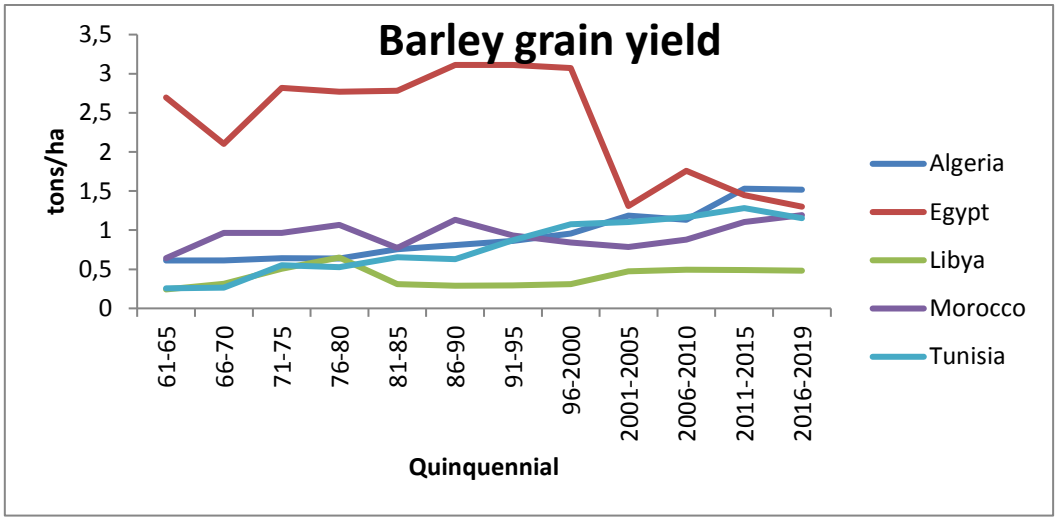

Figure 2. Three decades evolution of barley grain yield in North African countries (USDA database, 2020)

Barley production, presented quinquennially since 1961 (Figure 3) shows the production trend in the five countries of the region. As illustrated, Morocco is the leading barley producer in North Africa. From 1976 and until the 1990s, Morocco was the leading African and European country, with the exception of Spain (Ait Hamza, 1998). The production evolution for this country shows significant fluctuations, with record quantities (2.7 million tonnes) being recorded during the period (1981-1990) and then falling sharply. For Algeria, the production trend is rather upward, with current production quantities approaching 1.4 million tonnes. Barley production in Tunisia also shows a positive trend with stagnation for Libya and Egypt.

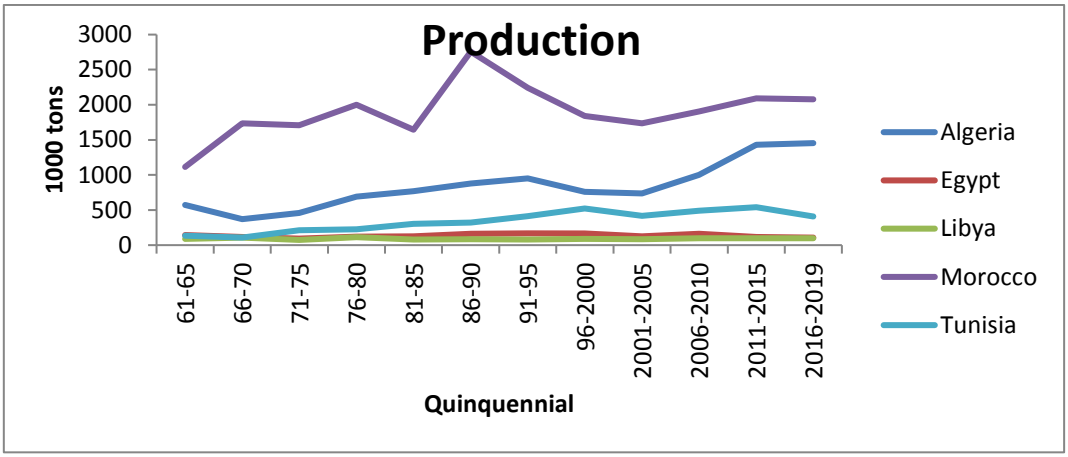

Figure 3. Three decades evolution of barley production in North African countries (USDA database, 2020)

Barley is generally grown in arid and semi-arid regions using low-input technologies. Due to low and unreliable rainfall, the production potential for barley is lower and more variable than in wheat-based systems. This largely explains the observed fluctuations in yield and production quantities.

In North African countries, barley is used for feed and food, but the importance varies from country to country. Figure 4 shows the consumption trend since 1961. Based on information reported in Figures 3 and 4, all the barley produced in the five North African countries was for designated to food uses. Morocco and Algeria have experienced large fluctuations in the quantities of barley for human consumption. From the 1980s onwards, despite the increase in the quantities produced, there was a decline in barley consumption, especially in Morocco and Algeria. For Morocco, these years coincided with the bread wheat intensification operation launched in 1986, which aimed to extend this crop over more than one million hectares with numerous financial facilities for farmers (subsidies, supply of inputs, seed distribution, supervision) (Ait Hamza, 1998).

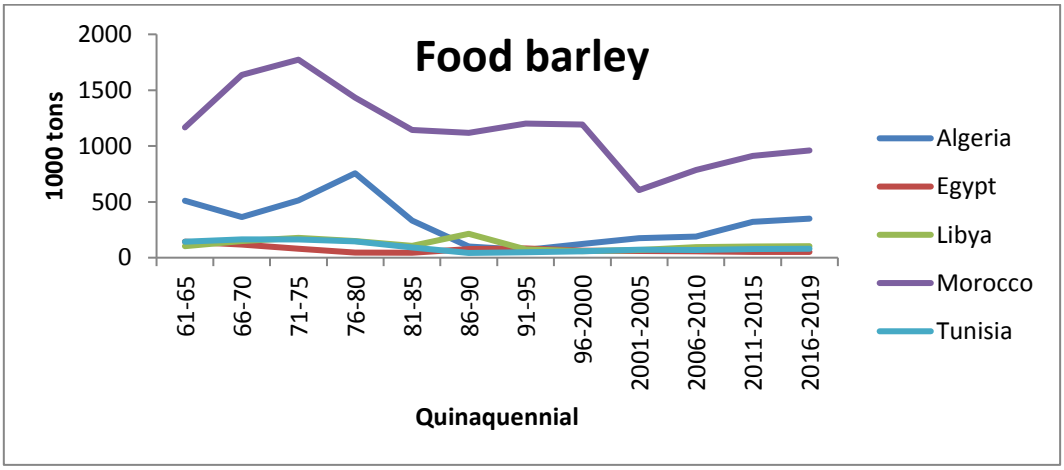

Figure 4. Three decades evolution of barley food consumption in North African countries (USDA PSD databases, 2020)

At present, the share of barley produced by the five North African countries is 22% for food and 78% for animal consumption (USDA PSD databases, 2020). In terms of the quantities produced in each country, Morocco is the leading user in North Africa, with 33% of its production for human consumption, followed by Egypt (27%), Algeria (18%), Libya (10%) and Tunisia (8%) (USDA database, 2020).

During the last five decades in North Africa, Morocco was the leader of barley food supply reaching more than 70Kg /person/year in 1977 (Figure 5). The trend was relatively stable until 1996 witnessing a sharp decrease due to drought season. A significant increase back to 70Kg /person/year was noticed in 1998 followed by acute decline by half in 2000 in favour of bread wheat. For the other countries, barley food supply didn't exceed 26 kg/person/year for the last 52 years (1961-2013).

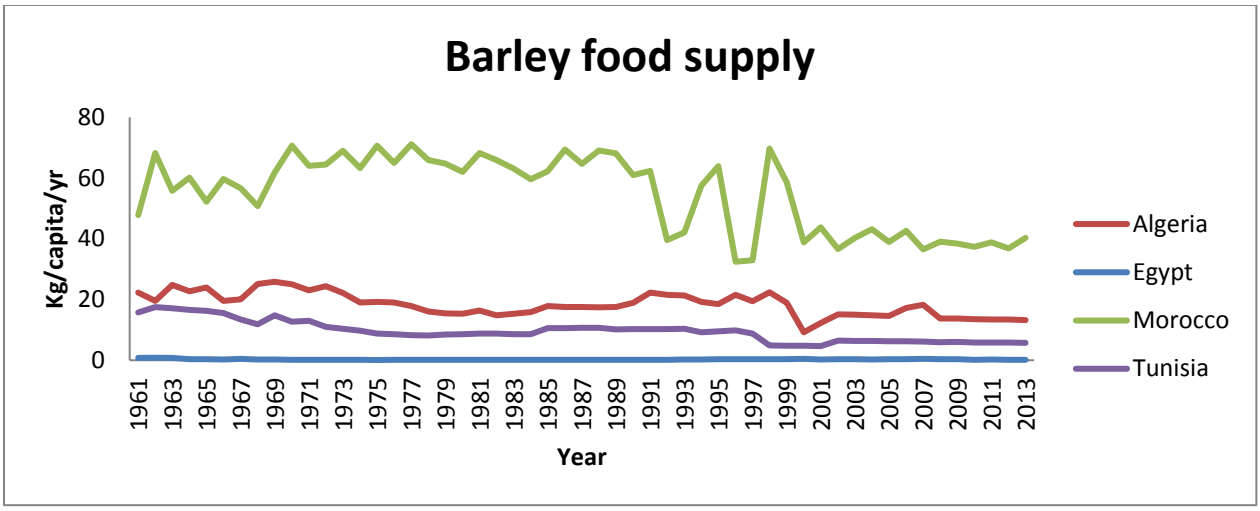

Figure 5. Evolution of barley food supply (Kg/capita/year) in North African countries (FAO, 2020)

Challenges facing North African countries

Environmental level

North Africa environments are characterized by hot dry summers and humid, cool winters with high variability in patterns of rainfall and temperature impacting yield gains (Bazza et al., 2018). Future projections of climate trends show that North Africa countries will get drier and hotter and might result in severe yield reduction (Cammarano et al., 2019; Semenov et al., 2014; Senapati et al., 2019). Studies on the potential effects of global climate change on agriculture predict a decline in cereal production in some currently high-producing areas, for example in Western Europe, the southern United States and Western Australia (Pörtner et al, 2022). Field studies conducted on wheat in different parts of the world have shown that global wheat production will decrease by 6% for every °C increase in temperature (Cammarano et al, 2019; Asseng et al, 2015). Overall, on many crops important for food security (e.g.

cereals, pulses, sugar cane), even a moderate increase in temperature is likely to have a major negative impact if no adaptation measures are taken. Negative impacts are expected to be most relevant in developing countries (Cammarano et al, 2019) and could have serious economic, social and political consequences for vulnerable and import-dependent countries relying on wheat, which is the basis of their food supply, as is the case for North African countries. Indeed, it is predicted, based on current trends in population growth, eating habits and the challenges of agricultural production (especially water stress), that dependence on agricultural imports from the Maghreb, Middle East and Near East regions would be more pronounced, reaching almost 70% of their demands (Le Mouël et al., 2015).

Climate change poses a great challenge to agricultural production worldwide (De la Casa and Ovando, 2014). North African countries are exposed to climate change, with increasing threats to their food security (Cammarano, 2019, El Kenawy et al., 2009; El Shaer and Al Dakheel, 2017). In fact, the adaptation of cereals to climate change through more resilient crops is in high demand, especially in arid environments (Elsawy, 2020; Dwivedi et al., 2017; Ingvordsen et al., 2015; Kole et al., 2015). With its wide environmental range, different end uses and wide variety of users, barley has become an excellent model for studying and responding to the impacts of various climate change scenarios (Dawson et al., 2015; Newton et al., 2011). In addition, barley is considered the most drought and soil salinity tolerant cereal and is also considered a semi-halophyte (Ceccarelli et al., 1987; Belaid and Morris, 1991; Li, Zhang & Lance, 2007). In fact, salinity is a major threat to agricultural production worldwide, especially in hot arid and semi-arid areas. It is estimated that salinity affects about 7% of the world's agricultural land, while in irrigated agriculture it accounts for almost one-third of irrigated agricultural land and the area affected by salinity is steadily increasing (El-Hendawy et al., 2004). According to Rousset and Arrus (2004), climate change in the Maghreb should lead, among other things, to an acceleration of soil erosion and degradation, which will be accentuated in coastal areas by the rise in sea level and the risks of soil salinization.

The future of cereal growing in the countries of North Africa is becoming compromising and makes it urgent to implement a substitution strategy. Adaptation to increasing water scarcity could aim to promote crops that are less demanding in terms of water resources (Lakhdari and Ayad, 2009). By providing an alternative to wheat for bread and other baked goods while increasing barley production, North African countries will save millions of dollars spent on wheat imports and can achieve self-sufficiency in grains. Barley, in view of its hardiness and its agronomic performance, is a cereal of choice for the North African region.

Health-wise

The North African region presents a typical case of the Mediterranean region where the high prevalence of overweight, obesity and non-communicable diseases coexists with some micronutrient deficiencies (Aboussaleh et al. 2009; Perignon et al., 2019).

In Morocco, for example, in recent decades there has been a rapid rise in diet-related pathologies that have a very high social cost (Allali et al., 2017), in particular diabetes, cardiovascular diseases, cancer and obesity. Changes in food consumption and production patterns are necessary to ensure more sustainable food systems and achieve food and nutrition security in the region. There is an urgent need to promote diets that are sustainable, nutritionally adequate, safe and healthy, culturally acceptable, affordable and with low environmental impacts (Food and Agriculture Organization of the United Nations, 2010).

Barley is not only a premium feed and malt, as well as a major foodstuff in some countries of the world, but also the richest source of grain in functional ingredients and the most abundant species for the production of functional foods. Barley grains are extremely rich in nutritional functional ingredients, including soluble and insoluble fiber, phenolic acids, flavonoids, phytosterols, alkylresorcinols, benzoxazinoids, lignans, tocol and folate. Functional ingredients in barley with antioxidant and immunomodulatory activities are associated with anticancer effects (Idehen et al, 2017). Regular daily consumption of whole barley flour can prevent chronic diseases, especially diabetes, colon cancer, hyperlipidemia, high blood pressure, and gallstones (Idehen et al, 2017).

Nutritionally, barley surpasses all other cereals in terms of nutrient content and its beneficial role to human health. It is a cereal that has gained much attention, primarily because of its high levels of soluble fiber "ß-glucan", which plays an important role in rebalancing plasma cholesterol, reducing glycemic response and promoting the growth of beneficial intestinal microflora (Brennan and Cleary, 2005).

Barley β-glucan can reduce blood pressure and cardiovascular disease by altering gut microbiota composition, decreasing body mass index, waist circumference, and triglyceride levels (Wang et al, 2016). Barley β-glucans may not only regulate immune responses and link innate and adaptive immunity (Jin et al, 2018), but also have a cardioprotective mechanism [116]. High dietary fiber barley (β-glucan) plays an important role in the prevention of colon cancer and cardiovascular disease (Lahouar et al, 2016); low molecular weight β-d-glucan can enhance antioxidant and antiproliferative activities (Shah et al, 2015). Aqueous extract of fermented barley can induce apoptosis of subcutaneous transplant tumors which can be used as a nutritional supplement in the treatment of human colon cancer (Yao et al, 2017). Les β-glucanes représentent des agents topiques efficaces pour le traitement des blessures et des brulures en raison de l'activation des cellules immunitaires et des cellules cutanées ce qui joue un rôle dans l'accélération de la cicatrisation des plaies (Fusté et al, 2019). Sur le plan allergique, un extrait d'orge fermenté a atténué la rhinite allergique chez les souris sensibilisées à l'OVA en régulant les cytokines liées à l'inflammation chronique (Iguchi et al, 2009).

Barley polyphenols have many bioactivities, including anti-diabetes, anti-obesity, anti-cancer, antioxidant, anti-inflammation, hepatoprotection, and prevention of cardiovascular and heart diseases (Zeng et al, 2020). Barley lignan, as natural

polyphenols, has anticancer, antioxidant and anti-inflammatory properties, and plays a preventive role in cardiovascular diseases. Anthocyanin is part of flavonoids, and flavonoids are part of polyphenols. Black, purple, and blue barley grains have recently received attention because their anthocyanins have anticancer, blood sugar and body weight regulation, anti-inflammation properties, and anti-aging effects (Ma et al, 2018; Chen et al, 2019). The phenolic content of barley and its antioxidant activity are reported to be higher than that of wheat (Ragaee et al., 2006). Experimental studies have shown the protective role of Tunisian barley varieties against several diseases such as cardiovascular diseases and colon cancer (Lahour et al., 2014; Lahouar et al., 2011, Lahouar et al., 2012). In other North African countries, similar information showing the therapeutic performance of the barley varieties used is still missing.

Despite the substantial history of barley as a sustainable food source evolving over eons, in recent times, the main use of barley is as animal feed and its ranking in comparison with maize, wheat, and rice has not changed significantly over the last years (Zhou et al., 2012) .The crop was even relegated to the status of « poor man's bread », however, the consumption of wheat products exceeds that of barley products in all the countries of the world and there is no country in which the diet is based exclusively, or even mainly on barley products (Grando & Stefania, 2005). This has resulted in changing consumption patterns, due to adoption of a western diet and lifestyle increasing with urbanization, this nutrition transition which can increase the risk of obesity and the appearance of chronic diseases that may lead to epidemiological transition (Steyn et al., 2012).

In industrialized countries, the non-communicable diet-related chronic diseases still always an obstacle due to its rising cost, which is far beyond the means of the still fragile economies of developing countries (Maire B., Lioret, Gartner, & Delpeuch, 2002).

As rates of chronic diseases have continued to increase all over the world which makes the authorities aware that for public health improvement, the largest gain can only come from changes in dietary behavior then growing interest has developed in functional foods which have shown promise in reducing the risk of some chronic diseases (Malla, Hobbs, & Sogah, 2014).

One of the key features of food barley research and development is the urgent need to draw attention of policy makers and development agents regarding the importance of barely food in the economy of developing countries (Grando & Stefania, 2005). Health claims can be one of the policies that may promotes the use of barley for human nutrition. A health claim should help the consumer to improve his health by providing information regarding proven health benefits associated with a specific functional food or components which help the consumer make healthy food choices and serve the food industry as marketing tools to increase purchase and consumption of food products (Ame & Rhymer, 2008).

Years of research led the U.S. Food and Drug administration in 2006, the European Food safety Authority in 2011 and Health Canada in 2012, approving health claims based on scientific evidences proven health benefits associated with consuming of barley ß-glucan, a type of soluble fiber, offers several health benefits to alleviate the problems of lifestyle disorder, these include control of blood cholesterol and glucose level which is a risk factor of heart disease. All this despite barley is not considered a popular food in these countries but they have managed to make people more aware of these health benefits by implying health claims. In Canada, several studies have been conducted to prove the need to allow health claims on soluble fiber of barley, it was expected to increase consumption on average by 0.12g/day per person, which reduced LDL cholesterol levels by 0.19% and in turn reduced CHD risk by 0.14%. This has resulted in annual estimated savings in direct and indirect costs of poor health (CHD) of $90.84 million annually (Malla, Hobbs, & Sogah, 2014). Health claim is confirmed to be one of the successful policies that have a great potential on health-related costs by increasing the consumption of barley and the development of its production by making the consumer more aware of its health benefits.

Unfortunately, these health claims are not applied yet in developing countries, despite the benefits that these claims can provide; taking always the example of barley which is considered one of the most popular and used cereal especially in North African countries. However, its rank remained almost constant without significant change over the last years because there are no applied policies which can promote the production and the consumption of barley and making the consumer aware of its health benefits. Hence, authorizing barley health claims in developing countries can help significantly in increasing consumption of barley and could result in non-negligible health cost savings by its potential to prevent against chronic diseases and that may lead to stimulating the development of new barley products which can provide the consumer with a wide range of healthy choice.

Opportunities for novel barley food products in North Africa

Local Knowledge

Food barley has played an important role in the food security of the populations of North Africa where it has been consumed not only for its nutritional virtues but also for its medicinal properties (Zentani, 2005). From region to region, barley processing methods can change according to the standard of living and the urban or rural status of the population. Barley is used as flour, semolina, and hulled whole grain. Various barley-based foods and beverages have been passed down as a family heirloom from mother to daughter, attesting to an ancestral know-how rooted in the food culture of the people in this region. Although barley consumption has declined significantly, some of this know-how still exists and barley continues to be the staple food in some areas, particularly in arid zones where the consumption rate can reach 80Kg/person/year (case of some regions in southern Morocco) (Amri et al, 2005).

In southern Morocco, there are popular sayings that testify the importance of barley as an adapted and multi-function crop such as, "barley is the owner of the farm and wheat is only a guest," "barley is the father crop in the farm," and "the house is empty without barley grain and straw" (Amri et al, 2005). In Morocco, barley is mainly used as food in rural areas, mountainous areas and in the south of the country. In recent decades, a renewed interest in the use of barley in the diet of citizens has been noticed in cities and a number of barley mills have been established (Saidi et al, 2005). There is a wide range of traditional barley products in Morocco: Khoubz chair (barley flat bread), couscous, Harcha, Dchicha (Belboula), Azenbou, Aballagh, birkoukss, etc. According to Zentani, 2005, in Libya, local barley-based meals have not only a food value but also a cultural one. During the festive season, barley-based preparations are the most preferred, which shows the value of barley in the Libyan culture. The main local preparations based on barley are: koubz (bread), bazin, zummeta (used mainly for breakfast), dshesha, harisa and couscous. Barley among Tunisians is synonymous with healthy food and is used in a variety of recipes (Abidi et al, 2015). Local Tunisian breeds are preferred for food over improved cultivars and most farmers are attached to their local germplasm (Abidi, 2015; El Felah, 2011). Crushed barley is used to prepare barley bread or kisra, malthouth, d'chich, mermez or fric. Meals prepared from barley flour include bazine, assida, b'sissa, hail and dardoura (El Felah and Medimagh, 2005).

In North African countries, there is a great diversity of local uses of barley for food depending on the processing of the grain and barley preparations are essentially based on the socio-ethnological origin of the communities. The return to these products whose health benefits are no longer to be demonstrated requires the rediscovery of local products in a modern form aimed at attracting a young population and to highlight the traditional barley-based products that constitute a potential of products not yet exploited by the agri-food industry. Production methods based on local know-how for barley-based products are nowadays on the agenda (of whom?) and constitute an alternative to the environmental and socio-economic problems of the rural world

Advances in scientific research on food barley in North Africa

In recent years, the scientific community in North African countries is increasingly aware of the importance of barley and its positive impact on food security and health of their population. Varietal selection programs that started since the twenties (El Sayed, 2005; Saidi et al, 2005; El felah and Medimag, 2005) with the selection of lines from domestic breeds, which have been used for both animal and human food. The introduction of lines from other regions of the world has resulted in the release of several varieties with improved yields and as equal as local cultivars for food purpose such as the naked barley “chifaa” variety released in Morocco that has 8% of ß-glucan (INRA Morocco, 2021) .

Currently, the need to develop food barley varieties in the perspective of climate change is a major concern. Studies on barley landraces in North African countries

(Dakir et al., 2002, Hamza et al., 2004, Mohamed et al., 2010, Zoghlami et al., 2011, Guasmi et al., 2012, Abidi et al, 2015; Allel et al., 2016) have shown various sources of tolerance to abiotic stresses with high food quality. This, could not only provide health benefits, but also promote barley cultivation and enhance its added value and stimulate industrial and economic growth.

The development of barley-based food products is becoming an important component in the research programs of North African countries. However, the impact of barley consumption on the health of North African populations has been only slightly elucidated. The example of the Tunisian variety Rihane which has been shown to decrease atherogenic risk factors in rats (Lahouar et al, 2011).

Current industry guidelines

The food industry is directing new product development towards the area of functional foods and functional food ingredients due to consumers' demand for healthier foods.

There are an increasing number of novel food products being developed and released in the market, which are frequently differentiated by the modified attributes they offer to the consumer. Many of these are being marketed in terms of the benefits they offer for consumer health as well as the potential to reduce the risk of diseases. Some of these new food product developments have been labelled as 'functional foods (Hellyer, Fraser, & Haddock-Fraser, 2012).

Wheat, owing to its protein network, Gluten, confers to the derived products sensory properties generally appreciated by the consumer. The use of barley with low quality gluten significantly affects the sensory attributes of the products. However, replacing a portion of wheat flour with barley flour can provide enough soluble dietary fiber to significantly improve human health while preserving the organoleptic qualities sought by the consumer (Noaman, 2017). In addition, the adoption of hull-less barley varieties that are easily removed by slaughtering could facilitate the use of barley grain for bread and nutritional foods.

Efforts for new product development are being directed by the food industry towards the newly emerging area of functional foods, primarily to meet consumer's demand for healthier foods. For this purpose, cereals such as barley, as well as its constituents offer unlimited opportunities for the production of functional foods (Sidhu & Kabir, 2007). Many functional foods can be produced from barley, however, we only discussed a few important products as Pasta which is a world-wide produced and consumed food and, could turn into a functional food with health benefits (De Paula et al., 2017), Nutri Bar which is supplemental bars containing cereals as barley targeted at people who require quick energy but do not have time for a meal (Farooqui et al., 2018), Cookies, the largest category of snack foods which is widely consumed throughout the world and can be made with barley flour (Herminia et al., 2017).

Conclusion

This article has shown the important place that barley occupied for the ancient civilization of North Africa. The functional ingredients contained in barley have undoubtedly contributed to the health of the population in the prevention and treatment of chronic human diseases. North African women have the highest risk of metabolic diseases, including obesity, diabetes, hypertension, dyslipidemia, and nonalcoholic fatty liver disease, of any women in the world, while men have the second highest risk (Fereidoun et al, 2019). Metabolic risk factors are responsible for more than 300 deaths per 100,000 individuals in this region, while the global average is less than 250.

On the other hand, climate change is expected to exacerbate health problems that already weigh heavily on vulnerable populations. Indeed, climate change will lead to new health problems related to heat waves and other extreme events. Heat stress can make working conditions unbearable and increase the risk of cardiovascular, respiratory, and kidney diseases (Zeng et al, 2020). Climate-related impacts are reducing crop yields in some regions of the world, and this is the case in North African countries, a trend that is expected to continue as temperatures rise. Affected crops include staples such as wheat and maize and rice (CPPI, 2014). Climate change is expected to increase price volatility of agricultural commodities and reduce food quality.

Barley is one of the most interesting potential natural sources for the development of functional foods and new, more effective and safer drugs. It is the most suitable cereal to face the constraints of climate change.

References

Abidi I., Mansouri S., Radhouane L., Riadh K., El Felah M., Bouzid S.(2015). Phenolic, Flavonoid and Tannin Contents of Tunisian Barley Landraces. International Journal of Agriculture Innovations and Research V 3 (5). p. 2319-1473.

Aboussaleh Y., Ahami A. (2009). Dietary determination of stunting and anaemia among pre-adolescents in Morocco. African Journal of Food, Agriculture, Nutrition and Development Vol. 9 (2). p. 728-747.

Ait Hamza M. (1998). Les céréales dans le Maroc du Centre-ouest. Méditerranée. V 88. p. 27-32.

Al-Jauziya I. I. (1999). Healing with the medecine of the prophet (PBUH). Darrussalam Publishers.

Allali K., Dhehibi B.,Kassam S.N., Aw-Hassan A.(2017). Energy consumption in onion and potato production within the province of el hajeb (Morocco): towards energy use efficiency in commercialized vegetable production J Agric Sci, 9 (1). pp. 118-127.

Allel D., Ben-Amar A., Badri M., Abdelly C. (2016). Salt tolerance in barley originating from harsh environment of North Africa. Australian Journal of Crop Science, 10. p. 438-451. https://doi.org/10.21475/ajcs.2016.10.04.p6663x

Ames N.P., and Rhymer C.R.(2008). Issues Surrounding Health Claims for Barley. The Journal of Nutrition. V 138, (6). p. 1237–1243.

Amri A., Ouammou L .,and Nassif F. (2005). Barley-based Food in Southern Morocco. In: Grando, S and Gomez Macpherson, H (eds) Food Barley: Importance, Uses and Local Knowledge. Aleppo: ICARDA. p. 22–28.

Asseng S., Ewert F., Martre P. et al (2015).. Rising temperatures reduce global wheat production. Nature Clim Change 5. p. 143–147. https://doi.org/10.1038/nclimate2470

Badr A., Muller K.,Schafer-Pregl R., El Rabey H.,Effgen S.,Ibrahim H.H.,Pozzi C.,Rohde W., and Salamini F. (2000). On the Origin and Domestication History of Barley (Hordeum vulgare). Molecular Biology and Evolution. V 17. p. 499-510.

Bazza M., Kay M., and Knutson C. (2018). Drought characteristics and management in North Africa and the Near East. FAO water reports 45.ISBN 978-92-5-130683-3,

Belaid A., and Morris M.L. (1991). Wheat and barley production in rainfed marginal environments of west Asia and North Africa: problems and prospects. CIMMYT Economics Working Paper. 76 p.

Ben Naceur A., Chaabane R., El-Faleh M., Abdelly C., Ramla D., Nada A., Sakr M.,Ben Naceur M. (2012). Genetic diversity analysis of North Africa's barley using SSR markers. Journal of Genetic Engineering and Biotechnology. 10(1). p. 13-21.

Bouajila A., Zoghlami N., Al Ahmed M., Baum M., Ghorbel A. and Nazari K. (2011). Comparative virulence of Pyrenophora teres f. teres from Syria and Tunisia and screening for resistance sources in barley: implications for breeding. Letters in Applied Microbiology, 53. p. 489-502. https://doi.org/10.1111/j.1472-765X.2011.03127.x

Brennan H.S., and Cleary LJ. (2005). The potential use of cereal (1→3,1→4)-β-d-glucans as functional food ingredients, Journal of Cereal Science, Volume 42, Issue 1. p. 1-13. ISSN 0733-5210.

Cammaranoa D., Ceccarelli S., Grando S., Romagosa I., Benbelkacem A., Akarf T., Al-Yassing A., Pecchionih N., Franciai E., and Rongaa i.j. (2019). The impact of climate change on barley yield in the Mediterranean basin. European Journal of Agronomy. 106. p. 1–11.

Ceccarelli S., Grando S., & Van Leur J.A.G.(1987). Genetic diversity in barley landraces from Syria and Jordan. Euphytica 36. p. 389–405. https://doi.org/10.1007/BF00041482

Chen, Y., Huang, J., Hu, J., Yan, R., & Ma, X. (2019). Comparative study on the phytochemical profiles and cellular antioxidant activity of phenolics extracted from barley malts processed under different roasting temperatures. Food & function, 10(4). p. 2176-2185.

Dakir E.H., Ruiz M.L., García P. et al (2002). Genetic variability evaluation in a Moroccan collection of barley, Hordeum vulgare L., by means of storage proteins and RAPDs. Genetic Resources and Crop Evolution 49. p. 619–631.

Dawson I.K., Russell J., Powell W., Steffenson B., Thomas W.T., Waugh R. (2015). Barley: a translational model for adaptation to climate change. vol206(3). p. 913-31. doi: 10.1111/nph.13266. Epub 2015 Jan 21. PMID: 25605349.

de la Casa A.C., Ovando G.G. (2014). Climate change and its impact on agricultural potential in the central region of Argentina between 1941 and 2010 Agricultural and Forest Meteorology, 195-196. p. 1-11.

De Paula R., Rabalski I. , Messia M. C. , Abdel-Aal E.-S. M., and Marconi E.(2017). "Effect of processing on phenolic acids composition and radical scavenging capacity of barley pasta," Food Research International, vol. 102. p. 136–143.

Dwivedi S.L. , Lammerts van Bueren E.T., Ceccarelli S. , Grando S. , Upadhyaya H.D. , Ortiz R. (2017). Diversifying food systems in the pursuit of sustainable food production and healthy diets Trends Plant Sci., 22. p. 842-856. 10.1016/j.tplants.2017.06.011

El Felah M. (2011). L'orge en Tunisie: historique, état actuel et perspectives Ann. INRAT, 84. p. 7-34.

El Felah M., & Medimagh S. (2005). Food barley in Tunisia. In S. Grando, & G.H. Macpherson, (Eds.), Food barley: Importance, uses and local knowledge. p. 29–35.

El Felah M., Gharbi M.S., Ben Ghanem H., and Elloumi M. (2015). Les céréales en Tunisie entre mythe et réalité. Ann. INRAT, 2ème Numéro Spécial Centenaire, 88. p. 1–17.

El Kenawy A.M. , López-Moreno J.I. , Vicente-Serrano S.M. , Mekld M.S. (2009). Temperature trends in Libya over the second half of the 20th century. Theoretical and Applied Climatology, 98. p. 1-8.

El Shaer H.M., Al Dakheel A.J. (2017) Adaptation to Climate Change in Egyptian Marginal Environments Through Sustainable Crop and Livestock Diversification: A Case Study. In: Leal Filho W., Belay S., Kalangu J., Menas W., Munishi P., Musiyiwa K. (eds) Climate Change Adaptation in Africa. Climate Change Management. Springer, Cham. https://doi.org/10.1007/978-3-319-49520-0_9

El-Hendawy S., Yuncai H., Sakagami J.I & Schmidhalter U. (2011). Screening Egyptian Wheat Genotypes for Salt Tolerance at Early Growth Stages. International Journal of Plant Production. 5. 1735-8043.

Elsawy R., Abdelmonem H., El-Kassas H.I., Medany M.A. (2020). THE SOCIAL EVALUATION FOR THE CLIMATE CHANGE CONFRONTATION TECHNIQUES AT THE NILE DELTA REGION: CASE STUDY AT KAFR EL-SHIEKH GOVERNORATE. Journal of environmental Science. Ain Shams. Volume 49, Issue 4. p. 81-110.

El-Sayed A. F.A. A.(2005). Improvement of Food hull-less Barley in Egypt. En: Food Barley: Importance, uses and local % knowledge. Aleppo, Siria: ICARDA. p. 7-12.

Fang, Y. A. O., Zhang, J. Y., Xiang, X. I. A. O., Ying, D. O. N. G., & Zhou, X. H. (2017). Antitumor activities and apoptosis-regulated mechanisms of fermented barley extract in the transplantation tumor model of human HT-29 cells in nude mice. Biomedical and Environmental Sciences, 30(1). p. 10-21.

FAO. (2010). Food and Agriculture Organization of the United Nations; http://www.fao.org/faostat/en/#data

FAO. (2017). Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/#data

Farooqui A.S ., Syed H.M., Hashmi S.A.S. , Katkade M.B., and Talpade N.N. (2018). Standardization, development and organoleptic evaluation of nutri bar supplemented with barley (Hordeum vulgare) International Journal of Chemical Studies, 6 (2). p. 2794-2798.

Fereidoun Azizi, Farzad Hadaegh, Farhad Hosseinpanah, Parvin Mirmiran, Atieh Amouzegar, Hengameh Abdi, Golaleh Asghari, Donna Parizadeh, Seyed Ali Montazeri, Mojtaba Lotfaliany, Farzin Takyar, Davood Khalili.2019. Metabolic health in the Middle East and north Africa. The Lancet Diabetes & Endocrinology, Volume 7, Issue 11. p. 866-879, ISSN 2213-8587, https://doi.org/10.1016/S2213-8587(19)30179-2.

Fusté, N. P., Guasch, M., Guillen, P., Anerillas, C., Cemeli, T., Pedraza, N., ... & Garí, E. (2019). Barley β-glucan accelerates wound healing by favoring migration versus proliferation of human dermal fibroblasts. Carbohydrate Polymers, 210. p. 389-398.

Grando S., Macpherson H.G., (2005). Food Barley: Importance, Uses and Local Knowledge. ICARDA, Aleppo, Syria.

Guasmi F., Elfalleh W., Hannachi H., Feres K., Touil L., Marzougui N., Triki T., Ferchichi A. (2012): The Use of ISSR and RAPD Markers for Genetic Diversity among South Tunisian Barley. Int Schol Res Net ISRN Agron 2012. p. 1-10.

Hamza S., Ben Hamida W., Rebaï A. et al (2004).. SSR-based genetic diversity assessment among Tunisian winter barley and relationship with morphological traits. Euphytica 135. p. 107–118. https://doi.org/10.1023/B:EUPH.0000009547.65808.bf

Hellyer N.E., Fraser I., Haddock-Fraser J. (2012).Food choice, health information and functional ingredients: An experimental auction employing bread, Food Policy, Volume 37, Issue 3. p. 232-245, ISSN 0306-9192, https://doi.org/10.1016/j.foodpol.2012.02.005.

Herminia S.S., Angélica T.L.I., Favian B.M., Bernarda R.C. (2017).Nutritional value and sensory properties of cookies prepared from flour mixes of carrot (Daucus carota), Lupine (Lupinus perennis) and Barley (Hordeum vulgare). Euro Sci J. 2017; 13(9). p. 378.

Houde M., Khodaei N., Benkerroum N., & Karboune S. (2018). Barley protein concentrates: Extraction, structural and functional properties. Food Chemistry. p. 367-376.

Idehen E., Tang Y., & Sang S. (2017). Bioactive phytochemicals in barley. Journal of food and drug analysis. p. 148-161.

Idehen, E., Tang, Y., & Sang, S. (2017). Bioactive phytochemicals in barley. Journal of food and drug analysis, 25(1). p. 148-161.

Iguchi, T., Kawata, A., Watanabe, T., Mazumder, T. K., & Tanabe, S. (2009). Fermented barley extract suppresses the development of atopic dermatitis-like skin lesions in NC/Nga mice, probably by inhibiting inflammatory cytokines. Bioscience, biotechnology, and biochemistry, 73(3). p. 489-493.

Ingvordsen C.H., Backes G., Lyngkjær M.F. et al (2015).. Genome-wide association study of production and stability traits in barley cultivated under future climate scenarios. Mol Breeding. p. 35, 84. https://doi.org/10.1007/s11032-015-0283-8

INRA Maroc. (2021) : Nouvelles Obtentions Variétales INRA Céréales, Légumineuses alimentaires et Oléagineux 2021.

https://www.inra.org.ma/sites/default/files/LivretNouvellesObtentions.pdf

Pörtner, H. O., Roberts, D. C., Adams, H., Adler, C., Aldunce, P., Ali, E., ... & Birkmann, J. (2022). Climate change 2022: Impacts, adaptation and vulnerability. IPCC Sixth Assessment Report.

Jin, Y., Li, P., & Wang, F. (2018). β-glucans as potential immunoadjuvants: A review on the adjuvanticity, structure-activity relationship and receptor recognition properties. Vaccine, 36(35). p. 5235-5244.

Kole C., Muthamilarasan M., Henry R., Edwards D., Sharma R., Abberton M., Batley J., Bentley A., Blakeney M., Bryant J., Cai H., Cakir M., Cseke L.J., Cockram J., de Oliveira A.C., De Pace C., Dempewolf H., Ellison S., Gepts PGreenland A., Hall A., Hori K., Hughes S;, Humphreys M.W., Iorizzo M., Ismail A.M., Marshall A., Mayes S., Nguyen H.T;, Ogbonnaya F.C., Ortiz R., Paterson A.H;, Simon P.W., Tohme J., Tuberosa R., Valliyodan B;, Varshney R.K., Wullschleger S.D., Yano M., and Prasad M. (2015). Application of genomics-assisted breeding for generation of climate resilient crops: progress and prospects. Front. Plant Sci. 6: 563. doi: 10.3389/fpls.2015.00563

Lahouar L., Ghrairi F., El Arem A., Sghaeir W., El Felah M., Ben Salem H., Sriha B., AchourL. (2014). Attenuation of histopathological alterations of colon, liver and lung by dietary fibre of barley Rihane in azoxymethane-treated rats, food Chemistry, Volume 149. p. 271-276. ISSN 0308-8146, https://doi.org/10.1016/j.foodchem.2013.10.101.

Lahouar L., Ghrairi F., El Felah M. et al. (2011).Effect of dietary fiber of “Rihane” barley grains and azoxymethane on serum and liver lipid variables in Wistar rats. J Physiol Biochem 67. p. 27–34. https://doi.org/10.1007/s13105-010-0045-3

Lahouar L., Pochart P., Salem H., El Felah M., Mokni M., Magne F., . . . Achour L. (2012). Effect of dietary fibre of barley variety ‘Rihane’ on azoxymethane-induced aberrant crypt foci development and on colonic microbiota diversity in rats. British Journal of Nutrition, 108(11). p. 2034-2042. doi:10.1017/S0007114512000219

Lahouar, L., Ghrairi, F., El Arem, A., Medimagh, S., El Felah, M., Salem, H. B., & Achour, L. (2017). Biochemical composition and nutritional evaluation of barley rihane (Hordeum vulgare L.). African Journal of Traditional, Complementary and Alternative Medicines, 14(1). p. 310-317.

Lakhdari H., Ayad A. (2009). Les conséquences du changement climatique sur le Développement de l'agriculture en Algérie: Quelles stratégies d'adaptation face à la rareté de l'eau ? Cinquième colloque international: Énergie, changements Climatiques et Développement Durable, Hammamet (Tunisie). p. 15–17.

Le Mouël C., Forslund A., Marty P., Manceron S., Marajo-Petitzon E., Caillaud M.-A., Schmitt B. (2015). Le système agricole et alimentaire de la région Afrique du Nord – Moyen-Orient à l'horizon 2050 : Projections de tendance et analyse de sensibilité. Final study report for Pluriagri. Paris and Rennes: INRADEPE & INRA-SAE2. 138 p.

Li C., Zhang G.P., & Lance R. (2007). Recent Advances in Breeding Barley for Drought and Saline Stress Tolerance. Advances in Molecular Breeding Toward Drought and Salt Tolerant Crops. p. 603-626. 10.1007/978-1-4020-5578-2_24

Ma, L., Sun, Z., Zeng, Y., Luo, M., & Yang, J. (2018). Molecular mechanism and health role of functional ingredients in blueberry for chronic disease in human beings. International journal of molecular sciences, 19(9). p. 2785.

Maire B., Lioret S., Gartner A., Delpeuch F.(2002). Transition nutritionnelle et maladies chroniques non transmissibles liées à l'alimentation dans les pays en développement. Cahiers d'études et de recherches francophones / Santé. 12(1). p. 45-55.

Malla S., Hobbs J.E., and Sogah E.K. (2014). Functional foods, health benefits and health claims. Athens Journal of Health, 1 (1). p. 37-46.

Miège E. (1950). Les céréales secondaires en Afrique du Nord. In: Revue internationale de botanique appliquée et d'agriculture tropicale, 30e année, bulletin n°337-338, Novembre-décembre 1950. p. 555-578. doi : https://doi.org/10.3406/jatba.1950.6364

Mohamed A.A., Matter M.A. & Rady M.R. (2010). Assessment of some barley germplasms based on RAPD analysis and anti-nutritional factors. J. Crop Sci. Biotechnol. 13. p. 61–68. https://doi.org/10.1007/s12892-010-0010-2

Morrell P.L., and Clegg M.T. (2007). Genetic evidence for a second domestication ofbarley (Hordeum vulgare) east of the Fertile Crescent. Proceedings of the National Academy of Sciences. 104. p. 3289-94.

Newman C.W ; Newman R.K. (2006). A brief history of barley foods. Cereal Foods World. 51(1). p. 4-7.

Newman R.N., and Newman C.W. (2008). Barley for Food and Health: Science, Technology, and Products.John Wiley & Sons, Inc., Hoboken, New Jersey ISBN 978-0-470-10249-7.

Newton A.C., Flavell A.J., George T.S. et al (2011).. Crops that feed the world 4. Barley: a resilient crop? Strengths and weaknesses in the context of food security. Food Sec. 3, 141. https://doi.org/10.1007/s12571-011-0126-3

Noaman M.M. (2017). New Utilization of Barley as Human Healthy Food. J Plant Breed Agric. Vol.1 No.1: 2.

Pastor A., Acanski M., Vujic D., Kondic-Spika A., & Hristov N. (2015). Lipid and sugar profiles of various barley cultivars (Hordeum vulgare). Original scientific paper. p. 65-75.

Percival J. (1921). The Wheat Plant. Duckworth Publishers, London.

Perignon M., Sinfort C., El Ati J., Traissac P., Drogué S., Darmon N.(2019). How to meet nutritional recommendations and reduce diet environmental impact in the Mediterranean region? An optimization study to identify more sustainable diets in Tunisia.Global Food Security. 23. p. 227–235.

Ragaee S.,Abdel-Aal E.M., and Noaman M. (2006).Antioxidant activity and nutrient composition of selected cereals for food use, Food Chemistry, Volume 98, Issue 1. p. 32-38, ISSN 0308-8146, https://doi.org/10.1016/j.foodchem.2005.04.039.

Rahal-Bouziane H. (2016). Quelques cultures stratégiques pour l'Algérie face aux changements climatiques: L'orge (Hordeum Vulgare L.) Et Le Mil [Pennisetum glaucum (L.) R. BR].Algerian journal of arid environment vol. 6, n°1. p. 15-31.

Rahal-Bouziane H., Mossab-Bouaboub K., Blama A., Hamdi S. (2005). LES RESSOURCES FOURRAGÈRES DES OASIS DU TOU AT, GOURARA ET TIDIKEI I HISTORIQUE, INVENTAIRE ET UTILISATION. Séminaire International sur l'Amélioration des Productions Végétales (APV 2005) -LRGB - INA- ALGER

Rousset N., and Arrus R. (2004). Economie de l'adaptation au changement climatique etagriculture dans le Bassin Méditerranéen. Environnement et identité en Méditerranée, IVe congrès international, Universita di Corsica Pasquale Paoli, Corte.

Saidi S., Jilal A., Amri A., and Ceccarili S. (2005). Amélioration génétique de l'orge. In La création variétale à l'INRA, méthodologie, acquis et perspectives (Eds Andaloussi, F.A. and Chahbar, A.). INRA Morocco.

Semenov M.A., Stratonovitch P., Alghabari F., Gooding M.J. (2014). Adapting wheat in Europe for climate change,Journal of Cereal Science,Volume 59, Issue 3. p. 245-256,ISSN 0733-5210,https://doi.org/10.1016/j.jcs.2014.01.006.

Senapati S., Kuanar S.R., Sarkar R.K. (2019). Improvement in anaerobic germination potential and grain yield of rice (Oryza sativa) through seed priming. SAARC J Agric 17. p. 37–48. https://doi.org/10.3329/sja.v17i1.42760

Shah, A., Ahmad, M., Ashwar, B. A., Gani, A., Masoodi, F. A., Wani, I. A., ... & Gani, A. (2015). Effect of γ-irradiation on structure and nutraceutical potential of β-d-glucan from barley (Hordeum vulgare). International journal of biological macromolecules, 72. p. 1168-1175.

Sidhu J.S., Kabir Y., & Huffman F.G. (2007). Functional Foods from Cereal Grains, International Journal of Food Properties, 10: 2. p. 231-244. DOI: 10.1080/10942910601045289

Sourki A., Koocheki A., & Elahi M. (2017). Ultrasound-assisted extraction of β-d-glucan from hull-less barley: Assessment of physicochemical and functional properties. International Journal of Biological Macromolecules. p. 462-475.

Steyn N.P., Parker W., Nel J.H., & Mbithe D. (2012).The nutrition transition and adequacy of thediet of pregnant women in Kenya.International Proceedings of Chemical, Biological and Environmental Engineering (IPCBEE),

USDA database (2020).

https://apps.fas.usda.gov/psdonline/app/index.html#/app/advQuery,

Wang Y., Harding S., Thandapilly S., Tosh S., Jones P., & Ames N. (2017). Barley β-glucan reduces blood cholesterol levels via interrupting bile acid metabolism. British Journal of Nutrition. p. 1-8.

Wang, Y., Ames, N. P., Tun, H. M., Tosh, S. M., Jones, P. J., & Khafipour, E. (2016). High molecular weight barley β-glucan alters gut microbiota toward reduced cardiovascular disease risk. Frontiers in microbiology, 7, 129.

Wendorf F., Wibjörn K., Romuald S.. (2007). Middle Holocene environments of north and east Africa, with special emphasis on the African Sahara. Climate Change and Cultural Dynamics. p.189-227.

Zeng, Y., Pu, X., Du, J., Yang, X., Li, X., Mandal, M., ... & Yang, J. (2020). Molecular mechanism of functional ingredients in barley to combat human chronic diseases. Oxidative medicine and cellular longevity, 2020.

Zentani A. (2005). Status of food barley in the Libyan Arab Jamahiriah. In: Grando, S and Gomez Macpherson, H (eds) Food Barley: Importance, Uses and Local Knowledge. Aleppo: ICARDA. p. 13–16.

Zhou G., Johnson P., Ryan P.R. et al. (2012). Quantitative trait loci for salinity tolerance in barley (Hordeum vulgare L.). Mol Breeding 29. p. 427–436. https://doi.org/10.1007/s11032-011-9559-9