Chapter 14
Contribution of Hassawi Rice to Food and Nutritional Security in Saudi Arabia

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Abstract Rice (*Oryza sativa* L.) is an essential agricultural species that plays a vital role in fulfilling the nutritional needs of over 60% of the world's population. It is well-documented that the Al-Ahsa oasis in the Eastern region of Saudi Arabia is the birthplace of Hassawi rice (*Oryza sativa* L. cv. Hassawi), which has been cultivated there for hundreds of years. For the past seven decades, Hassawi rice has been fundamental in food and nutritional security in Al-Ahsa oasis and surrounding regions, as it was considered a stable food alongside dates. However, currently, there has been a reduction in Hassawi rice production, and it is mainly served during special occasions. Despite the fact that Hassawi rice has a lower content of total carbohydrates than other rice varieties, it contains higher levels of protein, dietary fiber, calcium, phosphorus, iron, thiamine, and antioxidants than white basmati rice. For instance, 100 g of uncooked Hassawi rice provides an average of 25% of daily recommended dietary allowance of dietary fiber compared to only 4% from white Basmati rice. Its high nutritional values and the nature of its carbohydrates make Hassawi rice the best option for people with diabetes and those who want to control their weight rather than maintain their health. This chapter emphasizes the originality of Hassawi rice, its cultivation, production, significance in food and nutritional security, nutritional value, and health benefits.

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1 Introduction

Saudi Arabia is characterized by vast areas of sand dunes, some tall mountains, islands, coasts, and fertile oases. The largest and most famous oasis in Saudi Arabia is Al-Ahsa Oasis, which has plenty of environmental elements that meet the requirements for cultivating and growing a special type of rice variety known as Hassawi rice (*Oryza sativa* L. cv. Hassawi). Hassawi rice is the most distinctive product in Al-Ahsa Oasis (Al-Khayri and Al-Bahrany 2002). It is believed that Hassawi rice originated from the Indonesian variety Peta (Zhang et al. 2012) and has been cultivated in Al-Ahsa for hundreds of years (Al-Elawy 1976; Chang et al. 1981). The cultivation of Hassawi rice is even considered a milestone for some villages in Al-Ahsa, such as Shiraa Al-Ayouni, Shiraa Al-Batalia, Shiraa Al-Shu'bah, Al-Qurain, and Al-Julaijlah (see Fig. 1). This chapter primarily discusses the historical significance of cultivating and producing Hassawi rice, as well as the factors that influence its adaptation. It highlights the importance of Hassawi rice in securing food and meeting nutritional requirements.

Fig. 1 An instrument endowment for Hassawi rice issued in 1036 AH (1902 AD), more than 4 centuries ago. *Source* Pests and Plant Diseases Unit, College of Agricultural and Food Sciences, King Faisal University

1.1 Cultivation and Production of Hassawi Rice

The cultivation and production of Hassawi rice require specific conditions in terms of agricultural soil and appropriate climate. Al-Ahsa, where soil fertility and dark grey-brown loam with moderate acidity and high temperature strongly support the growth of Hassawi rice, is the origin of this type of rice (Chang et al. 1981). Hassawi rice is traditionally planted manually by hand in basins called Dhwahi, edged usually by date palm trees. The first Hassawi rice seedlings are obtained after sowing seeds in well-prepared, fertile soil during late May to early June. The second stage of cultivation, called Sanayah, occurs in July and August. It begins with the transfer of seedlings into Dhwahi, and soaking them in water for eight to fourteen days. The seedlings are usually irrigated once a week for 40 days. After that, irrigation is suspended for 10 days, and then the growth of seedlings is usually irrigated as normal until they are harvested between September and October of each year. The harvest time of Hassawi rice is called Al-Wasmi. This traditional cultivation process has been inherited over generations (Figs. 2 and 3). It is a labor-intensive process that takes about 5–6 months and just needs to be irrigated with plenty of water for the first 45 days. Compared to other varieties of rice, Hassawi rice requires less water for irrigation in general, due to its adaptability to high temperatures, soil salinity, and drought (Al-Jabr 1984; Zhang et al. 2012). The best time of cultivation for Hassawi rice is from late May to early June, and its growth period lasts for 160–180 days. This agricultural practice in Al-Ahsa oasis is facilitated by the availability of abundant fresh water from artesian or dug wells, and the traditional irrigation system there is based on flood irrigation. Indeed, the ground water sources are characterized by high salinity and high sodium hazard. In the past, manual or animal-powered devices were used to raise water from wells or bring water from distant groundwater sources through open ducts (Chang et al. 1981). However, nowadays mechanical pumping of groundwater resources is applied for irrigation.

The cultivation of Hassawi rice produces a large amount of grains per spike, with each spike containing approximately 80 grains. However, there is some annual variation in production. In fact, the production of Hassawi rice has declined (as shown in Fig. 4) due to several factors, including the depletion of groundwater and the reduction of arable land (Al-Jabr 1984). Moreover, many young farmers are not interested in cultivating Hassawi rice because the process requires a lot of hard work and full attention, as well as teamwork.

1.2 General Uses of Hassawi Rice

Hassawi rice is typically used in a traditional Saudi Arabian dish called Kabsa (Fig. 5), which is served with cooked vegetables and meat such as lamb, fish, or chicken (Al-Mssallem 2018). Research has shown that Hassawi rice has greater nutritional value compared to white rice (see Sect. 4), making it a recommended dietary option for

Fig. 2 To prepare Dhwahi, seeds are sown in late May or early June and covered with a layer of mud. The seeds are then watered to promote germination and left to grow for a period of 40–45 days. Another method involves immersing the Dhwahi with water (See **b**) to prepare for planting seedlings transferred from Dhwahi **a**. This process occurs in July and August (Sanaya), and the seedlings are left in water for 40 days before being watered normally until harvest time in late September to October (Alwasmi). Photos by AbdulAziz A. Al-Mssallem

women during the postpartum period (Al-Mssallem et al. 2011). Another popular Saudi Arabian dish, Saleeqah, is prepared similarly to Kabsa but with the addition of chard known as "Silq" (*Beta vulgaris* L.). Additionally, Hassawi rice is often used in dishes such as stuffed grape leaves as a substitute for Snow White rice, and is also being used more recently to produce rice flour for cookies and crackers.

2 Hassawi Rice Importance and Utilization

2.1 Socio-economic Values

In the past, Hassawi rice played a significant role in strengthening commercial relationships among the people in the Arabian Peninsula and neighboring countries. It was actually the second most produced crop in Al-Ahsa, after dates (Al-Jabr 1984). Even though the socioeconomic situation has rapidly and fundamentally changed in the last eight decades, cultivating Hassawi rice is still a traditional agricultural practice that has been passed down from ancestors and will continue to be passed down to descendants. It holds a fundamental place in the hearts of Hassawi farmers towards society. Agricultural practices of Hassawi rice were not only a means of livelihood for the farmer and his family, but also represented generosity and hospitality, and was proof of cooperation, brotherhood, love, and solidarity. The yield of Hassawi rice ensured the daily needs of the farmer and his family as well as being distributed among their relatives and neighbors. A document dating back to 820 AH (1417 AD)

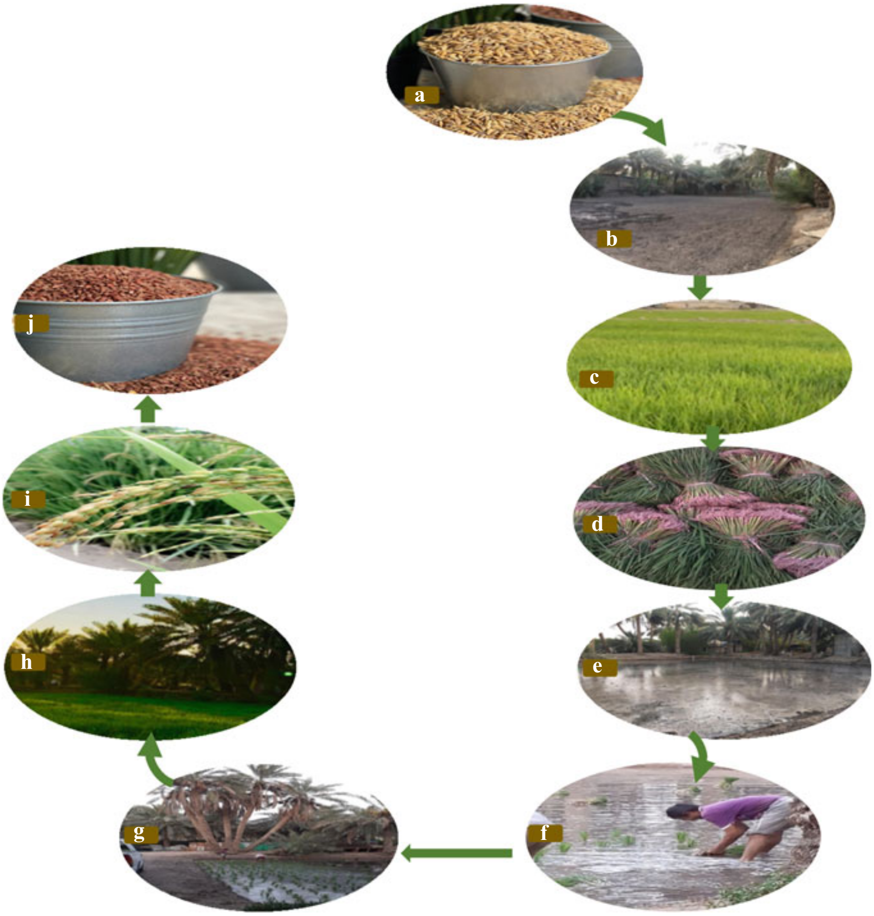

Fig. 3 Cultivation and production of Hassawi rice process. Hassawi rice seeds (shelb) are ready for planting (**a**). Basins 1 (Dhwahi) are prepared for sowing Hassawi rice seeds (**b**). Growth of seeds and form seedlings during 40–45 days (**c**). Seedlings are ready for Sanayah action (**d**). Basins 2 (Dhwahi) are prepared for planting seedlings (**e**). Planting seedlings (Sanayah) in prepared Dhwahi (**f**). Seedlings are soaked for 40–45 days (**g**). Seedlings growth (**h**). Rice spikes (**i**). Hassawi Rice grains are ready for consumer (**j**). Photos by AbdulAziz A. Al-Mssallem & Shareefa Q. Al-Mssallem

was found which endowed the names of Hassawi rice farms to the poor for their benefit (Al-Hussain 2019).

2.2 Research Advances

Hassawi rice has caught the interest of scientific researchers due to its ability to withstand the harsh environmental conditions of Al-Ahsa oasis, such as salinity,

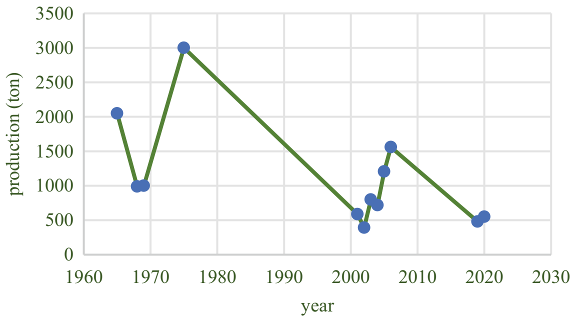

Fig. 4 The fluctuation in the production of Hassawi rice. *Source* Al-Jabr (1984), Al-Gazal (2021)

Fig. 5 Uncooked Hassawi rice Shelb [left, (**a**)] and grains [right, (**a**)]. Cooked Hassawi rice served into Kabsa (**b**). Photos by Shareefa Q. Al-Mssallem

drought, and extreme hot temperatures. However, it does have some unfavorable characteristics, such as sensitivity to day length, delayed maturation, and susceptibility to lodging (Chang et al. 1981). To overcome these undesirable traits, a breeding program was carried out between the Republic of China and Saudi Arabia, resulting in the production of Hassawi-1 and Hassawi-2 (CATM 1985).

Several scientific studies have been conducted on Hassawi rice by researchers from King Faisal University since the 1990s. One of the initial works focused on the storage protein of Hassawi rice (Al-Mssallem and Al-Mssallem 1997). Other studies have looked at in vitro regeneration (Al-Khayri and Al-Bahrany 2000), fatty acid analysis (Al-Bahrany 2002), response of cell cultures to water stress (Al-Khayri and Al-Bahrany 2002), effect of fertilizer nutrients on yield (Al-Gusaibi 2004), nutritional composition (Hadid and Elsheikh 2012; Al-Mssallem et al. 2011), glycaemic and insulinaemic index values (Al-Mssallem et al. 2011), breeding (Bimpong et al. 2014), in vitro carbohydrate hydrolysis (Al-Mssallem et al. 2014), genomics (Zhang et al. 2012), antioxidants activity (Al-Mssallem and Alqurashi 2021), and phytochemical components (El-Beltagi et al. 2022). It is important to continue conducting scientific studies on Hassawi rice to emphasize its role in improving food security and environmental sustainability.

The College of Agriculture and Food Sciences at KFU is interested in advancing scientific progress on Hassawi rice. Therefore, a Scientific Team of Hassawi Rice Researchers was established in May 2022. One of the team's most important tasks is to motivate and encourage researchers to conduct scientific work on Hassawi rice, such as clinical studies to investigate the benefits of Hassawi rice in protecting or treating chronic health conditions, biotechnological research to adapt the genes of Hassawi rice in order to improve production characteristics and increase nutritional value, manufacturing Hassawi rice, creating a database of annual production statistics of Hassawi rice, studying the economics of production, marketing, consumption, and consumer demand. As a result, some proposed research projects have been submitted to be considered for possible funds (Table 1).

3 Hassawi Rice Significance in Food Security

3.1 Historical Overview

Hassawi rice, also known as *Oryza sativa* L. cv. Hassawi, has been cultivated for several centuries. It is well adapted to the soil salinity and hot weather conditions of Al-Ahsa oasis in Saudi Arabia (Zhang et al. 2012). For over 7 decades, Hassawi rice has been a staple food for most of the Hassawi population, second only to dates in providing daily nutritional needs. Historically, Hassawi rice production was used to provide for the needs of poor people, as far back as the fourteenth century when the Princes of Al-Ahsa endowed their Hassawi rice farms for the benefit of the poor (Al-Hussain 2019).

3.2 Climate Change Implications

Climate change plays a significant role in natural resources and has a serious impact on food and nutrition security. The effects of climate change on food security can be observed through changes in food availability, accessibility, supply stability, and price volatility. In Saudi Arabia, the prevailing climate is arid, making it vulnerable

Table 1 Some suggested forthcoming researches on Hassawi rice

Proposed scientific research	Institution	Department	Proposed funding body
Hassawi rice biofortification to enrich micronutrients towards ensuring food and nutritional security	King Faisal University	Agricultural Biotechnology Central Laboratories Food Sciences and Nutrition	Deanship of Scientific Research, King Faisal University
Genome editing in Hassawi rice for high salinity tolerance to secure food and nutritional security in Saudi Arabia	King Faisal University	Agricultural Biotechnology Central Laboratories Food Sciences and Nutrition	Deanship of Scientific Research, King Faisal University
Genetic improvement of Hassawi rice to enhance food security in Saudi Arabia: molecular breeding for development of abiotic stress tolerance	King Faisal University	Agricultural Biotechnology Central Laboratories Food Sciences and Nutrition	Deanship of Scientific Research, King Faisal University
Morphological and molecular characterization of some genotypes of Hassawi rice	King Faisal University	Agribusiness and Consumer Sciences	Deanship of Scientific Research, King Faisal University
Using stochastic frontier to estimates and analysis the technical efficiency for rice production in Al Ahsa oasis, Saudi Arabia	King Faisal University	Agribusiness and Consumer Sciences Agricultural Biotechnology	Deanship of Scientific Research, King Faisal University
Bioactive compounds of Hassawi rice and their beneficial impact on gut health	A joint project between University of Northumbria, UK and King Faisal University, SA	Department of Applied and Health Sciences, NU, UK Department of Food Sciences and Nutrition	International Cooperation and Knowledge Exchange Administration, King Faisal University

to the adverse effects of climate change. There has been a decrease in precipitation and severe droughts, leading to the severe degradation of ecosystems (Haque and Khan 2022). Assessing temperature and rainfall is considered a reliable indicator for predicting future climate change trends. In Saudi Arabia, there has been a decrease in rainfall in many areas and an increase in temperature across the country (Tarawneh and Chowdhury 2018). It has been observed that there has been a significant increase in the average temperature by 1.9 °C in the last 5 decades. This increase in temperature indicates that a one-degree Celsius increase can lower crop yield by 7–25% (Haque and Khan 2022; Zhai and Zhuang 2009).

Like other regions in Saudi Arabia, the climate in Al-Ahsa is characterized by extremely hot weather that ranges from 46 to 51 °C during the summer, and reasonably dry and cool in the winter (Alharbi and Sultan 1985; Youssef et al. 2016). Hassawi rice, like any other crop, is sensitive to fluctuations in temperature and rainfall. In fact, the hot summer weather in Al-Ahsa is considered suitable for growing Hassawi rice because of its specific climatic needs. Additionally, the fertile loam soil found in Al-Ahsa retains water for longer periods of time and is compatible with the extreme hot climate conditions. Hassawi rice is unique in the sense that, during its 5–6 month growth period, it requires generous irrigation in the first two months. It also has a high tolerance for extreme dry weather, drought, and soil salinity, making it well-suited for cultivation in the challenging agro-environmental circumstances of the Al-Ahsa oasis (Almeida et al. 2017). However, the limited rain and scarce irrigation water from underground wells restrict Hassawi rice production and cause fluctuations in its economic sustainability. Therefore, implementing a sustainable water resource management strategy is necessary.

3.3 Relevance to Food Security and Farmer Livelihood Protection

Food security, as defined by the FAO, refers to a situation where all individuals have consistent access to sufficient, safe, and nutritious food that meets their dietary needs and preferences for healthy and active living at all times. Hassawi rice has played a significant role in ensuring this security for the local community's food and livelihood. Over the past 70 years, it has been grown in ample quantities to provide for the local populace and even exported to neighboring regions. Hassawi rice was a staple food for many local people after dates. Unlike other varieties, Hassawi rice can be stored for several years under dry and clean conditions. It has been documented that some Hassawi rice farms were established to benefit poor people (Al-Hussain 2019). However, the cultivation, production, and consumption of Hassawi rice has declined due to several reasons. These reasons include competition from imported rice varieties, the high demand for manual labor, and changing eating patterns (Al-Jabr 1984; Al-Mssallem 2018). Efforts are underway to improve the cultivation of Hassawi rice while also ensuring the preservation of the environment and the betterment of livelihoods. The Saudi Ministry of Culture, represented by the Culinary Arts Commission, has initiated a project to register Hassawi rice Dhwahi as a globally important agricultural heritage system (GIAHS) at FAO in the Al-Ahsa oasis. The registration of Hassawi rice Dhwahi as a GIAHS is a significant step towards preserving the continuity of its cultivation and preventing its extinction.

3.4 Factors Influencing Adoption

There are several factors that can influence the cultivation and production of Hassawi rice, including its high demand for irrigation water, soil salinity, drought, photoperiod sensitivity, susceptibility to lodging, and delayed maturity (Almeida et al. 2017; Chang et al. 1981; Zhang et al. 2012). Furthermore, cultivating Hassawi rice requires intensive labor and cooperative teamwork. However, some of these undesirable traits of Hassawi rice have been addressed. To improve its susceptibility to lodging, photoperiod sensitivity, and delayed maturity, two varieties—Hassawi-1 and Hassawi-2—were developed from local Hassawi rice through a breeding program carried out under the Agricultural Cooperation Agreement between the Republic of China and Saudi Arabia (Chang et al. 1981; CATM 1985). Hassawi rice possesses a unique property of being able to tolerate high levels of soil salinity, severe heat, and drought (Chang et al. 1981). For this reason, the Al-Ahsa oasis is well-suited for the growth of this variety of rice.

4 Hassawi Rice Significance in Nutritional Security

4.1 Nutritional Value and Health Benefits

Hassawi rice, like any variety of rice, is considered a source of carbohydrates (CHOs). However, its CHOs content is lower compared to other varieties of white rice (Al-Mssallem et al. 2011). Table 2 shows that Hassawi rice has higher protein, fat, non-starch polysaccharides (NSPs), mineral content (calcium, phosphorus, iron), water-soluble vitamins (thiamine, riboflavin), and phenolic compounds compared to Basmati rice (Al-Mssallem et al. 2011; Hadid and Elsheikh 2012; Al-Mssallem and Alqurashi 2021). Hassawi rice's most abundant fatty acids are linoleic, oleic, and palmitic acids. Hassawi rice's unsaturated fatty acids constitute 76% of its total fatty acids (Al-Bahrany 2002). Consuming Hassawi rice offers greater nutritional benefits than white Basmati rice. For instance, Hassawi rice provides 25% NSPs compared to Basmati rice's 4% NSPs (Table 2). As an unrefined and unprocessed crop, Hassawi rice is a good source of NSPs, minerals (e.g. calcium and iron), vitamins (e.g. thiamine), and antioxidants. Foods rich in NSPs have been shown to reduce the risk of obesity and diabetes (Al-Mssallem et al. 2011). Using Hassawi cell suspension culture, secondary metabolites can be produced on a large scale (El-Beltagi et al. 2022).

The quality of carbohydrates (CHOs) in Hassawi rice is characterized by gradual hydrolysis and slow absorption. This unique feature of its carbohydrates has been confirmed by in vitro and in vivo studies of the carbohydrates of Hassawi rice (Al-Mssallem et al. 2011, 2014). It has been found that Hassawi rice has a lower glycemic load (GL) and insulinaemic index (II) compared to white rice (Fig. 6), despite the fact that the glycemic index values of both varieties were close (Al-Mssallem et al.

Table 2 Nutrients contents and percentage of daily value in 100 g of raw Hassawi rice and Basmati rice

Components	Hassawi rice	% daily value	White rice	% daily value
Energy (calorie)	327	18	362	20
Total carbohydrates (g/100 g)	66.82	26	78.68	30
Non-starch polysaccharides (g/100 g)	6.22	25	0.96	4
Total protein (g/100 g)	10.49	14	7.97	10
Total fat (g/100 g)	1.99	4	1.66	3
Calcium, Ca (mg/100 g)	12.6	1.05	5.7	0.5
Phosphorus, P (mg/100 g)	185	15	125	10
Iron, Fe (mg/100 g)	1.3	9	0.89	6
Thiamine, B1 (mg/100 g)	0.55	50	0.18	16

Source Al-Mssallem et al. (2011), Al-Mssallem and Alqurashi (2021)

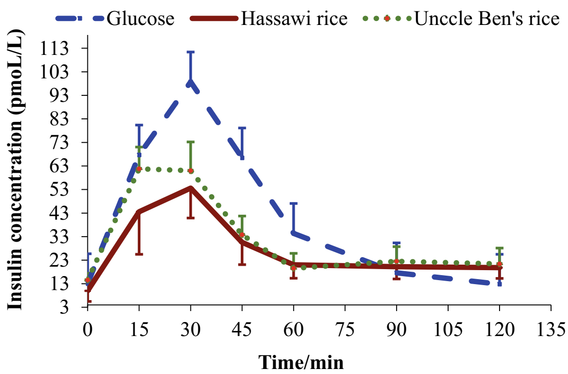

Fig. 6 Insulinaemic index of Hassawi rice and white Uncle Ben's rice. *Source* Al-Mssallem et al. (2011)

2011; Al-Mssallem 2018). Because of the nature of its carbohydrates, low GL value, and low II value, Hassawi rice is recommended for controlling weight and blood glucose levels (Al-Mssallem 2014). Research on exploring the impact of Hassawi rice contents on microbiota and their impact on human guts is in progress. More clinical research studies on its potential health benefits are required.

4.2 Physico-Chemical Properties

Hassawi rice is a type of pigmented rice that is characterized by its brown reddish color (as shown in Fig. 5a). The moisture content of both uncooked and cooked Hassawi rice is approximately 62%, according to Al-Mssallem et al. (2011). Like any variety of rice, the main chemical component in Hassawi rice is carbohydrates, with an amylose content of approximately 17.5/100 g in cooked Hassawi rice. The

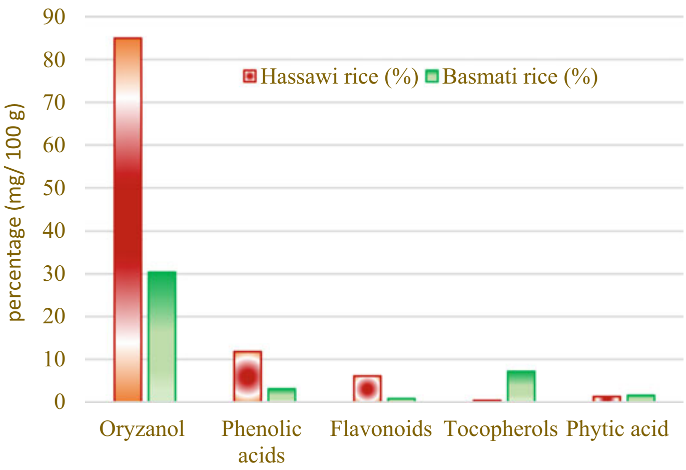

Fig. 7 Phytochemical contents in Hassawi rice in comparison to Basmati white rice. *Source* Hadid and Elsheikh (2012), Al-Mssallem and Alqurashi (2021)

macro and micro chemical compositions of Hassawi rice are detailed in Table 2. Furthermore, bioactive compounds such as phenolic compounds, flavonoids, and anthocyanins are present in Hassawi rice (as demonstrated in Fig. 7). The main lipophilic phytochemical compound in rice is oryzanol, and it is almost three times more prevalent in Hassawi rice than in Basmati rice. These bioactive compounds act as essential antioxidants, as they have the ability to scavenge free radicals and provide protection against chronic degenerative disorders. In fact, Hassawi rice has been found to have higher antioxidant activity than Basmati rice [as reported by Hadid and Elsheikh (2012) and Al-Mssallem and Alqurashi (2021)]. Further studies are recommended to explore the quality and quantity of bioactive compounds present in Hassawi rice.

4.3 Relevance to Nutritional Security Strategies

Food security is a major concern for policy makers in the Middle East, particularly in Saudi Arabia. As the country's local food production is not sufficient to meet domestic needs, the majority of food commodities are imported from other countries (Fiaz et al. 2018). In fact, around 80% of the country's food requirements are imported. Despite having the largest area among Arab countries (2,149,690 km^2) and a population of over 30 million, only 1.6% of Saudi Arabia's land is arable. Moreover, the country's agriculture sector consumes about 88% of its water, with the average consumption being around 24 billion m^3. To address this challenge, Saudi Arabia has established various intensive agricultural extension activities, including schemes, practices, universities, government bodies, and programs, aimed at increasing productivity and achieving nutritional food stability. The country's top priority should be to increase the availability of arable land to enhance crop productivity (Faridi and Sulphey 2019).

Land and water are the primary limiting factors for agricultural production. The Kingdom of Saudi Arabia is experiencing a water shortage due to several reasons, including increasing population growth, inappropriate distribution of water resources, poor water quality, low rainfall, high evaporation rates, aridity, and increasing demand for freshwater. These factors are putting additional pressure on water security and potentially affecting groundwater, which cannot withstand these circumstances. Thus, there is a high demand for an efficient and sustainable solution to manage water resources (Fiaz et al. 2018).

Recently, several potential technologies for saving land and water have been applied to meet domestic energy requirements. These include promoting traditional crops, harvesting seawater and rainwater, and utilizing greenhouse and hydroponic farming. Therefore, it is crucial to activate the role of extension agents to encourage the use of innovative agricultural technologies and increase farmers' awareness of guidelines to achieve sufficient production of dietary needs in Saudi Arabia. There are several methodologies that can be applied in Saudi Arabia to achieve national food security and expand national food manufacturing. Innovative conventional and non-conventional land and water technologies are essential for providing sustainable yields as well as conserving non-renewable resources. Conventional crops promotion is one strategy for achieving nutritional security (Fiaz et al. 2018). Additionally, hydroponic and greenhouse farming technologies have been found to be effective in producing sustainable, high-quality fruits and vegetables using nutrient-rich water under controlled conditions. The hydroponic greenhouse technique has increased vegetable production from 5 tonnes in soil fields up to 200 tonnes yearly for each planted acre. Moreover, low amounts of water (2–10%) are required for these techniques for the same crop production under soil conditions and only 3–5% of water under field conditions (Al-Karaki and Al-Hashimi 2012).

Seawater is a suitable, cost-effective technique that can be applied in desert areas. This technique involves building greenhouses in far-flung and coastal areas to use saltwater in planting food crops. The condensed freshwater resulting from seawater evaporation is utilized to grow these crops. The greenhouse creates cool air for plant cultivation through sunlight and seawater. Low humidity and the availability of seawater are ideal conditions for this technique, such as the Red Sea in Saudi Arabia. Harvesting rainwater is a beneficial technique for effectively using rainwater for lateral use. Rainwater harvesting requires effectively managing three landscape elements: the condition of soil and landscape runoff, water flow created by variations in the elevation of the landscape, and a sufficient deep soil horizon. Recently, the amount of water available has increased from 1400 to 3000 million m^3. King Fahad's dam, located in Wadi Bishah of Saudi Arabia, has the largest dam with a height of 103 m and a storage capacity of 325 million m^3 (Fiaz et al. 2018).

Biotic stresses, such as insect pests, pose a significant challenge to sustaining Hassawi rice production. They have the potential to affect up to 25% of rice production worldwide. The main insect pests that affect rice crops are stem borers (Chilo agamemnon Bles.), which can cause yield losses of over 70%. To reduce these losses, an economic, viable, and ecologically acceptable approach should be employed. Breeding for insect-resistant crop varieties is the most effective integrated pest management approach to combat stem borer infestations in rice production through a breeding program (Al-Daej et al. 2022).

5 Conclusions and Prospects

For hundreds of years, Hassawi rice has been grown in the Al-Ahsa oasis, increasing food and nutritional security due to its high nutritional value when compared to imported rice. However, the challenges of climate change mean that research must focus on improving this landrace rice to ensure that it can continue to be cultivated sustainably. Modern breeding technologies offer opportunities to improve specific traits, with the aim of increasing productivity and enhancing nutritional content. Given the scarcity of water in the region, it is vitally important to develop resilience to water stress, which is a major abiotic stress factor. In addition, research must prioritize developing tolerance to biotic stress to achieve sustainability. Hassawi rice is known for its numerous medicinal properties, and there is potential to produce pharmaceutical compounds at a commercial scale, adding significant value.

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