

ROLE OF HIGH-AMYLOSE WHEAT IN IMPROVING THE NUTRITIONAL QUALITY OF BAKED PRODUCTS: A COMPREHENSIVE REVIEW

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<p>Keywords: High Amylose Wheat (HAW); Resistant Starch (RS); Glycemic Index; Food Fortification; Starch Digestibility.</p> <p>Received on 11 October, 2025 Accepted on 21 December, 2025 Published on 31 January 2026</p> <p>Corresponding E-mails & Authors*: Zainab Chaudhary^{*1} ^{*1}zainabch087@gmail.com</p>	<h3>Abstract</h3> <p>High-amylose wheat (HAW) is a new breed of wheat or genetically modified to produce a significantly higher percentage of amylose (>70) than normal wheat. The modified starch structure enhances resistant starch (RS), a type of dietary fiber, which avoids digestion in the small intestine and is instead fermented in the colon to generate short-chain fatty acids (SCFAs), which are beneficial. HAW has been promoted as a functional ingredient because of its possibility to increase dietary fiber intake, lower post-prandial glycemic response, and promote gut and metabolic well-being, especially in children, adolescents, and risk groups of type 2 diabetes and obesity. Baked products such as bread, cookies, biscuits and noodles are the best matrices of HAW incorporation because thermal processing enhances the formation of RS and still retains gluten functionality and desirable sensory properties. This review provides a synthesis of existing information on HAW, its starch structure, physiological advantages of the fibre, and technological characteristics to use in bakery. It focuses on the so-called health-by-stealth strategy that allows the improvement of the nutritional content of refined-style baked products without the need to undermine consumer acceptance. The epidemiological, clinical, and technological studies evidence shows that HAW is a promising approach towards the development of next generation functional bakery products that can fill the gap between health promotion and consumer preference.</p>

INTRODUCTION

Bakery products (bread, cookies, and biscuits) are some of the most popular food commodities in the global market, based on their low cost, convenience, and sensory satisfaction (Petal, 2023). By 2025, the global bakery products market will have reached USD 253.4 billion and in 2035, it will reach USD 367.9 billion with a compound annual growth rate (CAGR) of 3.8% (Future Market Insights, 2024). The highest percentage of bakery consumption is on bread with the world production projected to advance over 140 million tons by 2030 and biscuit and cookies are the fastest growing segment with a long shelf life and high acceptability to consumers. The popularly used snacks are not everywhere, and high consumption regions show a great demand of up to 13 kg of biscuits per person per year, which makes these products a good delivery system to nutritional enrichment (Mordor Intelligence, 2024). Asia Pacific is the most promising market with its high growth rate because of the fast urbanization and evolving nutrition trends, whereas demand in high-end, low-calorie, gluten-free, and functional bakery in the United States (4.2% CAGR), Japan (5.1% CAGR), and the United Kingdom (3.9% CAGR) is becoming more advanced (Future Market Insights, 2024; Mordor Intelligence, 2024).

Although they are very popular, traditional bakery has often been formulated with refined wheat flour, added sugar, and fats, which formulate high-glycemic index (GI) foods with low dietary fiber content (Kamil et al., 2023). The Glycaemic index (GI) of foods was conceived in 1981 by Jenkins et al. to categorize not only foods rich in simple sugars but also starchy foods (Jenkins et al., 1981). However, the frequent use of these high-glycemic foods has been closely linked with the increasing worldwide incidence of type 2 diabetes mellitus, obesity, cardiovascular diseases, and other non-communicable diseases related to dieting (Harris et al., 2022). In turn, the consumer preferences are changing toward

bakery items with functional health benefits, in particular, aimed at serving at least three purposes: digestive health, glycemic regulation, and fiber enrichment of the product (Pinto et al., 2014). Recent product innovation statistics suggest that the number of gut-health-related claims (e.g., fiber and probiotic enrichment) in the launches of bakery products has increased by 22% in the last two years, whereas health-labeled bakery products (e.g., low-sugar, high-fiber, high-protein) keep growing every year (Guiné & Florença, 2024).

Fortified high-amylose starch foods have been widely assessed in terms of textural properties of firmness, chewiness, and resilience and also in terms of functional properties, such as resistant starch content, in vitro digestibility, predicted glycaemic index (pGI), and total dietary fibre (Aigster et al., 2021). It is important to note that cookies and biscuits are one of the major categories of health-oriented bakery innovation, which explains their appropriateness as carriers of functional food (Dossa & Ravis, 2024). Simultaneously, the World Health Organization advises not to exceed 10 percent of total daily energy on free sugar intake to reduce the risk of obesity and diabetes, further increasing the interest in the reformulated bakery products with better nutritional content (WHO, 2021). Most of the baked products are produced using wheat flour as the main raw ingredient because it has a special gluten-forming property and good processing qualities (Ortolan and Steel, 2017). But standard refined wheat flour is mostly made of fast digesting starch, which prompts a high post-prandial glycemic reaction. It is therefore becoming more popular to consider alternative wheat-derived ingredients, like high-amylose wheat (HAW), capable of providing resistant starch, reduced glycemic response, and added dietary fiber with no impact on product quality or consumer acceptability (Angelicola, 2022).

What Is High-Amylose Wheat (HAW)?

The major composition of wheat flour is fermentable carbohydrates with the larger portion starch, which is two polysaccharides amylose and amylopectin. Amylose is a linear polymer of alpha-D-glucopyranosyl units bonded with α -(1→4) glycosidic bonds and amylopectin is a highly branched polymer bonded with α -(1→4) and α -(1→6). A typical composition of starch in the traditional wheat varieties is 25% amylose and 75% amylopectin. In comparison, genotypes of wheat high in amylose contain a significant amount of amylose that may surpass 70% (Di Rosa et al., 2023). Genetically engineered or selectively bred wheat, high-amylose wheat (HAW) is a type of wheat whose starch fraction has significantly more amylose than a widely used wheat type (Li et al., 2023). Conversely, high-amylose types of wheat have over 70-80% amylose, which has been done by genetic manipulation or breeding programs to nullify the activity of starch branching enzymes that produce amylopectin (Regina et al., 2015). The resulting starch structure results in the creation of a compact enzyme-resistant granule, which adds to the percentage of resistant starch (RS) in wheat-based foods (Guiné & Florença, 2024). Adding amylose material (AM) is typically linked to slow digestion and elevated RS, and thus high-amylose starch (typically maize) has been utilized as food ingredient to enhance nutritional values of bread (H. Li et al., 2019).

2.1 Resistant Starch Formation and Physiological Significance

Resistant starch can be explained as the percentage of starch that does not get digested in the small intestine and is carried to the colon where it is fermented by the gut microbiota (Li & Hu, 2023). The short-chain fatty acids (SCFAs), especially acetate, propionate, and butyrate, obtained through this fermentation process are linked to better

gut health, heightened insulin sensitivity, and decreased inflammatory reactions (Harris et al., 2022). The presence of high levels of amylose in HAW improves the formation of RS that increases after thermal processing and cooling, which reinforces its nutritional value (Farooq & Yu, 2024).

2.2 Nutritional Advantages and “Health-by-Stealth” Concept

Nutritionally, HAW is especially appealing since it allows enriching foods with dietary fiber without using whole-grain formulations, which are undesirable among consumers, in particular, children and adolescents, due to sensory constraints, including rough texture, and bitter taste notes (Korczak & Slavin, 2020). This approach has been referred to as a health-by-stealth one in which fiber consumption is boosted by refined-style products that preserve sensory attributes preferred by consumers (Harris et al., 2022). There is epidemiological evidence that children and adolescents are not in accordance with recommended levels of fibers intake, despite the fact that the cereal grains are the largest sources of total dietary fiber in this group of the population (more than 50%). This shows the need to enhance the nutritional value of refined wheat-based foods that are commonly consumed (USDA, 2020; Reicks et al., 2014).

2.3 Glycemic Response and Metabolic Health Implications

The health value of HAW can also be justified by studies that high-amylose diets and resistant starch diets are associated with a reduction in the glycemic index (GI) response (Lim et al., 2020). Carbohydrates based diets that are characterized by a rapid rate of digestion have been linked with a higher risk of type 2 diabetes mellitus (T2DM) and obesity, as well as cardiovascular diseases (Liu, 2002; Harris et al., 2022). Since type 2

diabetes is a worldwide leader in cases of diabetes, the dietary intervention of enhancing the quality of carbohydrates with HAW-based foods is one of the encouraging dietary approaches to glycemic control (Guiné & Florença, 2024).

2.4 Technological Suitability of HAW for Baking Applications

In terms of technology, wheat flour continues to serve as the basis of baking systems in the form of gluten, which offers the system its elasticity, gas retention, as well as structural integrity (Zhang et al., 2023). HAW also maintains gluten functionality, unlike non-wheat fibers, and alters the digestibility of starch and is therefore exceptionally adaptable to use in baked goods, like bread, cookies, biscuits, pasta, and noodles (Guiné & Florença, 2024). Nevertheless, the amylose addition may affect rheology of the dough, water absorption, starch gelatinization, and the texture of the final product, and the optimization of formulation is necessary to compromise nutritional improvement and consumer acceptability (Cappelli et al., 2020).

2.5 Dietary Fiber Potential of HAW

High-amylose wheat (HAW) improves the levels of dietary fiber of baked goods by providing a high proportion of resistant starch (RS), which does not get digested in the small intestine and is fermented in the colon to yield short-chain fatty acids (SCFAs), including acetate, propionate, and butyrate (Harris et al., 2022). This fiber, which is being mediated by RS, leads to a better gut health, insulin sensitivity, and less inflammation. Adolescents and young individuals do not consume the suggested fiber, with whole grains supplying less than 30% of the total fiber in this group of people despite cereal grains supplying more than 50% (USDA, 2020; Reicks et al., 2014). HAW will enable a health-by-

stealth strategy, which boosts the amount of fiber in refined-type baked products without affecting the sensory attributes (Harris et al., 2022). Furthermore, the diets that are high in HAW-derived RS are associated with decreased glycemic reactions as well as decreased chances of obesity, type 2 diabetes, and other metabolic illnesses (Liu, 2002).

Transition to Baking Applications of High-Amylose Wheat

High-Amylose Wheat Reasons to use in Baking Systems Baked goods like bread, biscuits, cookies, cakes and crackers make up a significant share of daily carbohydrate consumption across most countries on the planet and they are mostly prepared with refined wheat flour because it forms an excellent processing ingredient and gluten activity (Angelicola, 2022). But, as has already been mentioned, traditional refined wheat flour is relegated to high and fast digesting starch, which has been associated with high post prandial glycemic reactions and incomplete dietary fiber consumption (Liu, 2002). Such nutritional deficits have increased the research focus on reformulation of baked goods by the use of functional ingredients that can enhance health outcomes without interfering with the product quality and its acceptance by the consumers (Cauvain & Clark, 2019).

The use of high-amylose flour in the composition of biscuits, taralli and bread led to significant rise in the content of resistant starch in the resulting products as compared to the control samples, which had less than 1% content of resistant starch. About 12% of the total starch was to be turned to resistant starch on average, which shows consistent results in all three types of products (Di Rosa et al., 2023). The baking phase and starch gelatinization can be cited as the reasons of these results. Increase in moisture content, subjecting starch to heating conditions causes an irreversible structural transformation connected to increase in viscosity and open and free form which results in an increase in

its vulnerability to enzymatic hydrolysis (Pellegrini et al., 2020). This renders HAW to be especially appropriate to bakery applications in which structure, volume and texture are quality characteristics of paramount importance.

Food Properties of HAW Relevant to Baking HAW has a high amylose composition that seriously changes the behavior of starch in mixing and baking of dough. High amylose starch has delayed gelatinization, low enzyme hydrolysis and is more resistant to starch upon cooling and storage (Cheng et al., 2024). The properties can be used to reduce the glycemic index of baked products which is an essential nutritional target because high-GI diets are strongly linked to metabolic conditions like type 2 diabetes and obesity (Vlachos et al., 2020). Technologically, HAW has the viscoelastic gluten network needed to maintain the gaseous trap and crumb formation unlike gluten-free or non-wheat fiber sources which tend to need the use of hydrocolloids or emulsifiers to counter structural losses. However, higher levels of amylose can affect the water absorption, dough strength, and crumb firmness and the development of the formulation needs to be modified to achieve optimal product quality (Rojhani et al., 2022).

Use of HAW in various baked products bread and leavened bakery products HAW has been widely applied in bread formulations, with the partial or total substitution of traditional wheat flour having been demonstrated to enhance the proportions of resistant starch and a lowering of the glycemic response with no severe effects on loaf volume and crumb structure under optimal processing conditions (Regina et al., 2015). These features are especially applicable to the population that needs to be provided with glycemic control, such as the people with diabetes. Cookies, Biscuits, and Short-Dough Products Cookies and biscuits demonstrate the most suitable HAW incorporation as they are less gluten developing and they enjoy massive consumption across the world. It has been

shown that cookies with HAW can reach a much higher level of resistant starch and lower predicted glycemic index without compromising the values of such attributes of cookies as flavor or appearance (Naseer et al., 2021). As biscuits contribute a significant portion of health-focused bakery innovations, these products present high potential as health-by-stealth nutritional enhancement. Cakes and Other Soft Bakery Products In cakes and other aerated type of products, HAW has been utilized to enhance the content of fibers and metabolic functionality (Sempio et al., 2024). Although the increased amylose content can impact textural parameters, such as viscosity of batter and softening crumb, fat optimization or the partial substitution of flour has been demonstrated to reduce the adverse effect of textural properties (Rojhani et al., 2022).

Table 1: Effect of High-Amylose Wheat Substitution on Resistant Starch Content and Glycemic Response in Bakery Products

Product/Substitution	RS (% Total Starch)	HI/pGI Reduction	Reference
Bread (100% HAWF 71-84%)	11-12x control (~28-33%)	Lower digestion rate	(Li et al., 2022)
Cookies (25% HAW)	Higher RS + slowly digestible	HI -37%, pGI -35%	(Sissons et al., 2014)
Cookies (optimized HAWF + xylitol)	Positively correlated with HAWF	Improved RS via amylose chain interactions	(Giuberti et al., 2015)

Product/Substitution	RS (% Total Starch)	HI/pGI Reduction	Reference
Biscuits/Taralli (HAW)	11.7-12.5 vs <1-3% control	pGI 84-91 vs 90-97	(Di Rosa et al., 2023)

Note: RS = resistant starch; HAWF = high-amylose wheat flour; HI = hydrolysis index; pGI = predicted glycemic index. The values are presented according to the respective studies. Control is associated with similar products developed using traditional wheat flour or standard specification. The content of RS, and its glycemic response difference are affected by the source of flour, amylose concentration, processing factors, and formulation factors. The references are mentioned in parentheses.

4. Challenges and Future Perspectives

Although high-amylose wheat (HAW) has good nutritional and functional benefits, some obstacles still exist that need to be met in order to achieve its massive use in bakery products. The amylose content is high and may affect the rheology of the dough, water absorption, gelatinization, and texture, thus requiring the tight control of the parameters of the formulations and processing to ensure consumer-acceptable quality (Rojhani et al., 2022). Sensory attributes, such as mouthfeel and crumb softness, can also not align with traditional products, especially in aerated baked goods such as cakes, as such, balancing, such as partial replacement of flour or ingredient changes, is required (Richardson, 2019). The research should be revisited in the future with the following questions:

1. Integrating optimization of HAW is coming up with product-specific bakery products.

2. Determining the long-term health advantages of consuming HAW among various groups of people, including children, adolescents, and patients with metabolic disorders.
3. Evaluation of the economic viability, acceptance and regulatory issues of HAW-enriched products.
4. The investigation of synergetic impact of HAW with other active compounds, including prebiotics, proteins and natural antioxidants.

The further investigation of HAW in bakery is a chance to develop the functional food that will not only be healthy but have high consumer acceptability between nutrition science and daily dietary habits.

5. Conclusion

HAW is a functional component of wheat that contains high amounts of amylose that have a high potential to improve the nutritional content of bakery products (Li et al., 2023). HAW improves intake of dietary fiber and post-prandial glycemic response as well as beneficial gut health by augmenting amylose content, resistant starch content, and does not affect gluten functionality or sensory quality (Guiné & Florença, 2024). Bakery products like bread, cookies, biscuits, and cakes are the perfect matrices of HAW incorporation, which help to adopt a health-by-stealth strategy to encourage progressive diet changes, particularly among children and adolescents (Harris et al., 2022). The use of HAW facilitates the consideration of the public health issues that are associated with poor fiber consumption and high-glycemic diets without deteriorating the quality of products, their texture, and acceptance by the consumer. The next step in the work should be aimed at optimizing the processing parameters, proving the long-term health effects and increasing the range of HAW-enhanced bakery products. In general, HAW is a potential

approach towards the creation of next-generation functional bakery foods that effectively balance the nutritional improvement with the consumer taste and to the requirements of the market.

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