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Applications of Green Banana Flour as a Functional Food Ingredient: A Review

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Abstract Banana is an edible, nutritive fruit in the genus *Musa* and is consumed in fresh or processed forms. As a sustainable solution for postharvest losses of banana, Green banana flour (GBF) manufacturing has been developed in many banana growing countries and is claimed as a rich source of slowly digestible starch, resistant starch, phenolic compounds and dietary fiber. GBF is a gluten-free alternative for wheat-based products and is used in a variety of food applications. Since functional food application is one of the most intensively and widely promoted areas in the food industry, many studies have been accomplished to investigate the health benefits of GBF incorporated products. Previous research findings have shown that the health benefits of GBF are related to gastrointestinal and non- communicable diseases. In comparison to the products made with 100% of wheat flour, these products have positive effects in digestibility, human health, and biological functions namely stimulation of gut health, immunostimulatory effect, and prebiotic effect. However, not all the GBF-based products developed for functional properties were supported by solid scientific evidence to verify such claims. Therefore, further clinical studies are required to investigate specifications related to varietal differences, standardized dosages, and age limits for GBF incorporated foods to provide a more detailed understanding of their potential health effects and to investigate the mechanisms thereof.

Keywords: Functional food ingredient, Green banana flour, *Musa*, Prebiotics, Resistant starch

Introduction

Banana (*Musa* spp.) grows in tropical and subtropical areas and yields throughout the year. It is the most important traded fruit in the world in terms of export value (Voora et al., 2020). With the increasing population, demand for bananas has also improved. Bananas are used in many industries related to nutrition, therapeutics, traditional medicine, pharmaceutical, and food processing (Jideani, 2020). In 2017, banana production represented about 20% of the global fruits production of the year, and about 22.7 million tonnes of bananas, excluding plantains have been traded (Voora et al., 2020).

Ripe banana is a perishable fruit and highly susceptible to mechanical injuries during harvesting and postharvest handling due to high moisture content and tender texture (Mebratie et al., 2015). According to a study conducted by Wasala et al. (2014), postharvest losses of bananas were about 28.5 % from farm gate to retailer in Sri Lanka. In Uganda, postharvest losses cause about 14.5% of the produced volume of cooking bananas annually making a loss of 1.1 million tons/year in terms of economical or physical losses in the cooking banana value chain (Kikulwe et al., 2018). In Ethiopia, the estimated total loss of banana is 26.5 % and a greater loss has occurred at the retail market than the farm level and wholesale market (Mebratie et al., 2015). Furthermore, in a postharvest losses comparison in Rwanda, a greater value of postharvest losses has occurred at the retail market of bananas compared to the farm and wholesale market due to many reasons like handling time, mechanical damage, ripeness and defects (Postharvest Loss Assessment of Green Bananas in Rwanda, 2018). According to Nayak (2018), the highest losses in the banana value chain occurred at the wholesale market, with transportation losses being the major contributor to overall post-harvest losses.

According to a project conducted by Feed the Future Innovation Lab for Horticulture (2018), postharvest losses and quality problems could occur due to lack of farmers' knowledge, lack of farmer organization, improper transportation conditions, improper temperature management, and lack of processing options. By introducing new processing options, high-quality packaging, and innovative products, postharvest losses could be reduced (Postharvest Loss Assessment of Green Bananas in Rwanda, 2018). Therefore, the manufacturing of banana flour is a postharvest agri-business opportunity that should be promoted as a solution for postharvest losses and quality related problems of bananas (Feed the Future Innovation Lab for Horticulture, 2018). Flour processing from the green banana helps to sustain the economic stability of agriculture products and presents as nutritious raw materials in other food product developments (Cheok et al., 2018). Green Banana Flour (GBF) has a high amount of Total Dietary Fiber (Resistant Starch+ Dietary Fiber + fructans) (56.24 g/100g of dry weight (dw)), a significant concentration of Resistant starch (RS) (48.99±0.04 g/100g dw), and exhibits undamaged starch granules, low energy value, and moderate antioxidant capacity (Menezes et al., 2011). It shows a potency of a functional ingredient (Menezes et al., 2011). Therefore, GBF can be used as a functional ingredient in many food applications. This new innovative strategy includes various products such as gluten-free muffins (Kaur et al., 2017), slowly digestible noodles (Ritthiruangdej et al., 2011), fermented flour with probiotic potential (Divisekara et al., 2019), noodles with low Glycemic Index (GI) (Saifullah et al., 2009) and functional probiotic ice creams (Prashanth et al., 2018). Modified banana flour can also be recommended for a diet with low GI used by diabetic patients (Nurhayati & Rahmanto, 2016) and it may be healthy for people with certain non-communicable diseases due to high RS levels (Sardá et al., 2016). Therefore, this review aimed to investigate the evidence to use GBF as a functional ingredient, and means of using GBF as a functional ingredient in different types of food applications.

Materials and methods

This review was conducted using a structured literature search to collect, analyze, and synthesize scientific information on GBF and its applications as a functional food ingredient. Relevant publications were identified through major scientific databases. Articles published mainly between 2000 and 2024 were considered, with emphasis on peer-reviewed research papers, reviews, and scientific reports written in English. Studies were included if they contained information on the processing of GBF, its chemical and functional properties, health effects, or its incorporation into food products. Publications unrelated to GBF, studies focusing only on ripe banana products, or those lacking adequate scientific methodology were excluded.

About 64 articles were selected and all selected articles were screened by reviewing titles, abstracts, and full texts. Relevant data were extracted and categorized into themes such as nutritional composition, antioxidant activity, prebiotic potential, human and animal health outcomes, and product development applications. The information was synthesized qualitatively, comparing findings across multiple studies to identify consistent patterns, functional attributes, and gaps in current knowledge. The methodology ensured that only credible and scientifically supported evidence contributed to the development of this review.

Green banana floor as a functional ingredient

Applications of GBF as a Functional Ingredient

Many studies have investigated the role of GBF and GBF based products in disease prevention and health. More recently, research efforts have focused on the development of banana flour fortified functional products since it has a high amount of DF (about 56%) with RS (about 87 % of total fiber) (Andrade et al., 2021). Table 1 shows the composition of green banana flour depending on the variety and processing conditions used. GBF has a huge potential to improve nutritional quality of food products due to its high RS content, specifically Resistant starch type 2 (Vernaza and Chang, 2017). According to Bezerra et al. (2013), consumption of RS is lower in Europe and Latin America (3 to 6g/day) than some other continents such as Asia (8-19 g/day). Even so, sources of RS can be used for functional foods with the potential of reduction of diverticulitis, colon cancer, constipation, and cholesterol, (Bezerra et al., 2013).

Table 1. Composition of Green Banana Flour

Variety of banana	Drying method	Protein (g/100g dw)	Ash (g/100g dw)	Lipid (g/100g dw)	TSS (g/100g dw)	Total Starch (g/100g dw)	RS (g/100g dw)	AS (g/100g dw)	Total fiber (g/100g dw)	TDF (g/100g dw)	References
Musaacuminata (AAA group), Cavendish	Air drying At 55 °C and 1m/s air velocity about 6hrs	3.60±0.19	3.14±0.02	0.89±0.04	1.81	76.77±0.54	48.99±0.40	27.78	-	56.24	(Menezes et al., 2011)
Musaacuminat a, Cavendis h	Spouted bed dried flour under (80°C, 50m3/h air flow	4.14±0.07	1.084±0.06	0.453±0.009	-	78.43±1.83	40.14±0.34	-	8.49±0.67	-	(Bezerra et al.,2013)
Wiliams	Forced-air oven Drying 60°C, 48hrs and hammer milling	5.40±0.05	3.20±0.03	-	-	68.55±1.1	-	-	1.52±0.04	-	(Ahmed et al., 2020)
Baradika	Forced-air oven Drying 60°C, 48hrs and hammer milling	2.96±0.04	2.10±0.03	-	-	73.12±0.92	-	-	1.59±0.03	-	(Ahmed et al., 2020)

TSS- Total soluble solid, RS- Resistant starch, AS- Available Starch, TDF- Total Dietary Fiber

GBF preparation from peeled unripe banana under air drying conditions have gained a product with a high amount of Total dietary fiber (TDF). A significant amount of RS (48.99±0.40g/100g dw) and the carbohydrate profile of GBF indicated that the possibility of application of GBF as a functional ingredient (Menezes et al. 2011). Taiwo and Kehinde (2019) reported that GBF samples had a considerable high amount of antioxidant properties while cardaba flour (*Musa cardaba*) had a higher 2,2- diphenyl-1-picrylhydrazyl (DPPH), Total Phenolic Content (TPC), Total Soluble Solid (TSS), Ferric reducing antioxidant powder (FRAP) and metal chelating abilities compared to plantain flour. Table 2 shows the TPC, TFC, and antioxidant activity of GBF. By inactivating lipid free radicals or eliminating the decomposition of hydroperoxides into free radicals, phenolic compounds exhibit their antioxidant capacity (Fatemeh et al., 2012). GBF can be considered a good source of non-starchy polysaccharides with dietary fiber, antioxidants, polyphenols, essential minerals, and Vitamin B1, B2 and C (Stragliotto et al., 2022).

Table 2. Antioxidant activity of GBF

Variety of banana	Total phenolic content (mg/g dw)	Total flavonoid content (mg/g dw)	DPPH scavenging activity (%)	FRAP (µmol TE/100g dw)	ORAC (µmol TE/100g dw)	References
Cavendish banana (*Musaacuminata* L, cv *cavendshii*)	3.74±0.92	281.18±1.88	35.21±0.98	-	-	(Fatemeh et al., 2012)
Dream banana *Acuminata* Colla. Berangan) (*Musa* AAA, cv)	0.94±0.53	32.64±1.07	31.82±0.93	-	-	(Fatemeh et al., 2012)
Cavendish (*Musaacuminata* (AAA group)	0.51± 0.80	-	-	358.67±0.01	261.00±8.80	(Menezes et al., 2011)
Musa paradisiaca (Raw flour)	0.94±0.02	0.71±0.02	33.58±4.53	-	-	(Shodehinde and Oboh, 2013)
Musa paradisiaca (elastic pastry flour)	1.09±0.04	0.73±0.01	27.44±0.65	-	-	(Shodehinde and Oboh, 2013)
Musa paradisiaca (boiled flour)	0.93±0.02	0.61±0.01	24.76±3.26	-	-	(Shodehinde and Oboh, 2013)
Musaparadisiaca (roasted flour)	0.89±0.04	0.48±0.03	31.77±2.21	-	-	(Shodehinde and Oboh, 2013)

DPPH- 2,2- diphenyl-1-picrylhydrazyl, FRAP- Ferric reducing antioxidant, ORAC- Oxygen Radical Absorbance TE-Trolox Equivalent

GBF as a Functional Ingredient

Prebiotic and probiotic properties

Green banana can be used as a functional food of prebiotics mainly due to its RS content (Bezerra et al., 2013). Based on a comparison of black cowpea flour *(Vigna unguiculata),* GBF (*Musa sapientum*), standard RS, and retrograded rice flour (*Oryza sativa*), Dangsungnoen et al. (2012) have found that the higher RS contents ($P < 0.05$) in standard RS sample (38.41 %) and GBF sample (26.59 %) than other samples and further, survival of *L. Bulgaricus* TISTR 895 can be promoted and protected by retrograded rice flour and GBF. According to Mahore and Shirolkar (2018), the presence of RS in raw banana pulp flour has significantly promoted the growth of *L. acidophilus in vitro*. Different studies have been conducted to investigate the prebiotic effect of GBF and body functioning such as immunostimulation (Horie et al., 2020), anti-hypercholesterolemic effect (Adekiya et al., 2018), gut health (Almeida-Junior et al., 2017), etc. An *in vivo* mice feeding trial which have especially examined the effect of symbiotic supplementation of probiotic *Bacillus coagulans* spores and prebiotic green banana RS on the inflammatory bowel disease have found that this supplementation improved the overall inflammatory status of the experimental mice model including maintaining gut barrier integrity, promoting beneficial microbial activity, and reduction of clinical signs of colitis and it has resulted with synergistic function of *B.coagulans* and green banana RS (Shinde et al., 2020). It has been observed that GBF decreases the problems related to the gut barrier from antibiotic perturbation by increasing the secretion of mucin. GBF also contributed in accelerating the recovery of gut microbiota by boosting the growth of various beneficial bacterial species (Li et al., 2022). A novel fermented green banana powder (GBF) has been developed and evaluated as a functional immunostimulatory ingredient. Its effects were studied through both *in vitro* tests and *in vivo* trials using a murine model. The results showed improved recovery and reduced impact of influenza A virus infection in mice fed with fermented GBF, compared to the control group which is fed without fermented GBF (Horie et al., 2020). Gut-derivative metabolites accumulation can burden the situation of chronic kidney disease (Andrade et al., 2021). Many studies have been evaluated to mitigate amino acid fermentation and modulate gut microbiota. Andrade et al. (2021) have evaluated the prebiotic effect of GBF (48 % RS- a prebiotic) to mitigate the accumulation of gut-derived uremic toxins such as Indoxyl sulfate (IS), p-Cresyl Sulfate (pCS), and Indole 3-Acetic Acid (IAA) in individuals having peritoneal dialysis and found that GBF had no effect on the level of IS, pCS and IAA in serum. But serum IS level was reduced with GBF daily intake depending on dialysis of uremic toxins, urinary excretion, and dietary intake (Andrade et al., 2021). Banana helps to keep normal bowel activity and help with both constipation and diarrhea because it is rich in non-digestible fibers (Kumar et al., 2012). According to Cassettari et al. (2|019), green banana biomass could be considered as an adjunctive therapy for functional constipation and to reduce the dosage of laxatives as a result of a clinical study done with 80 children and adolescents. Green bananas have hastened the curing of childhood diarrhea of 2968 children in rural Bangladesh which was managed at home (Rabbani et al., 2010). Green dwarf banana flour (*Musa* spp AAA) has been examined with a trinitrobenzene sulfonic acid treated rat colitis and that experiment was important to develop green dwarf banana flour as a dietary supplement. Furthermore, green dwarf banana flour has been identified as complementary medicine for human inflammatory bowel disease (Scarminio et al., 2012). Sardá et al. (2016) have conducted a clinical trial and suggested that the high level of RS of GBF may contribute to reduce the risk of certain non-communicable diseases and act as a functional food ingredient. According to the study conducted by Sardá et al. (2016), GBF has improved insulin sensitivity, and glucose homeostasis in healthy individuals. The adverse metabolic effect of a high-fat diet has been reduced and health has been promoted due to fermentation inside the colon by the banana flour mixed with agavins (Alvarado-Jasso et al., 2020).

Banana Flour Incorporated Food Product Developments

Banana flour or starch manufacturing from banana may increase the shelf life allowing them to incorporate into different food products, mainly as a substitute for wheat flour. Before incorporation, different modifications can be done to flour using physical, chemical, and enzymatic procedures. But physical modifications like heat moisture treatment, annealing, and pregelatinization are best among all other (Marta et al., 2022).

Incorporation into Noodles

There were many studies to determine the nutritional quality of noodles by incorporating different health-beneficial ingredients. Ritthiruangdej et al. (2011) have prepared organoleptically and nutritionally acceptable dried noodles sample by substituting wheat flour with 30% of GBF. A study has been conducted to increase dietary fiber content and enhance the nutritional values of yellow alkaline noodles by Choo (2007) and 30 % of banana flour incorporation into noodles has been significantly ($P<0.05$) enhanced the functional properties of noodles in terms of carbohydrate digestibility, the effect of postprandial GI, and antioxidant properties (TPC, antioxidant activity, and inhibition of peroxidation). For obese and geriatric patients, plantain flour noodles may be good due to low amount of fat content. (Ojure & Quadri 2012). According to the research conducted by Balmurugan et al. (2022), the incorporation of GBF into noodles reduces the strength of the gluten protein network while increasing moisture absorption, providing efficient heat transfer during cooking and reducing cooking time. So, it will facilitate the heat transfer resulting a decrease in the cooking time.

Incorporation into Pasta Products

Enrichment of wheat flour with banana powder has influenced both cooking parameters and quality of pasta, and increased the antioxidant capacity of the product (Biernacka et al., 2020). Incorporation of GBF into wheat pasta has slightly decreased the lightness of cooked pasta, increased the TPC and antioxidant capacity. Furthermore, the addition of banana powder higher than 3 % has decreased the firmness of pasta (Biernacka et al., 2020). Pasta made from plantain flour had a shorter cooking time and a lower loss of material in cooking water than those made with durum wheat semolina (Bertin et al., 2020). The addition of GBF for pasta production incorporates bioactive compounds such as RS and phenolic acids to the pasta product which are not included in pasta generally (Zandonadi et al., 2012). According to Ovando-martinez et al. (2009), GBF incorporated pasta has a reduced rate of enzymatic hydrolysis of carbohydrates, and it enhanced the low GI product range for consumers. Gluten-free pasta has been developed with different ratios of GBF (*Musa cavendishii*) and cassava flour (*Manihot esculanta*) and high amount of GBF in the formulation has decreased the glycemic effect of the product due to high amount of resistant starch and dietary fiber which slows down the digestion and absorption of carbohydrates (Rachman, 2020). Furthermore, high total fiber content was important to develop gluten-free pasta with a high nutritional value.

Incorporation into Cookies

According to a study conducted by Cahyana and Restiani (2017) a formulation consists of modified (retrogradated) banana flour and wheat flour (90% and 10%, respectively) to prepare cookies has been considered as a better treatment (GI value: 57.20) compared to other formulations in the study (banana flour and wheat flour- 0 and 100%, 50 and 50%, 60 and 40%, 70 and 30%, 80 and 20%, 90 and10%). Due to high level of RS, slowly digestible starch, and lipid-starch complex, composite biscuits made with Heat-Moisture Treated (HMT)- banana flour had a lower GI and Glycemic Load (GL) than biscuits made of 100 % wheat flour (Cahyana et al., 2020). Loza et al. (2017) have used wheat flour, banana flour and sesame seeds mixture to develop a functional biscuit type and observed that the protein content and moisture content were higher than biscuits made with only banana flour, but lower than biscuits made with only wheat flour. Sotiles et al. (2015) stated that GBF and birdseed flour combination can stimulate intestinal beneficial microbiota and add significant levels of minerals into a product prepared with this flour combination. Furthermore, cookies have been developed with a high nutritional value, especially including a high fiber content and protein content. Gluten-free products are really important as the only available treatment for celiac disease which is a genetically determined chronic inflammatory intestinal disorder induced by a gluten protein present in the diet (Kumar, 2018). High RS gluten-free rice cookies have been developed by replacing rice flour with GBF for up to 70 %, which contained gluten content less than 1 ppm (Detchewa et al., 2021). *In vitro* starch digestibility and starch content has differed significantly ($P>0.05$) in cookies according to amount of Batu banana flour, but the flour processing method had no effect (Ratnasiri et al., 2018).

Incorporation into Bread

The use of banana flour in bread preparation mixture has a new commercial value. But since it did not contain gluten protein which is very important to the texture of bread, bread could not be prepared using banana flour as a main ingredient and hence it is mixed with wheat flour in the production of quality baked products (Baba et al., 2015). Baba et al. (2015) have prepared an organoleptically acceptable toasted bread including wheat flour with 30% banana flour compared to 10 and 20% of banana flour incorporation.

According to Khoozani (2020), fortification of oven- dried (at 50ºC) GBF and freeze-dried GBF to wheat flour were good treatments to bread making with acceptable organoleptic properties. If bread is fortified up to 30%, it can be considered a prebiotic bread, and the RS content in that bread is within the range of recommended daily intake of RS (6-12g/day), creating as a valuable source of Dietary fiber (DF) (Khoozani, 2020). Bread made with banana powder incorporated into wheat flour had a higher amount of protein, fat, minerals, and moisture than bread prepared from wheat flour only (Rahman et al., 2021). With the increase of banana flour, bread volume has decreased and bread weight and moisture content has increased. Alcˆantara et al. (2020) stated that wheat-green banana bread increased blood glucose level of experimental rats and maintained for a longer period of time than bread prepared only with wheat flour. Furthermore, baking process may increase the amylose and amylopectin digestibility of starch and enhanced the blood glucose level of rats. Table 3 categorizes studies of banana flour incorporated products according to the usage of banana flour, type of evidence supporting their functionality, and the effect on health.

Table 3. Descriptive Characteristics and Outcomes of Studies of Banana Flour Incorporated Food Product Developments and Evidence to Use as Functional foods

Application of GBF	GBF content	Aim	Type of evidence to prove a functional food	Findings	Effect on health	References
Bread produced by wheat flour and GBF	0 % (Control), 10% and 20%	Evaluate baking effect on resistant starch levels, blood glucose levels and verify functional health attributes	*In vitro* analysis for resistant Starch *In vivo* study for blood glucose levels of rats (25 male, Wistar type rats (6 weeks old))	10 % of GBF is acceptable for bread processing A high level of GBF negatively effect on the quality, gluten network, and gas retention. The baking process increased amylose and amylopectin digestibility of starch	GBF substituted bread has enhanced the blood glucose levels of experimental rats	(Alcˆantara et al., 2020)
Chocolate crackers made with modified Kapok Banana (*Mussaparadisiaca L.*) flour	25, 50, and 75%	Determination of value as an alternative food for type 2 diabetes patients under different processes; Autoclaving-cooling (AC), Autoclaving-cooling with spontaneous fermentation (ACF) and No autoclaving-cooling with spontaneous fermentation (NON)	*In vitro* digestibility, GI and GL	75 % flour content with ACF method has the highest RS content Both AC and ACF groups had lower GI and GL than NON crackers.	ACF Kapok banana flour may be useful for the production of low GI and GL Food for type 2 diabetes patients	(Afifah 2018)
Cookies made with banana flour (*Musa balbisiana* Colla)	25, 50, and 75 %	Determination of RS and *in vitro* starch digestibility of cookies under AC, ACF and no treatment	*In vitro* starch digestibility	Processing method has no effect on *in vitro* starch digestibility and RS level	Importance to produce high RS and in vitro digestible food for type 2 diabetes patients	(Ratnasiri et al., 2018)

Application of GBF	GBF content	Aim	Type of evidence to prove a functional food	Findings	Effect on health	References
Cookies with retrograded banana flour	Banana flour: wheat flour 0:100,50:50, 60:40, 70:30, 80:20, 90:10	Production of cookies with good physical characteristics and low GI	*In vivo* study with 18 male Wister mice to analyze GI	90: 10 banana flour: wheat flour sample has a lower GI value and was the best treatment	Content of RS in banana starch may effective to lower glucose level in blood and important for those suffering from Diabetes Mellitus	(Cahyana and Restiani 2017)
Probiotic ice cream	2, 4, and 6 % of green banana flour for base ice cream mix	Enrichment of ice-cream with GBF	Colony count had the highest sensory score for overall acceptance and moderate viable counts of probiotic bacteria	Ice-cream with 4 %	GBF usage is effective for the development of functional probiotic ice cream rich in RS and fiber	(Prashanth et al., 2018)
Yellow noodles with green banana (*Musaacuminate* L, cv cavendshii) flour	Wheat flour: banana flour 90:10	Utilization of banana flour as a functional ingredient and assessment of *in vitro* starch digestibility and physicochemical properties	*In-vitro* starch digestibility	Banana pulp noodles have a lower estimated GI, higher elasticity value compared to 100% wheat flour Noodles	Banana pulp flour substitution was important for controlling starch hydrolysis	(Saifullah et al., 2009)
Cookies with two banana varieties; *Musaacuminata* cv. *Pisang awak* And *Musaacuminata* cv. *Red dacca*	Wheat flour: Banana flour 85:15, 75:25, 70:30, 0:100	Asses functional, physiochemical and antioxidant properties of flour and cookies prepared	In vitro study for radical Scavenging activity (DPPH), Ferric reducing antioxidant power assay (FRAP), ABTS assay, Total phenolic content	Antioxidant composition of banana flour is higher than cookies made out of banana flour 70% wheat flour :30% banana flour cookies howed the highest value for overall performance	Ability of protecting body against oxidative stress	(Amarasinghe et al., 2021)

Incorporation into Meat-based Products

As a natural fiber-rich ingredient and fat substitute, green banana is used in many meat products such as hamburgers (Cotrim et al., 2016), burgers (Bastos et al., 2014), meatballs (Suniati and Purnomo, 2019), frankfurters (Pereira et al., 2020), etc. Processed meat products contain moderate amounts of animal fat to achieve desired sensory and functional properties of the product (Pereira et al., 2020). Although these products are consumed worldwide, consumption of too much meat can adversely affect human health because of considerable amount of sodium and saturated fat (Santos et al., 2019). To make this product category healthier, some products have been developed to reduce the lipid content and enhance the dietary fiber content. Santos et al. (2019) have developed a green banana biomass flour enriched chicken hamburger with lower lipid content, and higher value of chewability and firmness. Furthermore, green banana biomass meal added a smaller shrinkage to the burger with cooking than the passion fruit peel flour as a fat substitute and it developed a viable alternative for processed meat reducing sodium and fat content. According to Cotrim et al. (2016), rabbit meat hamburgers prepared with 5 % of lard and 5 % of GBF have presented high acceptability compared to other samples (lard 10 % (control), lard 3 % + GBF 7 %, and lard 0 % + GBF 10 %) showing the highest sum of polyunsaturated fatty acids, highest unsaturated fatty acid/saturated fatty acid ratio, and lower caloric value compared to the control and as an alternative technology to improve nutritional quality of hamburger, GBF addition can be developed with further studies, improvements and commercialization. A research was conducted to reduce fat content in chicken mortadella due to consumer driven demand for healthier foods. Five treatment were prepared with 100% chicken skin and 25, 50, 75 and 100% of chicken skin replacement with green banana biomass flour. Chicken mortadella made with 100% chicken replacement had high water holding capacity without affecting the emulsion stability and typical mortadella flavor (Auriema et al., 2022). Suniati and Purnomo (2019) have developed an Indonesian meatball using goroho *(Musa acuminafe* sp) banana flour as a natural antioxidant source and noticed that a higher amount of banana flour enhanced the antioxidant activity of meatballs and delayed the rancidity. According to Suniati and Purnomo (2019), meatballs prepared with 5 % of banana flour and 5 % of tapioca flour can be recommended to be produced as functional Indonesian meatballs. Plant-based indigestible carbohydrates can increase the nutritional quality and functionality of comminuted meat products by improving thermal emulsification and cooking properties (Pereira et al., 2020). Alves et al. (2016) has produced the bologna type sausages using GBF and pork skin as fat replacers and observed significantly ($P<0.05$) less amount of fat contents and significantly($P<0.05$) high amount of RS, ash, and moisture contents. As a great strategy to improve health and nutritional characteristics, chorizos have been developed incorporating wheat flour or banana flour, and chorizos that can be labelled as “high fiber” have been obtained with banana peel flour while wheat flour or banana flour incorporated chorizos could be labelled as “source of fiber” (Salazar et al., 2020).

Conclusions and recommendations

GBF contains many health beneficial compounds including RS, dietary fiber, and phenolic compounds. Several studies have shown that indigestible starch may stimulate the functioning of immune system, and gut health. GBF acts as a prebiotic and has a synergetic effect with beneficial bacteria to enhance gut health. In some human studies, GBF has a positive effect on constipation, diabetics, childhood diarrhea, non-communicable diseases, inflammatory bowel disease, and reduction of adverse effect of a high fat diet. As a fiber-rich ingredient and fat replacer, GBF has been incorporated into meat-based products such as hamburgers, meatballs, and frankfurter. In human studies conducted, GBF incorporated bread, noodles and cookies have ameliorated the blood GI level diabetic patients while a few studies showing an increase of blood glucose level of animals used for experimental trials. Many products have been developed with GBF, and most of the scientific data suggest the enhancement of nutritional composition of products with health benefits. However, further clinical studies are needed to clarify the effects of different grain varieties, determine standardized dosages, and assess age-specific responses to GBF-incorporated foods, in order to better understand their health impacts and the underlying mechanisms.

Conflicts of interest

The authors declare that there are no conflicts of interest.

Author contributions

Sewwandi S.S.S. contributed to the development of the review concept, conducted the literature search and data analysis, and prepared the original manuscript draft. , De Silva A.B.G.C.J. provided expert guidance on the scientific aspects related to green banana flour, supported gaining practical and academic understanding of green banana flour, refined the scope of the review, contributed ideas for content development, and reviewed and edited the manuscript. , Samarakoon E.R.J. provided expert guidance and supported the selection and formulation of the review topic, offered academic direction throughout the project, guided the manuscript structure and content development, and critically reviewed and corrected the manuscript.

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