

Exploring Low Glycemic Index Innovations in Bakery Products: A Review

Abstract

Diabetes can be caused by various factors such as high sugar intake, hormonal imbalances, and genetics. Eating low-GI meals can reduce blood lipid levels, decrease postprandial blood glucose levels, decrease insulin demand, increase colon fermentation, and enhance satiety. The intention and the purpose of this review is to provide insight into the Glycemic Index (GI) and its effects on the human body. Low-GI foods are associated with a decrease in contemporary lifestyle conditions such as obesity, diabetes, some cancers, and heart attacks. This review discusses the significance of low GI foods, the factors influencing GI, and the fundamental processes and strategies for creating low-GI products. Additionally, the review summarizes research trends on the benefits of eating low-GI foods for health. Different formulations of snacks are also discussed, which incorporate several types of flours and fruit pulps that contribute to the reduced GI of the food and increase in fiber.

Key word: glycemic index, ingredients, bakery products, blood lipid levels

1. Introduction

The glycemic index helps determine how much a food can change blood sugar levels. Several factors, including cooking method, nutritional composition, and degree of ripeness in the case of fruits, impact the glycemic index of the foods. Whole grains and legumes are examples of complex carbohydrates with a lower glycemic index (GI) because they release glucose into the bloodstream more gradually, which helps to maintain stable blood sugar levels. Fruits, vegetables, and nuts are foods high in fiber that can lower a meal's GI by decreasing the influence of carbs on blood sugar levels through slower digestion and absorption. The concept of GI emerged in 1988; the idea of GI was first proposed by Jenkins et al., (1988) to measure glycemic response to carbohydrates in different food products. Generally, GI measures the quality of carbohydrates in meals and is a relative glycemic response. On the other hand, depending on GI and the total amount of carbohydrates consumed, the Glycemic level (GL) is calculated. GL indicates the number of carbohydrates that affect the glucose response (Ferrer et al. 2012). Foods are classified into three categories in the GI classification system: high, medium, and low GI foods (Cairano et al., 2022). The metabolic impact that was postulated has to do with how quickly glucose is absorbed in the small intestine. After consuming low-GI carbohydrates, glucose absorption will be slower, which will lessen the postprandial rise of gut hormones, including incretins and insulin. Over

33 time, the extended absorption of carbohydrates will continue to block the counter-regulatory
34 reactions and free fatty acids (FFA), resulting in a lower blood glucose content (Jerkins et
35 al.1988).Over time, glucose is removed from the circulation more quickly due to decreased
36 FFA concentrations and increased respiratory quotient brought on by tissue salinization.
37 Consequently, blood glucose levels return to baseline even though glucose is still absorbed by
38 the small intestine. This leads to a decrease in the peak postprandial blood glucose rise as
39 well as the incremental blood glucose area above baseline. Living in an obesogenic
40 atmosphere increases hunger and increases the risk of diabetes in many metropolitan
41 countries; approximately 425 million people worldwide suffer from diabetes mellitus (DM),
42 which has emerged as the world's first non-infectious epidemic. This represents 8.8% of the
43 population between 20 and 79(Jemal et al. 2005). The International Diabetes Federation
44 reports that the number of patients continues to rise quickly. Frequent use of processed foods,
45 such as white bread, is a dietary factor that aggravates these metabolic problems. The
46 international tables of GI and GL values show that breads have an average GI value between
47 24 and 100.Wheat white bread has a significantly high GI [GI > 70]. The GI, or glycemic
48 index, measures how much a portion of food is high in carbohydrates and influences blood
49 glucose levels after a meal compared to a reference product (usually white bread or mostly
50 glucose) with an equivalent amount of readily available carbohydrates.

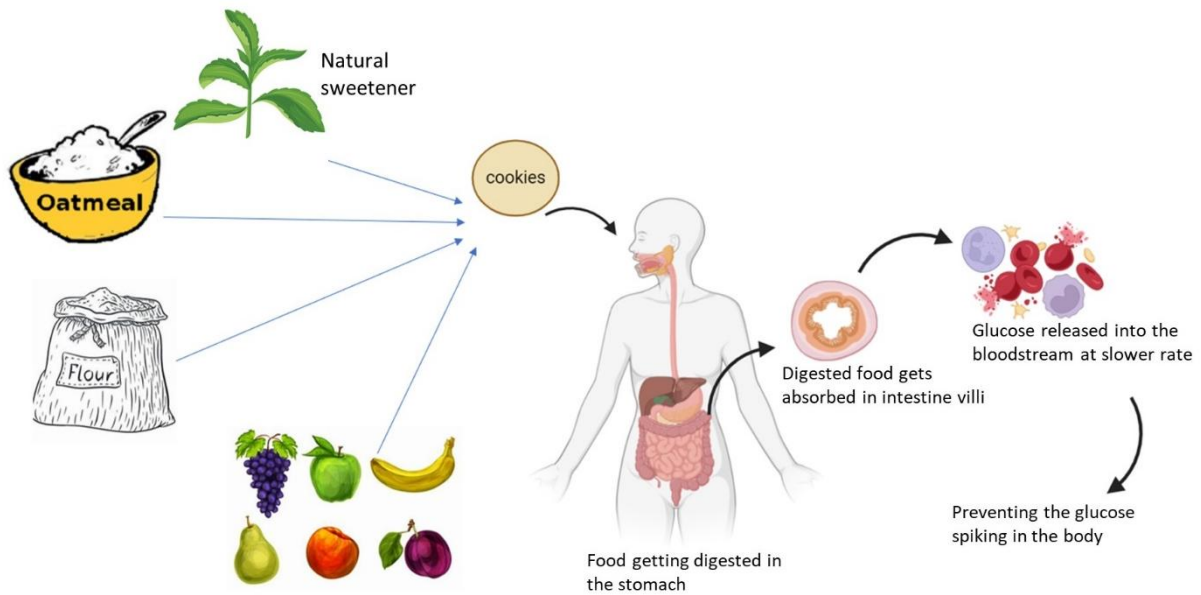
51 It is crucial to effectively control postprandial glycemia and insulinemia to minimize
52 the chances of developing cardiovascular disease and type 2 diabetes (Klimek M et al. 2019).
53 In contrast, the rise in glucose levels is not as noticeable after eating foods low in GI. The
54 glycemic index (GI) was created to measure "the blood glucose-raising potential of available
55 carbohydrates in high-carbohydrate foods" to manage postprandial glycemia and
56 insulinemia.It is commonly known that while a low GI diet can enhance health, high GI foods
57 can raise the chances of obesity, diabetes, several types of cancer, and cardiovascular
58 disorders (Giacco et al. 2001). Low GI foods emerge as an innovative and delicious choice
59 for satisfying sweet cravings without compromising health. People are becoming aware of
60 their health and have started choosing a new and healthy lifestyle. This awareness gives a
61 positive boost to such different products. These products are crafted with ingredients that
62 have a slower impact on blood sugar levels, offering a balanced alternative to traditional
63 high-GI treats.Some grains food products (oats, quinoa, or brown rice) are popular low-GI
64 ready-to-eat foods that come in the form of crackers, chips, and bars, remade salads using
65 low-GI ingredients, such as tofu or grilled chicken. Frozen meals include many veggies, lean
66 proteins, nutritious grains, pasta dishes, casseroles, and stir-fries. There are many options for

67 a healthy breakfast, such as healthy grains, nuts, seeds, granola bars, oatmeal sachets, and
68 low-GI morning cereals. Nuts, seeds, and dried fruits are provided in snack bars. Energy and
69 protein bars provide low-GI and easily portable food options. As people prioritize controlling
70 blood sugar levels for improved health, there is a growing demand for low-GI ready-to-eat
71 meals due to increased consumer awareness of the glycemic index (GI).

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73 Various studies have described the health benefits of consuming the low GI food. In
74 the study of (Barbosa et al. 2015), they found that most respondents stated that they had used
75 natural resources—especially plant species—as a treatment or supplement in their studies,
76 and people have been using medicinal herbs for ages worldwide. It also lowers blood sugar
77 levels and is a more accessible source than other medications. In the work done by (Salehie et
78 al. 2019), it has been found that conventionally used therapeutic Plants work well. Many plants
79 have been shown to have glucosidase-lowering, anti-hyperglycemic, and anti-diabetic
80 effects. The phytochemicals found in plant extracts are a group of compounds that give plants
81 their anti-diabetic properties. Alkaloids, glycosides, phenolic acids, stilbenes, saponins,
82 flavonoid polysaccharides, and tannins are the main phytochemicals with anti-diabetic
83 properties. The use of muesli in pasta preparation is justified, according to Oliveira et al.
84 (2018), because it improves the nutritional value of the product and results in a healthier meal
85 due to its significant increase in fibre content and decrease in glycemic index. This generally
86 happens with conditions that call for a diet that includes a small amount of fiber to reduce
87 blood glucose. The study done by Li et al. 2016, demonstrated that overweight patients'
88 glycolipid metabolism benefited from a low-fat, high-fiber diet; these benefits were amplified
89 when oats consumption was included. This suggests that this food can be useful in managing
90 excess weight and, primarily, lower glycemic levels. Santiago et al. (2017) highlighted the
91 high amount of minerals and proteins in diet cookies made with flour derived from passion
92 fruit peel and their low energy value and nutritional benefit from dietary fiber like pectin.
93 Robert et al. (2016) demonstrated that bread's blood sugar response and blood sugar index can
94 be considerably decreased by using fenugreek seeds instead of 10% refined wheat flour. As a
95 result, fenugreek powder is regarded as a useful component that can effectively reduce blood
96 sugar.

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Figure 1. Ingredients and metabolism of low glycemic index cookies.

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102 1.1 Glycemic index of different foods

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The glycemic index of different foods depends on composition and factors like the making process, use of sweeteners, etc. Based on the various levels of GI, the foods are classified as low GI, where the GI of food ranges from 55 or less; medium, where food GI levels range from 56 to 69; and high, where the glycemic index ranges more than 70. Fruits, legumes, and dairy products have also been shown to have low GI values. Some of the glycemic values of various common foods are represented in Table 1.

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Table 1 Different types of foods with glycemic index and glycemic load

S.no	Foods	GI index	Glycemic load
1	Almonds	15	1.9
2	Apple juice	41	4.5
3	Avocado	10	0.9
4	Banana	48	10.1
5	Barley flour	30	16.8
6	Bread	47	19.2
7	Brown rice	50	36.5
8	Cashew nuts	25	3.1
9	Cherry	25	4
10	Chick pea	10	6.1
11	Green apple	36	5
12	Kiwi	50	7.3
13	Milk	49	28.9
14	Multi grain cookies	51	33.2
15	Glucose	100	10
16	Cornflakes	92	24
17	Potato (Baked)	85	26
18	Instant rice	75	28
19	Bread (white)	70	10
20	Coca-Cola	63	16
21	Bread (Wheat)	52	10
22	Carrot	47	3
23	Spaghetti	41	20
24	Apple	40	6
25	Lentil beans	29	5
26	Peanuts	13	1

122 Source :Arya, Shalini. (2009). Glycemic index:An overview. Agro Food Industry Hi-Tech.
123 20. 30-32.

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125 **2.Different low-GI bakery foods**

126 Many bakery food products are staple foods in various countries, eaten as breakfast,
127 snacks, and decadent treats. These are accessible sources of energy, carbohydrates, and
128 pleasure for dieters. Obesity and diabetes are among the common health problems caused by
129 the excessive concentrations of processed carbohydrates and harmful fats in many traditional
130 bakery items. Reducing sugar content and adding whole grains can increase nutritional value
131 and decrease the glycemic index to overcome these issues. Healthy fats and fruits, vegetables,
132 nuts, seeds, and baked goods must be added to boost nutrient density.

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134 **2.1Low GI biscuits**

135 A biscuit is a tiny, baked, flour-based food item that can be savory or sweet,
136 depending on the recipe and local variations. Biscuits are usually crispy. A baked good with a
137 low glycemic index is composed of components that gradually release glucose into the
138 bloodstream, promoting stable blood sugar levels. Frequently used components in low-GI
139 biscuits are wholegrain flour, almond flour, among other nut flours, natural sweeteners (such
140 as erythritol, date syrup, and stevia), components high in fiber (such as flaxseed and oats),
141 and unsaturated fats (such as avocado and olive oil). Adding fiber and good fats from whole
142 grain and nut flour encourages slower digestion and a lower glycemic index. Natural
143 sweeteners provide sweetness without quickly raising blood sugar levels. Ingredients high in
144 fiber promote fullness and slow down digestion, and unsaturated fats help keep blood sugar
145 levels stable.A study conducted by (Anju et al. 2010) on the development of low glycemic
146 index biscuits concluded that based on the results obtained, refined wheat flour and millet
147 flour were used in the ratio of 45% and 55%, And other ingredients were eggs (5.5),
148 powdered sugar (14%), hydrogenated fat (23%), baking powder, and curd (11.5%). This
149 product has the highest crude protein, crude fiber, ash, carbohydrate, physiological energy,
150 starch, various minerals, low GI, and better sensory quality, storage stability, and nutritional
151 quality.This delicious product has been formulated and has had a great health benefit for
152 human health.The case study done by (Hussain, S.Z et al. 2020) developed biscuits using
153 waterchestnutandbarleyflour. Combining WCF and BF in a 70:30 ratio made it possible to

154 develop biscuits with the desired sensory properties. The finished product was found to have
155 a greater resistant starch concentration than WCF and BF. Research has shown that adding
156 BF instead of 30% WCF can result in biscuits with the right sensory qualities and a low
157 glycemic index. According to the storage investigation, the created metalized polyethylene
158 biscuits could be kept in a refrigerator for up to 35 days and in an ambient environment for up
159 to 28 days. (overall acceptability rating more than 3 on a 5-point scale). Another case study by
160 Marangoni et al. (2008) developed low glycemic index bread and biscuits and described
161 the time and temperature combination and glucose content while baking the biscuits. The
162 control and modified samples had 75g of carbohydrates available in a person after eating the
163 low glycemic index biscuits. After baking, the nutritional value of the low glycemic index
164 biscuit was 481 calories, carbohydrate % 55, fat % 25, protein % 9, total fiber % 6, and the
165 water was 5%

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167 **2.2. Low GI cookies**

168 Low glycemic cookies are the type of cookies that are formulated to have a low
169 impact on blood sugar levels. To obtain such results, the cookies are made with low GI
170 ingredients like whole grain flour and multigrain flour, including fibers, which have a
171 significant impact on the GI, by lowering the starch digestion time and slower glucose
172 absorption. One of the studies on the cardaba banana flour was used to make the cookies (B.
173 Olawoye et al. 2020). The cardaba bananas were de-bunched, peeled underwater, sliced, and
174 dried in a traditional hot air oven at 50 C for eight hours. The recipe from (Giubertiet al.
175 2015) was used to make the gluten-free cookies. To put it briefly, The ratio of modified
176 cardaba banana starch to cardaba banana flour was 20:80 (w/w) (Olawoye et al. 2020). The
177 results of the experiments conducted by (Olawoye et al. 2020) indicated L^* , a^* , and b^*
178 values of cookies were 49.83 0.84–61.39 0.80, -4.93 0.03–1.85 0.01, and 9.38 0.21–11.60
179 0.09. The Maillard reaction may have started or accelerated during the cookie-making
180 process, as evidenced by the reduction in L and a value and increase in b values that followed
181 an increase in baking time and temperature. Additionally, the hardness (which is correlated
182 with the force needed to shatter them) varied from 43.11 0.53 to 67.92 1.06 N for the cookies.
183 The study's findings showed that, as baking time increased, neither the baking temperature
184 nor the cookies' breaking strength increased.

185 In another study by Naseer et al. (2021) low glycemic, gluten-free cookies were made
186 from high amylose rice flour using broken grains of white rice (Lalat variety). The
187 carboxymethyl cellulose concentration, baking time, and temperature were adjusted to range
188 from 0.2 to 1%, 12 to 25 minutes, and 170 to 190 °C. Conversely, the anticipated glycemic
189 load and glycemic index declined as the carboxymethyl cellulose concentration increased.
190 Design experts determined that 0.8% carboxymethyl cellulose content, 185 °C baking
191 temperature, and 22 minutes of baking time would be ideal for creating rice flour to make
192 these gluten-free and low-glycemic index cookies. The generated cookies' dietary fiber
193 content was found to be 4.66%. According to in vitro studies on starch digestibility, resistant
194 starch rose from (2.85% in rice flour to 7.20% in cookies). Meanwhile, for rice flour, the
195 expected glycemic load and index dropped from 50.12 to 30.07, and for cookies, from (44.60
196 to 17.51). The cookie's overall acceptability was rated at 8.90 (on a 9-point hedonic scale).

197 Ng et al.'s (2020) investigation examined the nutritional content, sensory evaluation,
198 and gluten sensitivity of chocolate cookies prepared with overripe banana residue (OBR) in
199 substitution of wheat flour (8%) and overripe banana sweetener (OBS) in substitution of
200 some sugar (10, 15, and 20%). The nutritional qualities of chocolate cookies were increased
201 with the incorporation of OBR and OBS. With an 8% OBR + 20% OBS formulation,
202 chocolate cookies had the most significant (Total dietary fiber) TDF (7.80%) and ash (1.47%)
203 concentration. The amount of sucrose in chocolate cookies decreased significantly as the
204 OBS level rose. The control and 8% OBR-incorporated cookie groups' sensory scores did not
205 significantly differ in any sensory qualities. Furthermore, adding up to 15% of OBS resulted
206 in better ratings on flavor, aroma, and acceptance in general. For GI testing, three chocolate
207 cookie formulations (control, 8% OBR, and 8% OBR + 15% OBS) were used, and the GI
208 values for each were 63, 56, and 50. This study concludes that overripe bananas are useful for
209 low-GI and high-fiber cookie recipes.

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211 **2.3. Low GI bread**

212 Bread is a typical food usually made by baking dough made of flour, typically wheat.
213 Low glycemic bread is a type of bread that has a low glycemic index, meaning that it has a
214 minimal impact on sugar levels in the blood. This bread is made using ingredients that slow
215 the digestive process, as opposed to regular bread, which is usually made from refined white
216 flour that is easily digested and absorbed by the body. This prevents sudden spikes in blood

217 sugar levels, providing a more sustained energy supply by slowly releasing glucose into the
218 bloodstream (Ostman et al. 2006). Low-glycemic bread is often made using whole grains due
219 to its ability to retain natural nutrients and fiber. In this study by Prabhakar et al. (2022),
220 Glycyrrhiza glabra extracts were infused into regular bread to transform it into proper herbal
221 bread. Different amounts of Glycyrrhiza glabra, such as 2%, 4%, and 6%, are used to fortify
222 bread. Liquid chromatography-mass spectroscopy (LCMS) examined the Glycyrrhiza glabra's
223 functional components. The extract has a strong antioxidant potency, according to the
224 antioxidant study. The extract's anti-diabetic effectiveness was also examined in this
225 investigation. A number of sensory and flavor factors were reviewed in the enriched bread
226 analysis. The glycemic index and other biochemical tests, such as the in vitro digestibility
227 test, indicate that enriched bread lowers the glycemic index. Compared to 2 and 4%, it was
228 concluded from the study that 6% of infused bread had great potency as a functional food.
229 According to the study, as mentioned earlier, enriched bread lowers the glycaemic index and
230 is, therefore, ideal for diabetics and dieters adhering to a diet. Studies have demonstrated that
231 ingredient reformulation, such as partially substituting resistant starch, dextrin, lentil
232 flour, and wheat flour, can lower baked goods' glycemic index (GI). This is especially crucial
233 for gluten-free goods since their decreased protein, fiber, and mineral content frequently
234 results in a higher GI. It has also been discovered that the GI of cereal-based goods can be
235 reduced by adding pulse components, such as pea and lentil flour. Furthermore, because
236 coconut flour has a high dietary fiber content, its GI can be lowered with increasing amounts
237 in baked products that use it (Jagelaviciute et al., 2023).

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239 **2.4. Low GI crackers**

240 Low-GI crackers are a good choice for people who want to control their blood sugar
241 levels efficiently. These crackers are categorized as low-GI foods since their glycemic index
242 (GI) is less than 55. Low GI crackers have been linked to improved sensations of fullness and
243 control over postprandial glycemic reactions, which may benefit glycemic control and weight
244 management. The work done by Diana N et al. (2018) made chocolate crackers with a smooth
245 dough prepared with the appropriate amounts of wheat flour, margarine, stevia sugar, cocoa
246 powder, skim milk, baking soda, yeast, and modified kepek banana flour. The dough was then
247 flattened into sheets (1-2 mm) thick. After that, the sheets are cut into (2 by 2 cm) squares
248 and baked for 20 minutes at 100°C.

249 Additionally, chocolate crackers made with kepok banana flour felt hard and broke readily
250 because of the flour's low gluten level. These crackers also tasted bland since stevia was used
251 instead of sucrose. In terms of flavor, texture, and aroma of the organoleptic properties, the
252 chocolate crackers in the AC group that substituted 50% of the banana flour with kepok had
253 the highest values. Additionally, their starch concentration was the most resistant. Diana N et
254 al. (2018) observed that chocolate crackers made using 75% kepok banana flour using the
255 ACF method had the lowest digestibility of starch (22%) in vitro and the highest resistant
256 starch content (9%). The chocolate crackers in the AC group, which had 50% less banana
257 flour than kepok, exhibited the best organoleptic attributes in terms of taste, texture, and
258 scent. The AC and ACF group crackers had a lower GL and a low GI of less than 55
259 compared to non-crackers. Kepok banana flour, which is made by autoclaving, cooling, and
260 then fermenting bananas, might be a helpful component in lowering the GI and producing
261 low-GL snacks for people with type 2 diabetes.

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263 **2.5 Low GI muffins**

264 Muffins are quick breads resembling cakes that can be sweet or savory and baked in
265 individual servings. They are loved by many for their delicious taste and soft texture.
266 However, wheat flour is the primary ingredient in all bakery goods and has a medium to high
267 glycemic index (GI). When additional ingredients like sugar are added, the GI of the baked
268 goods is further increased, making them unsuitable for people with diabetes. The recipe used
269 to make the muffins was created by (Hussain et al. 2019). The recipe involves combining
270 sifted dry ingredients and beating eggs individually with a flat beater in a stand mixer. The
271 beaten eggs are then combined with creamed shortening while being constantly stirred. Water
272 and emulsion are added to the dry mixture and mixed well. The batter is then filled into
273 cupcake pans (65g) and frozen for four hours at a temperature of -20°C. The batter-filled cups
274 are baked for 30 minutes at 180°C in an oven. After cooling to normal temperature, the baked
275 muffins are placed in a bag and stored at -20°C for 72 hours. The glycemic response and
276 qualitative features of muffins were significantly ($p < 0.05$) impacted by the addition of
277 barley flour (BF). It was also discovered that the final product's resistant starch concentration
278 (43.5%) was more than that of BF (5.18%) and water chestnut (40.24%). The study
279 demonstrates that it is possible to create low-GI muffins with the appropriate sensory
280 qualities by substituting 30% of the water chestnut flour (WCF) with BF. The muffins made

281 with 70% WCF and 30% BF were found to have increased firmness, water activity, free fatty
282 acid, and peroxide value during storage, whereas moisture content and overall acceptability
283 dropped.

284 **2.6 Low GI pasta**

285 Pasta is a cuisine typically made by mixing wheat flour, eggs, and water to form a flat
286 dough. The dough is then shaped into sheets of various shapes and cooked by boiling or
287 baking. Although traditionally, only durum flour was used to create pasta, the term now
288 includes other gluten-free flour substitutes such as rice flour, legumes like beans, and
289 alternates like lentils. While pasta is believed to have originated in Italy and is an essential
290 component of Italian cuisine. The case study of (Pachipulusu M et al. 2020) developed low
291 glycemic index noodles and concluded that these flours can be added to noodle formulations
292 with legume flour (X2-35%), and leafy green vegetable powder (X3-12.5%),millet flour (X1-
293 52.5%) without compromising the sensory and textural qualities of the finished product, out
294 of all the products created, this one contains the most fiber, protein, and low GI content. It is
295 also the most sensory-friendly.A blend of these flours is employed to enhance pasta's sensory
296 qualities. It is possible to create goods that are both nutrient-dense and aesthetically pleasing
297 by utilizing the capabilities of the combination of different ingredient designs and sensory
298 analysis. Therefore, this pasta has excellent potential to bring good health benefits to public
299 health.

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301 **3. Conclusion**

302 In affluent societies, the increase in the number ofcases of obesity,type-II diabetes
303 mellitus, and cardiovascular diseaseis linked to increased energy intake that is exacerbated by
304 physical inactivity. Consuming too much fat is a significant contributing factor to these
305 conditions. As a result, a low-fat diet is advised by a number of public health groups (like the
306 American Diabetes Association, 1997), (Gabir et al., 1997) dedicated to managing and
307 avoiding obesity and diabetes. One potentiallyharmful consequence of these
308 recommendations might be an actual decrease in fat intake combined with an increase in
309 dietary CHO, which would increase the Glycemic levels and potentially the diet's overall GI.
310 Making low-GI meal choices is crucial for those who see a notable drop in dietary fat
311 intake.This kind of diet has potential benefits like weight reduction (Maziarz et al. 2017)and
312 slowing aging as the foods are rich in antioxidants. Also, the free radicle formation is

313 minimized by reducing oxidation. Low GI diets also protect the heart from various CVDs and
314 prevent various cancer-causing factors (Liu et al. 2000); this kind of study helps educate
315 people and helps them make better choices for leading a healthy life. This study will help us
316 understand recent advancements. Much research has been done on the topic, and many
317 advancements have been made. Advancements such as using different alternative flours like
318 banana starch, quinoa flour, waterchestnuts, etc., to make the product instead of wheat flour
319 increase the fiber and decrease the GI. Other factors, such as ingredients, also play a major
320 role in decreasing GI, so using ingredients with low glycemic levels can have a significant
321 effect on GI. There are many different options for a healthy breakfast, such as healthy grains,
322 nuts, and seeds, granola bars, oatmeal sachets, and low-GI morning cereals, nuts, seeds, and
323 dried fruits in snack bars. Low-GI and easily portable food options provide energy and
324 protein. People focus on controlling blood sugar levels for improved health, so there is a
325 growing demand for low-GI ready-to-eat meals due to increased consumer awareness of the
326 glycemic index (GI).

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