Chapter 10

Role of Barley in Maternal Health

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ABSTRACT

Barley is a cereal of the Poaceae family and it is produced and consumed widely across the world. It is a multipurpose crop that is cultivated for human use as well as for animal feed and in terms of production it is the fourth most produced grain. Barley consists mainly of carbohydrates, protein, low fat, and micronutrients such as vitamin E, potassium, magnesium, and antioxidants, especially polyphenols. Moreover, barley's functional properties relate to the various phytochemicals found in it including flavonoids, sterols, folates, phenolic acids, and lignans as well as β-glucan. These are known to improve various health aspects and prevent the incidence and progression of chronic diseases. Barley also plays an important role in maternal health as it is a galactagogue that improves milk supply in lactating women, maintains blood glucose levels and reduces insulin resistance in gestational diabetes, prevents obesity during gestation and is used in its management, and its antioxidative potential to reduce oxidative stress prevent pregnancy complications and adverse pregnancy outcomes including preeclampsia.

KEYWORDS
Barley, Maternal health, Galactagogue, Gestational diabetes, Obesity, Oxidative stress, Preeclampsia.

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INTRODUCTION

Barley is a cereal of the Poaceae family and it is produced and consumed widely in Asia, Africa and semi-arid regions although it is also produced in Europe, Australia and America (Hussain et al., 2021). It is a multipurpose crop that is cultivated for human use as well as for animal feed and in terms of production it is the fourth most produced grain; this also owes to the fact that it adapts to various environmental conditions, it has an early maturation and has a lower need for water and nitrogen fertilizers to give a high yield (Idehen et al., 2017; Ruggeri et al., 2022).

Its resilient nature allows it to be cultivated in various climatic zones including the Arctic and Mediterranean countries. In Tibet it is grown at high altitudes where it adapts to low temperatures (Meng et al., 2023). Therefore, its ability to adapt to unfavorable conditions allows it to be used widely in areas where other cereals are not produced (Idehen et al., 2017; Ruggeri et al., 2022).

Furthermore, Barley varieties vary in their genetic composition and can be categorized as winter or spring variety, two-rowed or six-rowed, and naked (hulless) or covered (having the outer inedible husk intact). The naked variety is richer in soluble fiber, protein, and antioxidants than the covered variety thus it has a greater nutritional value and potential for food production (Lukinac and Jukić, 2022). In addition, the various colors of different barley varieties relate to their flavonoid content found in the seed (Meng et al., 2023).

Barley consists mainly of carbohydrates, protein, low fat, and micronutrients such as vitamin E, potassium, magnesium, and antioxidants, especially polyphenols. Starch content in barley is about 68%, protein is up to 17%, non-starch polysaccharide β-glucan ranges from 4-9%, (4%–9%), and total dietary fiber ranges from 11-34% with 3-20% of it being soluble dietary fiber (Hussain et al., 2021).

Moreover, barley's functional properties relate to the various phytochemicals found in it including flavonoids, sterols, folates, phenolic acids, and lignans. These are known to improve various health aspects including growth, development, and reproduction, and boost immunity (Hussain et al., 2021). Barley is also a cereal rich in the bioactive component β-glucan, which confers functional and health benefits such as lowering cholesterol and antihyperglycemic effects (Koren et al., 2021).

Furthermore, barley's health-promoting properties also relate to its high resistant starch, and tocol content. With resistant starch working to promote intestinal health, regulate blood sugar and cholesterol and tocols working to reduce serum cholesterol. In addition, among cereals, barley has the lowest glycemic index and the greatest amount of soluble fiber glucans as well as the greatest antioxidant potential (Raj et al., 2023).

Studies have also found that whole grain barley consumption has been linked to a reduced risk of chronic diseases such as cancer, cardiovascular disease, and diabetes. Consumption of wholegrain barley as a part of a balanced diet also has a preventive effect against obesity. Furthermore, barley grass has been found to be an important functional food as it has shown to have antihyperglycemic, antihypertensive, antihyperlipidemic, anticarcinogenic, antioxidative, anti-inflammatory, and antidepressant effects, improves sleep, cognition, and digestion (Zeng et al., 2018).

As a versatile grain, barley has many applications in food and barley-containing foods are termed functional foods as they are nutritious and play a role in promoting health and preventing disease. Thus various cereal products including bread, pasta, biscuits, muffins, malted beverages are produced using barley (Lukinac and Jukić, 2022). Different types of barley are used in the production of different food products for instance, pearl barley has use in soups, malted barley is used to produce brewed beverages, milk-based beverages, and syrups, and milled barley is used in the production of infant foods, bread, and cookies.

Furthermore, Malted barley is the primary form used for human consumption and malting has three steps. These include steeping to elevate the moisture content in the grain, followed by regulated germination to produce green malt that undergoes kilning in the last step. Moreover, it has been found that germination and kilning of the grain alter the texture, flavor, taste, and nutritional value of the grain (Koren et al., 2021).

The purpose of this chapter is to further explore the health-promoting effects of barley, owing to its nutrient composition and bioactive components, particularly its role in promoting maternal health and wellbeing.

Galactagogue

Lactogenesis in humans begins due to a rise in prolactin levels post-delivery, but the amount of milk produced depends of the frequency and duration of breastfeeding and pumping during the first few weeks of lactation. Delayed or inadequate milk production and a reduced milk supply are a challenge that is especially faced in preterm deliveries and this related to lower prolactin levels in mothers who give birth before term.

Animal studies found that β-glucan in barley promote milk production by improving prolactin levels. Moreover, a study involving human mothers with inadequate milk supply also found that the consumption of a barley malt-based product for 14 days improved milk supply (Wesolowska et al., 2021).

Further investigation was conducted in mothers of premature infants with low milk supply and it also found that barley malt-based product functions as a galactagogue. The group of mothers given the galactagogue composition were found to produce 30% more milk thus this barley malt-based product was found to be a lactation stimulant and its use was found to be a safe way to increase the mothers' milk supply. The study concluded that the barley malt-based galactagogue formula was safe to be given during the lactation period and in the first two weeks of lactation it greatly increased milk production. The galactagogue effect was widely associated with the glucan content of barley malt and it was also found that the malting process of barley releases bioactive components that have the potential to elevate milk production.

Moreover, in many cultures barley is used by mothers to increase their milk supply and although allergy to barley is rare mothers with celiac disease are advised to avoid it (Wesolowska et al., 2021; National Institute of Child Health and Human Development, 2024).

In addition, barley is also used to produce nonalcoholic beer which is beneficial against inflammatory diseases, respiratory issues, and diarrhea and is also used to initiate and enhance breastfeeding. A study also found it to increase serum prolactin in lactating mothers thus concluding that the phytochemicals other than alcohol are responsible for the lactation-stimulating effects of beer. Another trial found that supplementation of lactating mothers' diet with nonalcoholic beer increased the antioxidant content of breast milk as well as the amount of coenzyme Q_{10} in breast milk (Javan et al., 2017; Monte-Guedes et al., 2018).

Gestational Diabetes

Gestational diabetes (GDM) is a kind of diabetes mellitus (DM) that is considered as a pregnancy complication in which hyperglycemia occurs in pregnant women who previously did not have diabetes and this usually resolves postpartum. GDM occurs when maternal beta cells cannot maintain the insulin balance required during pregnancy. There are adverse consequences of GDM for the mother and infant. These include a greater risk of maternal and infant heart disease and type 2 DM, macrosomia, and premature birth (Nakshine et al., 2023).

Moreover, a high triglyceride-glucose index during early pregnancy presents a greater risk of GDM and studies have found that supplementing with dietary fiber, before 20 weeks of gestation, can prevent GDM as well as preterm delivery in women with an elevated triglyceride-glucose index as dietary fiber plays a role in metabolizing glucose and lipids (Cao et al., 2023).

Furthermore, women who were overweight or obese prior to pregnancy are at greater risk of GDM as obesity in linked to elevated inflammatory markers which lead to insulin resistance and GDM. A study also confirmed that a greater intake of dietary fiber for these women may also prevent insulin resistance leading to GDM, preterm delivery, glucose intolerance, and excess weight gain during pregnancy; women supplementing dietary fiber in their diet were found to have lower fasting plasma glucose levels and HbA1c levels thus showing better tolerance to glucose post intervention (Zhang et al., 2022).

In addition, β-glucan has been found to reduce blood sugar in diabetics by promoting delayed gastric emptying, decreasing appetite, and promoting the activation of signaling pathways. Moreover, whole grain consumption is associated with a reduced risk of type 2 diabetes and whole grains and fiber have antidiabetic properties through promotion of various mechanisms such as energy depletion. In pregnancy, 25-35g/day of fiber is recommended and wholegrains can provide a majority of it especially barley which is rich in fiber. High fiber intake was also found to improve blood sugar levels as well as reduces hyperinsulinemia in diabetics (Barati et al., 2021).

Furthermore, β-glucan from barley grains has been found to reduce post-prandial blood glucose levels after the consumption of a meal high in carbohydrates and intake of ≥ 6 g/day β-glucan for at least 4 weeks significantly affects post-prandial blood glucose levels. The consensus of most studies in humans is that at least 4g of β-glucan is required for every 30g of available carbohydrates to significantly reduce glucose levels post meals. β-glucan reduces blood glucose by interacting with enzymes on the intestinal brush border as well as interacting with nutrient transporters to inhibit the intestinal uptake of glucose (Malunga et al., 2021; Lante et al., 2023).

Obesity

Pregnant women who are obese before pregnancy or those who become obese during gestation present a lipotoxic environment in the placenta with elevated pro-inflammatory cytokine levels thus leading to various complications in the mother and infant. Obesity is a risk factor for preeclampsia, GDM, delivery complications, insulin resistance, anemia, and inflammation in the newborn (Jiménez-Osorio et al., 2023).

Moreover, studies have found that women who are obese are less insulin sensitive than women of normal weight thus the risk of GDM is higher in these women along with hypertension during gestation, macrosomia, and cesarean deliveries (Kim and Ayabe, 2023).

Obesity is also a challenge for fertility as it leads to problems in conception and also increases the risk of miscarriages and stillbirth as well as maternal death. Moreover, an excess gain of weight during gestation and weight retention post birth further increase difficulties conceiving in the future as well as elevate the risk in pregnancies that may result (Langley-Evans et al., 2022).

Barley promotes satiety and reports found that consuming barley before lunch led to feeling less hunger than consuming wheat and rice-based products. The satiety-promoting effect of barley relates to its high fiber and β-glucan content which regulate appetite, and delay gastric emptying and absorption. Whole-grain barley is also known to prevent insulin resistance, hyperlipidemia, and obesity. Due to its high viscosity and interactions with nutrient transporters, it slows the digestion and absorption of glucose and leads to the feeling of early satiety.

Moreover, dietary fibers undergo fermentation in the large intestines to produce short-chain fatty acids that promote satiety by increasing the satiety hormones which increase energy expenditure and fat oxidation while preventing fat accumulation. In addition, other phytochemicals in barley also prevent obesity including coumaric acid and ferulic acid which are the major anti-obesity agents in hulled barley extracts and prevent fat accumulation in mice and rats (Gong, 2019).

Other studies have also found that an increase in dietary fiber consumption promotes satiety by increasing the food volume in the stomach while lowering the meal's calorie density and ultimately leading to weight loss (Zhang et al., 2022). Furthermore, barley foods are rich in fiber, are nutrient-dense, and promote satiety thus making them appropriate choices for weight maintenance diets. Evidence also suggests that these foods are associated with lower body weight, adiposity, and waist circumference owing to their β-glucan content (Mathews et al., 2021).

In addition, foods with a low glycemic index are used to manage obesity and barley is one such cereal that lowers blood sugar and lipid levels. Barley is rich in fiber β-glucan, and bioactive components that have antioxidant effects to reduce inflammation, lower serum cholesterol, and reduce the absorption of glucose into the bloodstream thus making barley appropriate for obesity management (Gong et al., 2019; Sharma et al., 2022).

Antioxidative Potential to Prevent Adverse Pregnancy Outcomes

Oxidative stress in the body due to the increased production of free radicals increases the risk of chronic diseases as well as pregnancy complications. Certain dietary crops can scavenge these free radicals and reduce oxidative stress. In barley, β-glucan and phenolic compounds have antioxidative potential against various chronic conditions (Desta et al., 2024).

Flavanoids in barley are potent antioxidants against cancer, allergies and inflammation. Moreover, tocols or vitamin E are also found in barley which are protective against neurodegenerative conditions and heart disease, as well as in lower serum cholesterol levels and reduce platelet aggregation (Abebaw, 2021).

Oxidative stress plays an important role in the incidence of GDM and obesity as it leads to insulin resistance, reduced glucose tolerance and impaired β-cell function. The phytochemicals in barley work to prevent the incidence and advancement of these diseases especially phenolic acids, tocols, flavonoids, and phytosterols which are potent antioxidants. In addition, a study using methanolic extracts from various grains found barley to have the highest antioxidant potential compared to wheat, oat, and rye. This antioxidant potential reduces the inflammatory markers, particularly in adipose tissues, that are an important feature in obesity and diabetes (Idehen et al., 2017).

Another study isolated the flavonoids lutonarin and saponarin from barley grass and found that saponarin is a strong antioxidant that can prevent the incidence of oxidative damage in various inflammatory conditions, heart disease, and cancer (Zeng et al., 2018).

Oxidative stress is linked to chronic inflammation and various diseases that include reproductive disorders and pregnancy complications. During gestation oxidative stress normally increases as the placenta produces increased amounts of free radicals but these are usually neutralized by antioxidant levels. On the other hand, when these levels are not balanced the oxidative stress can lead to harmful effects for the mother and fetus and conditions such as preeclampsia, GDM, and hypertension during pregnancy can occur which greatly increase the risk of mortality in the mother and child (Phoswa and Khaliq, 2021).

Preeclampsia (PE) is a pregnancy complication in which hypertension occurs accompanied by proteinuria and this appears in after the first trimester of pregnancy. This condition may be accompanied by comorbid conditions such as edema, eclampsia, and hepatic alterations for the mother, and intrauterine growth restriction and low birth weight, premature birth, and stillbirth for the fetus. Preeclampsia is a result of oxidative stress causing oxidative damage in the placenta resulting in an increase in inflammatory factors and vasoactive compounds which leads to impaired endothelial function that is presented as increased constriction and inflammation of vessels. Therefore, oxidative stress plays a vital role in the etiology of preeclampsia (Aouache et al., 2018).

Preeclampsia and hypertension during gestation both present reduced placental perfusion which leads to hypoxia in the placenta that causes maternal inflammation. In the case of preeclampsia this inflammation affects kidneys and results in proteinuria. As for GDM, oxidative stress leads to hyperinsulinemia during gestation leading to an increase in lipid peroxidation factors which also prevent the release of antioxidants thus free radicals increase and prevent glucose utilization by body tissues (Phoswa and Khaliq, 2021).

In addition, oxidative stress is also associated with polycystic ovary syndrome, endometriosis, and infertility in women. Studies on pregnant women and laboratory animals have also found that oxidative stress in the placenta can transcend to distal tissues and cause oxidative damage resulting in complications and abnormalities in gestation. These include brain damage, retinopathy, and birth defects in the fetus and nausea, vomiting, damage to placental DNA as well as the above mentioned conditions (Grzeszczak et al., 2023).

Neural tube defects, cleft palate, and brain and cardiac defects in the fetus are some common adverse pregnancy outcomes and these are strongly associated with folate deficiency. Folate is another potent antioxidant and barley is a cereal rich in folate, which is found mainly in the outer layers of the kernel. Moreover, pearled barley flour has been found to provide a higher folate content. Foods such as pasta, and biscuits made from this flour are a means of providing increased folate content compared to unfortified products. These products play an important role in improving folate status in mothers and reducing the risk on congenital abnormalities and cardio-cerebral diseases (Ruggeri et al., 2022).

Furthermore, magnesium is another important antioxidative micronutrient involved in metabolic functions and its deficiency also contributes to diabetes and hypertension as well are neurodegenerative conditions. Women are more prone to magnesium deficiency as estrogen promotes the uptake of magnesium by tissues thus hormonal changes in women can affect magnesium status. Moreover, during gestation magnesium requirements increase due to increased fetal needs and renal output, and changes in tissue distribution. According to recent research, low magnesium levels during gestation are associated with pregnancy complications such as preeclampsia and intrauterine growth restriction in the fetus (Orlova et al., 2021).

Magnesium also plays an important role in glucose regulation and insulin signaling and insulin also regulates the accumulation of magnesium in cells. Low serum levels of magnesium are often associated with increased insulin resistance in diabetics and GDM is also observed with hypomagnesemia where total magnesium levels are low (Qu et al., 2022).

Moreover, barley is a rich source of magnesium with some varieties providing >600mg/kg magnesium (Hussain et al., 2021). Furthermore, one study found barley varieties to have Mg (546-643) mg/kg and it was the third most abundant macromineral in barley after potassium and calcium (Tilahun et al., 2022).

Conclusion

Barley is an important cereal that is widely consumed across the globe and beyond its nutritional benefits it also acts as a functional food to promote health and prevent disease. Its functional properties relate to its nutritional value and the phytochemicals found in it which work to regulate blood glucose, reduce serum cholesterol, reduce insulin resistance and inflammation, and prevent the incidence and progression of various chronic diseases. Moreover, barley is also important for maternal health as it improves milk supply, is effective against gestational diabetes and obesity and prevents pregnancy complications and adverse pregnancy outcomes such as preeclampsia, neural tube defects, cleft palate, cardiac and brain defects, premature birth and stillbirth. However, further research is required to further understand the precise role of barley and its components in promoting maternal and fetal health and preventing complications during pregnancy and birth as well determining the exact amount required to achieve these benefits.

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