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# Impact of cooking and processing methods on the glycemic response of legumes and cereals: A review

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**Abstract**
The glycaemic index (GI) is a pivotal nutritional tool that classifies carbohydrate-containing foods based on their impact on postprandial blood glucose levels. Cereals and legumes, which form dietary staples globally, generally exhibit low to moderate GI values; however, cooking and processing methods can significantly modify their glycaemic response. This review comprehensively examines the effects of various thermal and non-thermal food preparation techniques, including boiling, steaming, pressure cooking, roasting, frying, fermentation, germination, soaking, and dehulling—along with industrial processing methods like extrusion, milling, parboiling, puffing, canning, and retort processing on the GI of legumes and cereals. Findings indicate that heat-intensive treatments often raise GI by promoting starch gelatinisation and enzymatic accessibility, while methods like fermentation and germination tend to reduce GI by generating organic acids, enhancing resistant starch content, and modifying the food matrix. Factors such as cooking time, cooling conditions, and food matrix integrity further modulate the GI response. Despite significant advancements, gaps remain in understanding cumulative effects, individual variability in glycaemic response, and the long-term health implications of processed diets. Future research should focus on standardising GI measurement techniques, exploring personalised dietary responses, and developing low-GI functional foods that maintain consumer acceptability and shelf-life. Understanding the interplay between processing techniques and glycaemic behaviour is vital for informed food formulation, public health nutrition strategies, and managing metabolic disorders such as diabetes and obesity.

**Keywords:** Glycaemic index, glycaemic response, legumes, cereals, cooking methods, food processing, starch digestibility, fermentation, resistant starch, functional foods

## 1. Introduction

A critical nutritional concept, the glycaemic index (GI) assigns a ranking to meals that include carbohydrates according to how they affect postprandial blood glucose levels (Jenkins *et al.*, 1981) [21]. Low GI foods have the potential to help manage diabetes, obesity, and cardiovascular disease because they are absorbed and digested more slowly, which raises blood glucose and insulin levels gradually (Bhupathiraju & Hu, 2014) [3]. Legumes and cereals, among other food groups, are staples in diets all over the world and are becoming more and more well-known for their low to moderate GI values and related health advantages (Foster-Powell *et al.*, 2002) [13]. However, heating and processing techniques can drastically change these foods' glycaemic response, which is not intrinsic. Accelerated carbohydrate digestibility can raise GI values due to factors like starch gelatinisation, fibre breakdown, particle size reduction, and changes in food matrix integrity (Englyst *et al.*, 1992) [11]. The structure and digestibility of starch in legumes and grains are affected differently by conventional home cooking procedures like boiling, soaking, or pressure cooking as well as industrial processing processes like extrusion, grinding, and canning (Wolever, 2006; Tovar *et al.*, 1992) [56, 54]. Understanding how cooking and processing affect glycaemic behaviour is crucial as food systems change and grow more reliant on processed and ready-to-eat foods. This information is essential for food scientists working to create low-GI food products that are appropriate for glycaemic control and the prevention of chronic diseases, as well as for public health nutrition. The purpose of this review is to critically analyse the body of evidence on the effects of different processing and cooking techniques on the glycaemic response of cereals and legumes, emphasising underlying processes, potential health risks, and research gaps.

## 2. Overview of Glycemic Index and Glycemic Response

The glycemic index (GI) is a classification system that ranks carbohydrate-containing foods based on their effect on postprandial blood glucose levels. First given by Jenkins *et al.* (1981) [21], it provides a physiological foundation for choosing sources of carbohydrates for diabetic patients' diets. A reference food, typically glucose or white bread, with a given GI of 100, is used to determine the GI by calculating the incremental area under the blood glucose response curve (AUC) over a two-hour period after consuming a test food (Brand-Miller *et al.*, 2003) [7]. Based on their glycaemic response, foods are classified as low (GI < 55), medium (GI 56-69), or high (GI ≥ 70). Later, the idea was expanded with the development of glycaemic load (GL), which provides a more accurate depiction of a food's glycaemic effect by taking into account both the quantity and quality (GI) of carbs in a meal (Salmerón *et al.*, 1997) [40]. After consuming a carbohydrate-rich meal, the body's actual blood glucose changes are known as the glycaemic response (GR). A person's insulin sensitivity, metabolic rate, meal composition, food matrix, and even gut microbiota are some of the physiological, biochemical, and food-related factors that affect glycaemic response, even though GI offers a consistent benchmark for comparing different foods (Wolever *et al.*, 2003) [57]. The glycaemic response is mostly determined by the rate and degree of carbohydrate digestion and absorption. While resistant starches (RS) and slowly digestible starches (SDS) help to produce a slower and longer-lasting release of glucose, rapidly digestible starches (RDS) are linked to a higher glycaemic response (Englyst *et al.*, 1992) [11].

Food's GI is greatly influenced by a number of intrinsic characteristics, including the type of starch, amylose-to-amylopectin ratio, fibre content, presence of anti-nutrients like phytates and tannins, and physical form (Nugent, 2005) [33]. Amylose, a linear starch molecule, tends to be more resistant to digestion than branched amylopectin, resulting in lower GI values (Frei *et al.*, 2003) [14]; similarly, the presence of soluble dietary fibre slows gastric emptying and glucose absorption, lowering the glycaemic response; and the food matrix, which includes proteins, fats, and organic acids, can alter the enzymatic accessibility of carbohydrates, ultimately influencing glucose metabolism (Bornet *et al.*, 1987) [6]. Crucially, the glycaemic response of foods high in carbohydrates can be altered by processing and preparation techniques. Milling, grinding, extrusion, boiling, roasting, fermenting, and freezing are some of the processes that can change the structure of starch granules, increase the surface area available for enzyme action, or encourage the breakdown of cell walls and gelatinisation. Depending on the technique, these processes can either raise or lower the GI (Tovar *et al.*, 1992; Wolever, 2006) [54, 56]. For example, because finely ground cereals digest and absorb nutrients more quickly than their whole grain counterparts, they have higher GI values. The development of functional foods targeted at enhancing metabolic outcomes as well as therapeutic nutrition, particularly in the treatment of diabetes, cardiovascular disease, and obesity, depend on an understanding of the glycaemic index and glycaemic response. A thorough grasp of how processing impacts glycaemic behaviour is becoming more and more important for making educated dietary decisions and developing public health initiatives as dietary trends around the world change towards processed foods.

## 3. Impact of cooking methods on Glycemic Index

### 3.1 Boiling and Steaming

Two of the oldest cooking methods used worldwide to prepare cereals and legumes are boiling and steaming. According to Singh *et al.* (2003) [50], these techniques mainly affect the glycaemic index (GI) of meals by starch gelatinisation, a process in which moisture and heat break down the crystalline structure of starch granules, making them easier for amylolytic enzymes to digest. Because rapidly digestible starch (RDS) hydrolyses more quickly, it causes rapid glucose absorption and increases postprandial blood sugar levels, which in turn causes a greater glycaemic response (Nugent, 2005) [33]. Nevertheless, meal type, cooking time, and post-cooking treatment all affect how much GI rise occurs. Legumes like lentils and chickpeas, for example, maintain some resistant starch (RS) even after boiling, which greatly gelatinises their starch content. This is especially true when the legumes are cooled and stored. RS type 3 (RS3), which is more resistant to enzymatic digestion and may reduce the GI upon warming, can be formed through retrogradation after cooling (Sajilata *et al.*, 2006) [39]. Steaming may result in less extensive starch gelatinisation and possibly lower glycaemic responses in some foods because it includes less direct water contact and more gradual heat transfer than boiling (Chung *et al.*, 2006) [9]. Furthermore, cellular structures and dietary fibre, which function as physical barriers and postpone the hydrolysis of starch, are better preserved by steaming.

Overall, post-cooking chilling techniques and their controlled application can assist maintain or lessen the glycaemic impact, even if boiling and steaming can both raise the GI due to improved starch accessibility. When creating low-GI diets for people with diabetes and metabolic diseases, these techniques are very pertinent.

### 3.2 Pressure Cooking

A popular thermal processing technique for effectively softening cereals and legumes is pressure cooking, particularly in Asian and Indian cuisines. In order to expedite the gelatinisation of starch and the disintegration of plant cell walls, it entails cooking food with steam under high pressure, which raises the boiling point of water to 100 °C (Tovar *et al.*, 1992) [54]. This improved gelatinisation increases the starch's accessibility to digestive enzymes like α-amylase, which speeds up absorption and digestion and raises the glycaemic index (GI) (Mitra *et al.*, 2010) [30]. According to studies, the glycaemic responses of pressure-cooked legumes, like mung beans and lentils, are noticeably higher than those of their raw or slightly processed counterparts. The decline in resistant starch (RS), especially RS1 and RS2, which are naturally found in raw legumes and grains, and the loss of structural integrity of the starch-protein-lipid matrix are the main causes of this (Fuentes-Zaragoza *et al.*, 2011) [15]. However, post-cooking procedures like cooling and reheating can mitigate the glycaemic impact of pressure-cooked foods by encouraging the production of RS3, a resistant starch type linked to a lower glycaemic response, and the retrogradation of gelatinised starch (Sajilata *et al.*, 2006) [39]. Additionally, pressure boiling may improve protein and mineral bioavailability by breaking down antinutritional elements such phytic acid and tannins (Shimelis & Rakshit, 2007) [45], but at the expense of starch digestibility. Therefore, meal content, cooking time, and cooling conditions all affect the overall GI effect. Pressure cooking improves food accessibility and palatability, but it also requires careful attention in glycemic-sensitive diets, especially for those with metabolic syndrome or diabetes.

### 3.3 Roasting and Frying

Two common dry-heat cooking techniques that alter the structural, chemical, and nutritional characteristics of grains and legumes and have a substantial impact on their glycaemic index (GI) are roasting and frying. Through gelatinisation, Maillard browning reactions, and fat incorporation, these heat mechanisms change the digestibility of starches. Depending on the circumstances and dietary matrix, these processes can either raise or lower the GI. According to Leong *et al.* (2016) [26], roasting, which usually involves temperatures between 150 and 200 °C, partially gelatinises starch and produces components of the Maillard process, which can decrease starch digestibility. When reducing sugars and amino acids interact, a process known as the Maillard reaction can form starch-protein complexes that reduce the accessibility of carbs to digestive enzymes, potentially lowering the GI (Moejes & van Boxtel, 2017) [31]. Excessive roasting, however, might denature protein structures and break down resistant starch (RS), which typically slows the digestion of carbohydrates and raises the glycaemic response (Chung *et al.*, 2006) [9]. Food moisture, temperature, time, and seed content all affect how much the GI changes as a result of roasting. Due to a slower rate of starch breakdown, lipids introduced into the food matrix by frying, especially deep frying, can postpone stomach emptying and lessen the glycaemic response (Karupaiah & Sundram, 2007) [23]. Fat reduces enzymatic access by forming hydrophobic barriers around starch granules. Furthermore, frying may reduce the digestibility of starch and cause the synthesis of RS due to the creation of the lipid-amylose complex (Biliaderis, 1991) [4]. Long-term high-temperature frying, however, can break down these complexes, lower RS, and raise GI. Frequent reheating of fried foods can also increase the availability of starch by promoting the reversal of starch retrogradation (Frei *et al.*, 2003) [14].

### 3.4 Fermentation and Germination

Traditional food processing methods like fermentation and germination have a big impact on the glycaemic profile and nutritional makeup of grains and legumes. In ways that impact the glycaemic index (GI) and overall glycaemic response of diets, both processes are known to increase the bioavailability of nutrients, decrease antinutritional substances, and change the structures of carbohydrates. Microorganisms, mainly lactic acid bacteria and yeasts, are responsible for the biochemical process of fermentation, which breaks down carbohydrates and creates organic acids like lactic and acetic acid. It has been demonstrated that these acids reduce the postprandial increase in blood glucose by slowing stomach emptying (Liljeberg & Björck, 1996) [27]. Furthermore, organic acids can decrease starch hydrolysis and block amylolytic enzymes, both of which lower GI. Enzymatic activity during fermentation can break down complex carbohydrates and alter the starch-protein matrix in fermented grain and legume products, reducing the starch's accessibility to digestive enzymes (Chavan & Kadam, 1989; Sharma *et al.*, 2020) [43, 8]. When compared to their non-fermented counterparts, fermented meals like idli, dosa, and injera prepared from rice, lentils, or teff usually show lower glycaemic responses (Shukla & Srivastava, 2014) [46]. Lactic acid bacteria's fermentation-induced generation of exopolysaccharides can also make the food matrix more viscous, which decreases the intestinal absorption of glucose (Kohajdová & Karovičová, 2007) [25]. Moreover, fermentation lowers phytic acid, a recognised antinutrient that binds minerals and might indirectly hinder glucose metabolism by decreasing the availability of magnesium and zinc (Elkhalifa *et al.*, 2005) [10]. The process of soaking seeds in water and letting them sprout under carefully monitored circumstances is known as germination. This starts enzymatic activity, especially that of amylases and proteases, which causes proteins and starch to partially degrade. Lower GI values are linked to structural changes in carbohydrates during germination, particularly an increase in resistant and slowly digested starch (Mbithi-Mwikya *et al.*, 2000; Kayode *et al.*, 2007) [28, 24]. Because of their improved antioxidant status, increased polyphenol activity, and changed fibre content, germinated legumes, like sprouted lentils and mung beans, show slower glucose release, which lowers glycaemic responses (Mubarak, 2005) [32]. Apart from the glycaemic advantages, germination raises the concentrations of bioactive substances such vitamin C, flavonoids, and gamma-aminobutyric acid (GABA), which may have complementary effects on glucose metabolism (Pawłowska *et al.*, 2012) [35]. The formation of a denser food matrix and structural alterations in cell wall polysaccharides further hinder the enzymatic digestion of starches, supporting lower GI results.

### 3.5 Soaking and Dehulling

Traditional pre-processing techniques like soaking and dehulling are frequently used to improve the palatability, shorten cooking times, and increase digestibility of legumes and cereals. By changing the food's nutritional composition and structure, these techniques also have a big impact on the glycaemic index (GI). Soaking is submerging grains or pulses in water for a predetermined amount of time, which hydrates them and causes some water-soluble ingredients to leach. The elimination of anti-nutritional elements such phytic acid, tannins, and enzyme inhibitors that would otherwise obstruct the absorption of nutrients and the digestion of carbohydrates is one of the main advantages of soaking (Shimelis & Rakshit, 2007) [45]. Soaking might increase enzymatic activity during digestion by eliminating these substances, which may improve the glycaemic response and starch digestibility (Elkhalifa *et al.*, 2005) [10]. However, the type of legume or cereal, temperature, and soaking time all affect how much the GI changes. It's interesting to note that soaking may also encourage the leaching of low-molecular-weight carbohydrates, such as stachyose and raffinose, which are known to induce flatulence but have little effect on the glycaemic response. Furthermore, soaking can alter the permeability of cell walls and induce partial enzymatic hydrolysis, thereby increasing the accessibility of starch to digestive enzymes (Chavan & Kadam, 1989) [8]. GI may somewhat increase as a result of this increased availability of quickly digested starch (RDS) if it is not counterbalanced by further processing, like fermentation or chilling. Dehulling, or the removal of the bran layer or seed coat, is another important element that affects GI. Significant levels of insoluble dietary fibre are found in the outer layer of grains and legumes, which inhibits the absorption of carbohydrates and delays stomach emptying (Tharanathan & Mahadevamma, 2003) [53]. Eliminating this layer enhances the grain or pulse's surface area and digestibility, which speeds up the enzymatic breakdown of starch and raises the glycaemic index (Elkhalifa *et al.*, 2005) [10].

## 4. Impact of Industrial Processing Methods
### 4.1 Extrusion
A common high-temperature, quick processing technique in the food business is extrusion cooking, which is especially useful for producing ready-to-eat goods including breakfast cereals, snacks, and weaning foods. Extrusion greatly changes the physicochemical characteristics of carbohydrates, which affects the glycaemic index (GI) of food products even if it has benefits like longer shelf life, texture, and safety. Starch gelatinisation, in which heat, shear, and moisture cause native starch granules to be broken up and undergo molecular rearrangement, is one of the main consequences of extrusion. By making the starch more susceptible to enzymatic hydrolysis, this gelatinisation increases its digestibility (Singh *et al.*, 2007) [48]. As a result, extruded goods frequently have greater GI values than their raw counterparts (Bjorck *et al.*, 1994) [5]. For example, higher proportions of quickly digested starch (RDS) and lower levels of resistant starch (RS) in cereals and legume-based extrudates result in higher glycaemic responses (Robin *et al.*, 2015) [38]. Additionally, extrusion damages the food matrix, which could otherwise serve as a barrier to enzyme access, and decreases the integrity of dietary fibre. Additionally, it can break down naturally existing anti-nutrients like tannins and phytates that prevent enzymes that break down carbohydrates, raising the GI even more (Alonso *et al.*, 2000) [1]. However, a number of extrusion characteristics, including screw speed, feed composition, barrel temperature, and moisture content, affect how much GI modification occurs. Interestingly, formulations and processing conditions have been optimised in an attempt to create low-GI extruded foods. The GI-elevating effects of the method can be offset by adding high-amylose starches, legumes, dietary fibre, and protein isolates to extruded products (Zhao *et al.*, 2005) [60]. Extruded legume-cereal blends can maintain moderate GI values if processed under regulated conditions, according to several research (Sharma *et al.*, 2017) [43].

### 4.2 Milling and Grinding
Primary food processing methods like milling and grinding are used to turn whole grains and legumes into flours or meals that can be utilised in a variety of culinary recipes. By altering the finished product's physical structure, particle size, and starch digestibility, these techniques considerably change its glycaemic index (GI), even though they improve palatability, convenience, and shelf life (Fardet, 2016) [12]. These modifications may result in faster digestion and more accessibility to carbohydrates, which would raise the postprandial glycaemic response. The degree to which the bran and germ layers—which are abundant in dietary fibre, lipids, polyphenols, and other phytochemicals that serve as organic barriers to enzymatic digestion—are removed is closely correlated with the degree of milling, especially in cereals. The endosperm, on the other hand, is easier to digest because it mostly consists of starch. Refined flours reduce the fibre content of whole grains while increasing their surface area, which speeds up the hydrolysis of starch and increases the release of glucose during digestion (Jenkins *et al.*, 1981; Zhang & Hamaker, 2009) [21, 58]. The heavily milled white bread and rice, for example, have greater GI values than their whole grain counterparts. Higher glycaemic reactions are further facilitated by fine-grinding particles to reduce their size. Because finely ground flours have more surface area, digestive enzymes (such α-amylase) and starch granules interact more. Conversely, because of their restricted accessibility, coarser particles withstand enzymatic attack and release glucose more slowly (Liljeberg *et al.*, 1996) [27]. Granfeldt *et al.* (1994) [5] showed that intact kernels and coarsely ground cereals resulted in glycaemic responses that were much lower than those of flaked or finely powdered cereals. Additionally, the cell wall integrity and starch-protein matrix that typically envelope starch granules in whole legumes and cereals are compromised by milling. Faster starch digestion and absorption result from this disturbance, which lowers the physical barriers to enzymatic hydrolysis (Singh *et al.*, 2010) [47, 51]. After severe milling or grinding, one of the main factors raising GI is the loss of intact plant cell walls, which are crucial in decreasing starch digestibility, especially in legumes (Gebruers *et al.*, 2008) [16]. However, starch structure can also be affected by the type of milling procedure used, such as wet or dry milling. By removing more refractory starch and protein-bound components, wet milling—which frequently entails soaking, steeping, and mechanical separation—tends to improve the digestibility of the starch fraction. Dry milling causes significant structural disintegration that affects the final product's glycaemic potential even if it is less harmful to resistant starch (Aravind *et al.*, 2012) [2].

### 4.3 Parboiling and Puffing
Puffing and parboiling are two common commercial and traditional food processing methods for grains like wheat, rice, and millet. These techniques drastically change the chemical and structural characteristics of starch, which affects the finished product's glycaemic index (GI). It is essential to comprehend how these mechanisms impact glucose response and digestibility, particularly when it comes to controlling chronic conditions like diabetes and obesity. A hydrothermal process called parboiling entails soaking, steaming, and drying paddy before to milling. Water-soluble nutrients like thiamine can move from the bran to the endosperm thanks to this mechanism, which also partially gelatinises the starch (Ramaswamy & Patindol, 2003) [36]. More significantly, during the cooling and drying phases, parboiling causes the starch to retrograde, resulting in the creation of resistant starch (RS), a starch fraction that avoids small intestinal enzymatic digestion (Odenigbo *et al.*, 2014) [34]. According to a number of studies, parboiled rice has a lower glycaemic index than polished or raw rice. For example, because parboiled rice has a stronger grain structure that inhibits enzymatic breakdown and more resistant starch, it greatly reduced the postprandial glycaemic response, according to Juliano *et al.* (1989) [22]. Additionally, parboiling promotes the production of the amylose-lipid complex, which further decreases the digestion of starch (Singh *et al.*, 2005) [49]. Standardising the method is essential for reliable results because the final GI can be affected by the level of gelatinisation and the length of time spent parboiling. A popular high-temperature, short-

time (HTST) processing technique for making snack foods from cereals including rice, wheat, and millets is puffing, sometimes referred to as popping or expansion. Through the quick application of pressure and heat, the water in the grain abruptly evaporates, inflating the kernel and producing an enlarged, porous structure (Mishra *et al.*, 2015) [29]. Although puffing enhances digestibility and flavour, it also breaks down the starch's granular structure, which causes widespread starch gelatinisation. This structural change raises the glycaemic index of puffed cereals by increasing enzymatic access and speeding up starch breakdown. Singh *et al.* (2010) [47, 51] claim that since gelatinised starch digests quickly, puffed rice and wheat have high GI values that are frequently on par with glucose. Additionally, puffing may change the protein-starch matrix and lower the amount of dietary fibre, which increases the glycaemic response (Sangamithra *et al.*, 2016) [41].

### 4.4 Canning and Retort Processing on Glycemic Index

The food sector frequently uses canning and retort processing as preservation methods to guarantee the microbiological safety and extended shelf life of foods, particularly grains and legumes. These procedures cause substantial physical, chemical, and structural changes in food matrices by exposing sealed food containers to high temperatures (usually between 115 °C and 130 °C) under pressure for a predetermined amount of time (Holdsworth & Simpson, 2007) [19]. By changing the digestibility of starch and related nutrients, these techniques may significantly affect the glycaemic index (GI), even while they improve the safety and convenience of food products. The widespread gelatinisation of starch is one of the most noticeable consequences of canning and retort processing. The crystalline structure of natural starch is broken down by high temperatures, which increases its accessibility to digestive enzymes such α-amylase (Singh *et al.*, 2007) [48]. As a result, glucose is absorbed and digested more quickly, raising the food's GI. Because of a higher degree of starch gelatinisation and leaching of soluble starch into the cooking medium, canned legumes, such chickpeas and lentils, frequently exhibit higher glycaemic responses than their traditionally cooked counterparts (Goni *et al.*, 1997) [17]. Higher GI values may also result from the heat breakdown of cell wall constituents during retort processing, especially dietary fibre and pectin. The pace at which glucose is released during digestion is accelerated by the breakdown of physical barriers that inherently restrict enzyme access to starch granules (Tharanathan & Mahadevamma, 2003) [53]. Furthermore, retort processing frequently results in protein denaturation and the degradation of anti-nutritional components like tannins and phytic acid, which can also indirectly improve starch digestibility and affect GI (Rehman *et al.*, 2001) [37]. The effect is not always detrimental, though. Retrogradation of starch can occasionally happen when canned goods are cooled and stored. Retrograded starch, sometimes referred to as resistant starch type 3 (RS3), might lower the food's total glycaemic response and is less amenable to enzymatic digestion (Zhao & Lin, 2009) [59]. Therefore, a variety of parameters, such as the particular food matrix, processing temperature and time, storage conditions, and formulation ingredients like fat and fibre, influence the overall effect on GI. Additionally, research has indicated that depending on their structural integrity and starch type, canned legumes such as kidney beans and navy beans may still have a low to moderate GI even after high-temperature processing (Truswell *et al.*, 1988) [55]. According to these results, the final glycaemic behaviour is a complicated result of conflicting structural and compositional changes, even though canning and retort processing frequently tend to increase GI.

## 5. Conclusion and Recommendations

Cooking and processing techniques have a significant impact on the glycaemic response of grains and legumes. By encouraging starch gelatinisation and improving enzymatic accessibility, methods including boiling, pressure cooking, and canning frequently raise the glycaemic index (GI) and accelerate the release of glucose after meals (Singh *et al.*, 2007; Goni *et al.*, 1997) [48, 17]. By producing organic acids that slow stomach emptying, boosting fibre quality, and increasing resistant starch content, fermentation and germination, on the other hand, have been repeatedly demonstrated to lower GI (Scazzina *et al.*, 2009; Huma *et al.*, 2008) [42, 20]. These results highlight the intricate and occasionally conflicting effects of both thermal and non-thermal mechanisms on glycaemic behaviour. The cumulative and long-term impacts of processing methods on glycaemic response in real-life dietary patterns are still poorly understood, despite the wealth of research on specific cooking techniques. Furthermore, the impact of processed meals on blood glucose levels can be influenced by individual variability, such as genetic variables, gut microbiota makeup, and insulin sensitivity; this underscores the need for more individualised research methodologies (Wolever *et al.*, 2003) [57]. To guarantee consistency and comparability, future studies should give priority to standardised approaches for GI assessment across various preparation processes. *in vivo* human studies that assess the glycaemic effects of conventionally and industrially processed composite meals based on legumes and cereals are also necessary. Furthermore, the goal of food technology advancements should be to create low-GI functional foods without sacrificing shelf life or sensory appeal.

In order to develop evidence-based dietary recommendations and food formulations that promote metabolic health and the prevention of non-communicable illnesses like type 2 diabetes and obesity, it is essential to comprehend these relationships.

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