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Development and characterization of gluten-free noodles from whole rice flour and green banana flour

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Abstract

The food industry is constantly seeking to identify and valorise new natural and sustainable sources, such as plant powders and unconventional flours, as alternatives to traditional flours. The objective of this study was to evaluate the nutritional potential of green banana flour (GBF) to develop and optimize a gluten-free noodle assortment with superior nutritional profile and improved sensory and technological qualities. GBF contains health-promoting compounds that enhance the nutritional value of flour products when combined with whole rice flour (WRF). GBF was used to replace RF in percentages of 0% (control sample), 10%, 20%, 30% and 40% (w/w). Standard methods were used to examine the proximate composition, physical, sensory characteristics and storage stability of the noodle formulas. The sensory analysis of the noodle samples revealed that the 20% GBF sample was the most highly regarded by the evaluators. The results also demonstrated an enhancement in the nutritional profile of the noodles, proportional to the increase in the proportion of GBF in the composite flour blends, in terms of fibre and mineral content, as well as a reduction in cooking time and cooking losses. Consequently, the incorporation of RF and GBF in noodles constitutes a promising avenue for promoting health and culinary excellence.

Key words: green banana flour, gluten-free noodles, sensory evaluation, nutritional profile, cooking properties.

1. Introduction

Although nutritional trends have been moving towards whole grains in recent decades, refined grains, particularly white flour and white bread varieties, are very often preferred. This trend is due to the general consumer desire to consume products with superior technological properties, which has led to the selection of wheat varieties with high gluten content in order to obtain bulky, highly porous products with a longer shelf life. As a result, we now face a growing epidemic of gluten-related disorders such as celiac disease, allergy and gluten sensitivity. The number of individuals with gluten intolerance is on the rise, with a concomitant widening of the affected population, as a result of the globalisation of celiac disease. Improved diagnostic techniques have led to an increase in the number of people identified with celiac disease [1, 2, 3].

In Romania, the number of patients with celiac disease has risen five- to tenfold compared to ten years ago, due to both an increase in the rate of diagnosis and an overall rise in autoimmune diseases. Celiac disease is a chronic autoimmune (the body's own immune

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system causes the disease) disorder of the small intestine that occurs in people with a certain genetic predisposition and can manifest itself at any age, starting in childhood. The pathogenic process is caused by an intolerance to gluten - the protein found in cereals such as wheat, barley, rye and oats [4, 5].

In this context, research in this area is looking for solutions to improve the nutritional, sensory and technological properties of gluten-free foods. The global market for gluten-free products has grown significantly over the last few decades, not only due to the increasing number of celiac disease sufferers, but also due to growing demand from non-celiac disease sufferers, as gluten-free products are believed to help alleviate and treat conditions such as autism, chronic fatigue, schizophrenia, attention deficit disorder, multiple sclerosis and migraine headaches [6, 7].

The design and development of gluten-free flour products based on balanced formulations and components that would help to mimic the gluten matrix is a major challenge for food scientists. The use of different gluten-free cereals and flours makes it necessary to find ways for other ingredients to take over the gluten burden. Gluten-free flour products differ significantly from standard wheat flour products and usually have inferior properties. The absence of a resistant protein matrix, capable of expanding and retaining gas, results in the formation of weak doughs with high carbon dioxide permeability and great difficulty in maintaining their structure, leading to a reduction in baking volume [7, 8].

In recent years, there has been a growing interest in gluten-free flour products in Romania. This interest is based on the desire to satisfy consumer preferences, needs and, last but not least, the growing demands of consumers. The optimisation of recipes and the technological process for the production of gluten-free flour products represents a significant challenge, particularly in terms of enhancing the sensory characteristics of the final product. A variety of ingredients are frequently employed as substitutes for gluten functionality. In addition to gluten-free flours derived from cereals and pseudocereals, such as rice, oats, buckwheat, maize, millet, quinoa, amaranth, sorghum, flax, linseed, nuts, beans, soy and lentils, which have become increasingly familiar, there are other unconventional raw materials that can be used to make a variety of gluten-free flour products are available, including almond flour, acorn flour, chestnut flour, walnut flour, coconut flour, teff flour, green banana flour, tapoica flour, tamarind flour, pistachio flour, chia flour, maranta flour, ashwagandha flour, and moringa flour. These flours can be employed as valuable and versatile ingredients in the formulation of innovative gluten-free flour products with enhanced nutritional value [6, 8].

The flours used in this study to obtain gluten-free noodles with functional potential were: WRF and GBF. The use of GBF as an ingredient in different proportions in the production of gluten-free noodles by partial substitution of WRF is justified by its complex chemical composition, implicitly by its nutritional and biological value. GBF is an excellent source of resistant starch, dietary fibre, vitamins (in particular vitamin B6 and vitamin C), minerals (potassium and magnesium) and it has strong antioxidant activity, phenolic compounds making it an appealing source for the development of pasta [9, 10]. Due to its high resistant starchand polyphenol content, GBF has the potential to help control glycemic control and combat many diseases such as cancer, diabetes and cardiovascular disease. The content of insoluble fiber stimulates metabolism, speeds up digestion and helps contributes to lowering cholesterol, the content of antioxidants prevents premature aging, and the content of complex carbohydrates helps to stabilize blood sugar [10].

GBF contains a substantial quantity of fibre and resistant starchand, which are classified as functional components. The high resistant starch and amylopectin content of this ingredient may permit its use as a substitute for gluten-free flours without affecting the texture and structure of the resulting products [9, 11].

The utilisation of GBF in the production of noodles has been demonstrated to facilitate the aggregation of bioactive compounds, including resistant starch and phenolic acids, which are typically absent from this product. Moreover, the utilisation of GBF as a substitute for wheat flour has been shown to reduce preparation costs and it is available for purchase by the general public in a variety of retail outlets. GBF has been used to make a variety of foods, including bread, baby food, pancakes, pastries, dry noodles, and pasta [11, 12].

Noodles are a staple foodstuff in many regions of the world, and it is widely recognised that wheat noodles are one of the most popular types of noodles among consumers thanks to their convenience of preparation, unique taste, and affordable price. The expansion of the world economy and increasing awareness of health and nutrition have led consumers to demand higher standards for the nutritional qualities, texture, taste and flavour of food products [13, 14]. The advent of automation in the production of noodles has prompted manufacturers to seek the incorporation of functional ingredients, with the aim of enhancing the processing and eating qualities of the noodles, as well as increasing their functionality. This development has led to a proliferation of new noodle products, which has in turn resulted in the noodle processing industry experiencing rapid growth in recent years [14, 15].

The objective of this study was to develop a gluten-free noodle using commercially available functional ingredients that possess favourable nutritional properties, such as green bananas, and which are affordable. To this end, a series of noodle samples were prepared in which a proportion of the WRF was substituted with GBF, with the aim of enhancing the sensory, nutritional and technological attributes of the resulting product. Subsequent analysis was then conducted on the samples to ascertain their physico-chemical characteristics, sensory acceptability of cooked pasta and storage stability.

2. Material and methods

2.1. Materials

WRF (Solaris), GBF (Balance Food)**,** fresh whole eggs (Auchan), egg whites (Auchan), guar gum (Fit Food), and xanthan gum (Fit Food), transparent and metallic packages were purchased from local specialized stores in Timisoara, Romania**.**

2.2. Technological process of production and storage of gluten-free noodles

The gluten-free noodles were prepared from different amounts of WRF and GBF, with a control sample made only from WRF, thus obtaining five noodle samples: **NC** - Noodles control made from 100% WRF and 0% GBF; **N10GBF -** Noodles made from 90% WRF and 10% GBF; **N20GBF -** Noodles made from 80% WRF and 20% GBF; **N30GBF -** Noodles made from 70% WRF and 30% GBF; **N40GBF -** Noodles made from 60% WRF and 40% GBF. Each sample was manually kneaded into a firm and homogeneous dough, which was then permitted to repose for a duration of one hour. The dough was then subjected to a process of rolling, employing a kitchen noodle maker, to produce sheets with a thickness of approximately 3 mm. The noodle sheets were then cut and were dried at 60°C, until the moisture content was around 11%. After obtaining the samples, they were packaged in transparent and metallic packages (400 g) for a period of 60 days, at room temperature (25°C). The changes in cooking time were evaluated at the initial time, storage of 30 days and 60 days in transparent and metallic packages [12, 13].

Table 1. Recipes for gluten-free noodles with WRF and GBF

Ingredients (%)	**Gluten-free noodle samples**				
	NC	**N10GBF**	**N20GBF**	**N30GBF**	**N40GBF**
WRF	200	90	80	70	60
GBF	0	10	20	30	40
Fresh whole eggs	40	40	40	40	40
Egg whites	30	30	30	30	30
Water	16	16	16	16	16
Guar gum	2.5	2.5	2.5	2.5	2.5
Xanthan gum	2.5	2.5	2.5	2.5	2.5

***WRF** – Whole rice flour, **GBF** – Green banana flour; **NC** – Noodles control made from 100% WRF; **N10GBF** - Noodles made from 90% WRF + 10% GBF; **N20GBF** - Noodles made from 80% WRF + 20% GBF; **N30GBF** - Noodles made from 70% WRF + 30% GBF; **N40GBF** - Noodles made from 60% WRF + 40% GBF.*

2.3. Proximate composition of gluten-free noodles

The control sample and four noodle samples made from WRF and GBF were analysed to determine their proximate composition. The following parameters of the products were analysed: moisture content, protein content, fibre content, fat content, carbohydrate content and ash content. All determinations were made according to standardized test protocol (AOAC, 2005) and performed in triplicate [16]. Carbohydrate content was calculated by following the Food energy - methods of analysis, and conversion factors method (FAO, 2003) [17]. All samples were measured in triplicate. The energy value of the products was determined considering the following correlations: 1 g lipids = 9 kcal, 1 g carbohydrates = 4 kcal, and 1 g proteins = 4 kcal.

$$\textit{Energy value (kcal/100 g)} = (9 \times \textit{lipids}) + (4 \times \textit{carbohydrates}) + (4 \times \textit{proteins}) \qquad (1)$$

2.4. Cooking properties of gluten-free noodles

In order to ascertain the cooking properties of the noodle samples, the cooking time, cooked weight and cooking loss of noodles obtained from WRF and GBF were analysed [12, 14, 18].

Cooking time: The experiment was conducted in accordance with the following methodology. The cooking time of each dried noodle sample was determined by placing 5 g of noodles in a pot with 50 mL containing boiling distilled water. The noodles were cooked with periodic stirring. The optimal cooking time was evaluated by squeezing the noodles between two transparent glass slides and observing the time of disappearance of the white core of the noodle, with this observation made every 30 seconds.

Cooked weight: The experiment was conducted as follows: each noodle sample was cooked in boiling distilled water according to the optimal cooking time. The noodles were then rinsed with 50 mL distilled water and left to drain for three minutes. The cooked weight of each sample was determined by weighing the mass of the cooked noodles.

Cooking loss: The cooking and rinsing water of each noodle sample was collected in pre-weighed containers and dried in an oven at 105°C until dry. The residues of cooking and rinsing water were weighed after cooling in a desiccator to determine the percentage of cooking loss. This was calculated with the following equation according to Bouasla et al. (2017) and Anggraeni et al. (2018) [15, 19]:

$$Cooking\ loss\ (\%) = \frac{\text{Dried residue (g)}}{\text{Noodle sample (g)}} \times 100 \qquad (2)$$

$$Water\ absorbtion\ (\%) = \frac{\text{Weight of cooked drained noodles (g)} - \text{Weight of raw noodles (g)}}{\text{Weight of raw noodles (g)}} \times 100 \qquad (3)$$

2.5. Sensory evaluation

All the samples undergo sensory evaluation for color, flavor, taste, texture, and overall acceptability after cooking, and that was carried out by semi-trained panel of 25 members of from University of Life Sciences "King Mihai I of Romania", Faculty of Food Engineering, Timisoara. Nine point hedonic scales was used, where 9 like extremely, and 1 represents dislike extremely. The panelists were asked to grade for color, appearance, flavor, taste and overall acceptability. To perform this test, the method reported by Olorunsogo et al. (2019) was employed [20].

3. Results and Discussion

3.1. Proximate composition of flours and gluten-free noodle samples

Table 2 shows the proximate composition of the flour and noodle samples. The results obtained indicate that the partial replacement of WRF by GBF significantly influenced the chemical composition of the composite flour blends obtained, which had higher ash and fibre contents.

The moisture content was found to be lower in the GBF (11.68%) in comparison to the WRF (12.36%). High water content is not desirable because it will cause the flour to become moist and encourage the growth of food spoilage and pathogenic microorganisms. GBF are characterized by a protein content of 5.63%, in contrast to the 8.32% observed in WRF, a fat content of 2.38%, in comparison to the 2.65% found in WBF, a fibre content of 8 .82% compared to 4.44% in WBF and ash content from 4.50% compared to 2.55% in WBF. These findings support the recommendation of GBF as a functional matrix in flour products [6, 8]. The carbohydrate content was lower in the GBF from 69.68% compared to WRF from 66.99%, contributing to the decrease of carbohydrate content in noodle samples. Energy value for GBF is 311.90 kcal/100g compared to 335.85 kcal/100g for WBF. The results obtained from this study are similar to those obtained by Anggraeni et al. (2018) [15] and Oupathumpanont et al. (2021) [6] which noted that as the level of GBF substitution increased, some compounds increased.

Table 2. Proximate composition of flours and gluten-free noodle samples

Samples	**Chemical Parameters**						
	Moisture (%)	Fat (%)	Protein (%)	Crude fibre (%)	Ash (%)	CRB* (%)	Energy value (kcal/ 100 g)
				Flours			
WRF	12.36±0.07	2.65±0.04	8.32±0.12	4.44±0.14	2.55±0.21	69.68	335.85
GBF	11.68±0.13	2.38±0.08	5.63±0.05	8.82±0.12	4.50±0.22	66.99	311.90
				Noodle samples			
NC	10. 65± 0.11	2.48 ±0.14	11.18 ±0.24	4.33 ± 0.33	2.46 ± 0.08	68.90	342.64
N10GBF	10.42± 0.22	2.36 ±0.04	9.92 ± 0.09	5.84 ± 0.22	3.88 ± 0.03	67.58	331.24
N20GBF	10.24± 0.09	2.24 ±0.11	9.48 ± 0.14	6.66 ± 0.06	4.26 ± 0.44	67.12	326.56
N30GBF	10.08± 0.33	2.14 ±0.08	8.86 ± 0.33	7.72 ± 0.21	4.54 ± 0.33	66.66	321.34
N40GBF	9.92± 0.22	2.08 ±0.12	7.82 ± 0.03	8.99 ± 0.08	5.38 ± 0.05	65.81	313.24

*All determinations were done in triplicate and the results were reported as average value ± standard deviation (SD). *CRB – carbohydrates.**WRF** – Whole rice flour, **GBF** – Green banana flour; **NC** – Noodles control made from 100% WRF; **N10GBF** - Noodles made from 90% WRF + 10% GBF; **N20GBF** - Noodles made from 80% WRF + 20% GBF; **N30GBF** - Noodles made from 70% WRF + 30% GBF; **N40GBF** - Noodles made from 60% WRF + 40% GBF.*

It has been demonstrated that noodle formulations with added GBF (N10GBF, N20GBF, N30GBF and N40GBF) exhibit a superior nutritional profile in comparison to NC, a correlation that is consistent with the percentage of added GBF. Furthermore, an inverse relationship has been observed between moisture content and the content of GBF, with a concomitant decrease in WRF in the noodle samples. It can be observed that as the proportion of GBF incorporated into the dough increases, the moisture content concomitantly decreases. Specifically, the moisture content of the sample containing 40% GBF was found to be 9.92%, representing a decrease from the initial moisture content of 10.65% in NC. The noodle samples with the addition of GBF exhibited elevated levels of fibre and mineral substances in comparison to NC, with these concentrations increasing in proportion to the amount of GBF included at WRF. The noodle formulations derived from this research were found to be substantial sources of fibre, with the fibre content ranging from 5.84% in N10GBF to 8.99% in N40GBF, as opposed to 4.33% in NC. A similar upward trend was observed in the ash content, which ranged from 3.88% in N10GBF to 5.38% in N40GBF compared to 2.46% in NC. These findings suggest that the noodle formulas obtained in this study have the potential to be significant sources of fibre and mineral substances [6, 8, 15]. In relation to the fat content, a decrease in fat content was observed to be directly proportional to the increase in the amount of GBF added. Consequently, the fat content was reduced from 2.36% in N10GBF to 2.08% in N40GBF in comparison to 2.48% in NC. These results with the observations reported by Ritthiruangdej et al. (2011) [21], Anggraeni et al. (2018) [15] and Stoin et al. (2022) [10]. Moreover, the presence of a lipid-amylose complex during the production process of raw banana flour has been shown to result in a low-fat content [22]. The results showed that the protein content of noodles decreased in proportion to the increase in GBF content, from 9.92% in N10GBF to 7.82% in N40GBF, in comparison to 11.18% in NC. This phenomenon can be attributed to the low protein content of GBF, and the higher protein content of WRF. These results are not consistent with those obtained by Choo and Aziz (2010) [22], who found that levels of noodle protein increased with the addition of raw banana flour. As posited by Ovando-Martinez et al. (2009) [23] in their seminal study, this phenomenon is associated with a decline in protein content concomitant with an increase in GBF levels in noodles. This phenomenon is attributed to a diminution in gluten network formation, which consequently engenders enhanced water separation during the drying process. The results showed that the carbohydrates content from the noodle formulas with added GBF decreases, since GBF has a lower carbohydrate content than WRF. Thus, the highest carbohydrate content is found in the NC, with a value of 68.90% and decreases in the case of N40GBF sample, to 65.81%. These results are similar to those reported by Anggraeni et al. (2018) [15] and and Stoin et al. (2024) [12]. The energy value of noodle formulations, calculated from the lipid, protein, and carbohydrate intake provided by the constituent raw materials, varies in the following order: NC > N10GBF > N20GBF > N30GBF > N40GBF. The energy value of the samples decreased in proportion to the increase in the percentage of GBF, from 342.64 kcal/100 g in NC to 313.24 kcal/100 g in N40GBF. Therefore, the incorporation of GBF in noodle formulations results in a less caloric product. The outcomes of this investigation are consistent with those reported by Choo and Aziz (2010) [22], Anggraeni et al. (2018) [15], Oupathumpanont *et al.* (2021) [6] and Stoin *et al.* (2022) [10], who observed an increase in certain compounds as the level of GBF.

3.2. Cooking properties of gluten-free noodles

When it comes to the cooking properties of gluten-free noodle samples, we can distinguish three important characteristics with different roles, namely: cooking time, water absorbtion and cooking loss. Table 3 shows the changes caused by the addition of GBF in the noodles on the cooking properties. The optimal cooking time is defined as the duration required for the noodles to reabsorb water, thereby restoring their pre-drying elasticity. The analysis of the optimal cooking time reveals that all raw dried noodle samples supplemented with GBF ranged from 5 to 7 minutes (see Table 3). The optimal cooking time is influenced by several factors, including the thickness of the noodle strands [24] and the gelatinized temperature of the starch used [25]. An increase in cooking time was observed as the percentage of GBF used increased. For the control sample, the cooking time was approximately 5.20 minutes. This value increased to 6.25 minutes for the P20GBF sample and reached 7.44 minutes for the final sample with 40% GBF. These observed variations in cooking time can be attributed to the different gelatinization temperatures of the starches from WRF (60°C) and GBF (65°C) [10, 26].

Table 3. Cooking properties of gluten-free noodle samples

Treatments	**Gluten-free noodle samples**				
	NC	**N10GBF**	**N20GBF**	**N30GBF**	**N40GBF**
Cooking time (min)	5.20 ± 0.12	5.84 ± 0.08	6.25 ± 0.22	6.93 ± 0.04	7.44 ± 0.04
Water absorbtion (g)	3.56 ± 0.09	3.77 ± 0.22	3.92 ± 0.33	4.16 ± 0.09	4.38 ± 0.19
Cooking loss (%)	3.32 ± 0.24	3.64 ± 0.08	3.92 ± 0.06	4.27 ± 0.11	4.66 ± 0.13

All determinations were done in triplicate and the results were reported as average value ± standard deviation (SD). ***WRF*** *– Whole rice flour,* ***GBF*** *– Green banana flour;* ***NC*** *– Noodles control made from 100% WRF;* ***N10GBF*** *- Noodles made from 90% WRF + 10% GBF;* ***N20GBF*** *- Noodles made from 80% WRF + 20% GBF;* ***N30GBF*** *- Noodles made from 70% WRF + 30% GBF;* ***N40GBF*** *- Noodles made from 60% WRF + 40% GBF.*

The percentage of water absorption indicates the maximum amount of water that can be absorbed by the noodles. As shown in Table 3, the absorption value of raw noodles with GBF increases with increasing GBF content in the noodle sample. Thus, the highest cooking weight was observed in the NC, of 4.56 g, this gradually decreased with increasing percentage of GBF used, thus, the lowest value being 3.04g, obtained by the noodle sample with 40% GBF. The protein content of the sample has a significant influence on water absorption. During the heating process, the gluten protein present in the noodles undergoes denaturation, forming a bond that hinders water penetration and prevents its entry into the starch granules at the temperature of gelatinization. This results in the noodles acquiring a strong and chewy texture [27]. However, given the established fact that the protein content of GBF is considerably lower compared to WRF, the likelihood of bond formation that hinders water penetration into the starch granules is reduced. The cooking loss percentage is a metric of the quality of starch noodle cooking, defined as the resistance of starch noodles to disintegration during the cooking process. The results indicate that the value of the cooking loss increases with the addition of GBF (see Table 3). The lowest cooking loss was 3.32% in the control sample, while the highest cooking loss was 4.66% in the noodle sample with 40% GBF. According to Widaningrum et al. (2005) [28], the cooking loss percentage is associated with the bonding between amylose and protein. The hypothesis that the amylose-binding protein (gluten) is weaker, the greater the dissolution of noodles during cooking [29].

3.3. Sensory evaluation of gluten-free noodle samples

The results of the sensory evaluation of noodles with WRF and GBF are presented in Table 4. The evaluation of the five samples of cooked noodles was conducted by 25 untrained panelists, who analysed the noodles' color, appearance, flavour, taste and overall acceptance.

Table 4. Sensory evaluation of gluten-free noodle samples

Sensory evaluation	Gluten-free noodle samples				
	NC	**N10GBF**	**N20GBF**	**N30GBF**	**N40GBF**
Color	6.22 ± 0.27	7.34 ± 1.22	7.82 ± 0.11	6.52 ± 0.02	6.42 ± 0.44
Appearance	7.19 ± 0.11	7.44 ± 0.12	7.78 ± 0.08	6.36 ± 0.24	6.09 ± 0.14
Flavor	6.36 ± 0.16	7.58 ± 0.32	7.92 ± 0.11	7.63 ± 0.08	6.94 ± 0.13
Taste	7.16 ± 0.47	7.42 ± 0.13	7.86 ± 0.55	7.40 ± 0.09	7.06 ± 0.09
Overall acceptance	6.34 ± 0.33	7.45 ± 0.14	8.09 ± 0.26	7.52 ± 0.41	7.19 ± 0.41

All determinations were done in triplicate and the results were reported as average value ± standard deviation (SD). ***WRF*** *– Whole rice flour,* ***GBF*** *– Green banana flour;* ***NC*** *– Noodles control made from 100% WRF;* ***N10GBF*** *- Noodles made from 90% WRF + 10% GBF;* ***N20GBF*** *- Noodles made from 80% WRF + 20% GBF;* ***N30GBF*** *- Noodles made from 70% WRF + 30% GBF;* ***N40GBF*** *- Noodles made from 60% WRF + 40% GBF.*

Sample N20GBF had the highest mean preference scores for appearance, color, flavor and taste and overall acceptance. In relation to the color, no significant differences were detected between the samples. However, a heightened appreciation was evident with the escalation in the proportion of GBF in the recipe. The noodle samples with 20% GBF gave the best result (7.82), while the worst result was obtained from the WRF control sample (6.22). The results obtained in this study showed an average better color compared to Widaningrum et al. (2005) [28] with a value of 2.5 - 3.4, this is influenced by the type of raw material used.

The appearance value increased successively until sample N20GBF, reaching 7.78 compared to 7.19 in the NC sample, after which it dropped to the lowest value of 6.09 for the N40GBF sample.

There were also variations in the flavor and taste scores of the noodle samples, which increased proportionally with the percentage of replacement of WRF by GBF up to sample N20GBF. Thus, the scores recorded for flavor and taste ranged from NC at 6.36 and 7.16 to 7.92 and 7.86, respectively, for sample N20GBF and decreased to 6.94 and 7.06, respectively, for sample N40GBF.

The same increasing trend proportional to the increasing substitution rate of WRF with GBF was also recorded for the overall acceptance scores for noodle formulas with GBF compared to the NC. For instance, sample N20GBF attained a score of 8.09, in contrast to the 6.34 score obtained by NC. In other studies [20, 26-28] observed similar increase in the sensory attributes of the noodle samples when WF was substituted with increasing levels of GBF. Moreover, 75% of the consumers showed their interest in buying the gluten-free noodles made using GBF because it was a healthy and nutritious food product.

1.1. Changes in the cooking time of gluten-free noodle samples

The result of the optimum cooking time is given in Table 5. The ideal cooking time is the amount of time it takes for the noodles to absorb water and become elastic before drying.

Table 5. Changes in the cooking time of gluten-free noodle samples

Storage days	Gluten-free noodle samples				
	NC	**N10GBF**	**N20GBF**	**N30GBF**	**N40GBF**
Initial	5.20 ± 0.12	5.84 ± 0.08	6.25 ± 0.22	6.93 ± 0.04	7.44 ± 0.04
30	5.06 ± 0.08	5.62 ± 0.33	6.04 ± 0.26	6.66 ± 0.02	7.28 ± 0.08
60	4.84 ± 0.09	5.33 ± 0.03	5.88 ± 0.35	6.54 ± 0.06	7.07 ± 0.24

All determinations were done in triplicate and the results were reported as average value ± standard deviation (SD). ***RF*** *– Rice flour,* ***GBF*** *– Green banana flour;* ***PC*** *– Pasta control sample made from 100% RF;* ***P10GBF*** *- Pasta made from 90% RF + 10% GBF;* ***P20GBF*** *- Pasta made from 80% RF + 20% GBF;* ***P30GBF*** *- Pasta made from 70% RF + 30% GBF;* ***P40GBF*** *- Pasta made from 60% RF + 40% GBF.*

The utilization of metallic packages for the storage of gluten-free noodles with added GBF has been demonstrated to induce alterations in their cooking properties, specifically the duration of the cooking process. The extent of these alterations in cooking time is found to be contingent on both the duration of storage and the method of packaging employed. The longest cooking time, based on the analysis, was determined for fresh samples before storage. Specifically, the cooking times for the control sample were 5.20 minutes, 6.25 minutes for the N20GBF sample, and 7.44 minutes for the N40GBF sample. Subsequent to 30 days of storage, a decline in cooking times was observed for the same samples. For instance, the cooking time for sample NC decreased from 5.20 minutes to 5.06 minutes after 30 days of storage, while for sample N20GBF, it decreased from 6.25 minutes to 6.04 minutes, and for sample N40GBF, it decreased from 7.44 minutes to 7.28 minutes. After 60 days of storage, a further decrease in cooking time was observed. For the control sample, the cooking time decreased to 4.84 minutes; for the N20GBF sample, the value reached 5.88 minutes; and for the N40GBF sample, the cooking time was 7.07 minutes. The decrease in cooking time of noodles is beneficial in the way do time saving instant cooking and fuel saving. The quality of the noodles stored at 25°C was found satisfactory after the end of the storage duration. The results of this research are consistent with those reported by Anggraeni et al. (2018) [15], Vimercati et al. (2020) [29] and Balmurugan et *al*. (2022) [30], who observed a decrease in cooking time with storage time.

4. Conclusion

The results of this study demonstrate that GBF flour has significant potential in the development of functional foods. Partial replacement of WRF with GBF in the noodles recipe resulted in increased nutritional value as reflected by increased fiber and mineral content. These changes highlight the potential health benefits of the product. Sensory evaluation of WRF- and GBF-based gluten-free noodles shows that the use of up to 20% GBF in the recipe results in increased consumer acceptance. The overall nutritional, physical and sensory evaluation of the obtained noodles showed that GBF can represent a valid vegetal source in the formulation of new food products with improved functionality. In view of these considerations, the industrial implementation of these noodles is recommended to facilitate their availability as a high quality food product with high nutritional value. They can be included in the diets of consumers suffering from celiac disease, as well as in diets aimed at promoting a healthy lifestyle through the consumption of nutritious and health-promoting products.

References

1. Szakály, Z.; Szente, V.; Kover, G.; Polereczki, Z.; Szigetim, O., The influence of lifestyle on health behavior and preference for functional foods, *Appetite* **2012**, *58*, 406-410
2. Awolu, O.O.; Oluwaferanmi, P.M.; Fafowora, O.I.; Oseyemi, G.F.; Optimization Of The Extrusion Process For The Production Of Ready-To-Eat Snack From Rice,Cassava And Kersting's Groundnut Composite flours, *LWT-Food Science and Technology* **2015**, *64* (1),18–24
3. Vicentini, A.; Mastrocola, D., Functional Foods: Trends And Development Of The Global Market, *Ital. J L.. Food Sci.* **2016**, *28*, 338-351
4. Makhlouf, S.; Jones, S.; Ye, S.H.; Sancho-Madriz, M.; Burns-Whitmore, B.; Li, Y.O., Effect of selected dietary fibre sources and addition levels on physical and cooking quality attributes of fibre enhanced pasta, *Food Quality and Safety* **2019**, *3*(2), 117– 127
5. Cao, Z.B.; Yu, C.; Yang, Z.; Xing, J.J.; Guo, X.N.; Zhu, K.X., Impact of gluten quality on textural stability of cooked noodles and the underlying mechanism, *Food Hydrocolloids* **2021**, *119*, 106842
6. Oupathumpanont, O.; Wisansakkul, S., Gluten-free Pasta Products with Improved Nutritional Profile by Using Banana Flour, *Journal of Food and Nutrition Research* **2021**, *9*(6), 313-320
7. Guo, J.; Gutierrez, A.; Tan, L.; Kong, L., Considerations and strategies for optimizing health benefits of resistant starch. *Current Opinion in Food Science* **2023**, 2023*51*, 101008.
8. Islam, M.F.; Islam, S.; Miah, M.A.S.; Bhuiyan, M.N.I.; Abedin, N.; Mondol, M.M.H.; Linkon, K.M.M.R., Quality assessment and sensory evaluation of green banana starch enriched instant noodles. *Applied Food Research*, **2024**, *4*(1), 100431
9. Balmurugan, M.; Saravanakumar, R.; Kanchana, S.; Vellaikumar, S.; Mini, M.L.; Haripriya, S., Development of noodles using unripe banana flour and evaluation of its cooking characteristics and nutritional profile, *Pharma Innovation* **2022**, *11*(5), 954-959
10. Stoin, D.; Vîrsta, D.L.; Robert, R.; Bicu, O.M.; Jianu, C.; Velciov, A.B.; Poiană, M.A., Quality evaluation of noodles based on black bean flour and wheat flour, *Journal of Agroalimentary Processes and Technologies* **2022**, *28*(4), 292-298
11. Scarton, M.; Clerici, M.T.P.S., Gluten-free pastas: ingredients and processing for

technological and nutritional quality improvement, *Food Science and Technology* **2022**, *42*, e65622

12. Stoin, D.; Jianu, C.; Velciov, A.; Poiana, M.A.; Cozma, A.; Radu, F.; Moigradean, D.; Popescu, S.; Rinovetz A., Red kidney bean flour and rice flour: potential ingredients in the production of gluten-free pasta with functional quality, *30th International Symposium on Analytical and Environmental Problems* **2024,** 204-208
13. Chintong, S. The Effect of Partial Wheat Flour Substitution by Unripe Banana Flour and Particle Sizes on the Physical, Chemical Properties and In Vitro Digestibility of Instant Noodles, *Journal of Food Technology, Siam University* **2022**, *17*(2), 69-82
14. Akubor, P.I.; Agada, T.O.; Okereke, G.O., Quality evaluation of noodles produced from blends of wheat, unripe banana and cowpea flours, *JN food sci tech* **2023**, *4*(2), 1-13
15. Anggraeni, R.; Saputra, D.; Adib, A., Physicochemical characteristics and sensorial properties of dry noodle supplemented with unripe banana flour, *Food Research* **2018**, *2*(3), 270-278
16. Official methods of analysis (18th ed.), Association of Official Analytical Chemists, Washington DC **2005**
17. Food energy - methods of analysis and conversion factors, Report of a Technical Workshop, Rome, 3-6 December 2002, 77, FAO FOOD AND NUTRITION PAPER **2003**
18. Yahya, F.; Xiang, Y.K.; Zainol, M.K.; Hasmadi, M., Effect of different ratios of wheat flour to black bean (Phaseolus vulgaris L.) flour on physicochemical properties and sensory acceptability of cooked noodle, *Food Research* **2021**, *6*(2), 457 – 464
19. Bouasla, A.; Wojtowicz, A.; Zidoune, M.N., Gluten-free precooked rice pasta enriched with legumes flours: physical properties, texture, sensory attributes and microstructure, *LWT - Food Science and Technology* **2017**, *75*, 569-577
20. Olorunsogo, S.T., Adebayo, S.E., Orhevba, B.A., Awoyinka, T.B., Sensory evaluation of instant noodles produced from blends of sweet potato, soyabean and corn flour, *Food Research* **2019**, *3*(5), 515-524
21. Ritthiruangdej, P.; Parnbankled, S.; Donchedee, S.; Wongsagonsup, R., Physical, chemical, textural and sensory properties of dried wheat noodles supplemented with unripe banana flour. *Kasetsart Journal – (Natural Sciences)* **2011**, *45*, 500-509
22. Choo, C.L.; Aziz, N.A., Effects of banana flour and b-glucan on the nutritional and sensory evaluation of noodles. *Food Chemistry* **2010**, *119*, 34-40
23. Ovando-Martinez, M.M Sáyago-Ayerdi, S.; Agama-Acevedo, E.; Goñi, I.; Bello-Pérez, L.A., Unripe banana flour as an ingredient to increase the undigestible carbohydrates of pasta, *Food Chemistry* **2009**, *113*(1), 121–126
24. Huang, Y.C.; Lai, H.H., Noodle quality affected by different cereal starches, *Journal of Food Engineering* **2010**, *97*, 135-143
25. Yadav, B.J.; Ritika, B.Y.; Mahesh, K., Suitability of pigeon pea and rice starches and their blends for noodle making, *Food Science and Technology* **2011**, *44*, 1415-1421
26. Cao, Z.B., Yu, C.; Yang, Z.; Xing, J.J.; Guo, X.N.; Zhu, K.X., Impact of gluten quality on textural stability of cooked noodles and the underlying mechanism, *Food Hydrocolloids* **2021**, *119*, 106842
27. Kovacs, M.I.P.; Fu, B.X.; Woods, S.M.; Khan, K., Thermal stability of wheat gluten protein: its effect on dough properties and noodle texture, *Journal of Cereal Science* **2004**, *39*(1), 9–19
28. Widaningrum, W.S.; Soekarto, S.T.; Enrichment soy flour in the manufacture of wet noodles with flour raw material substituted arrowroot flour, *Postharvest Journal* **2005**, *2*(1), 41-48
29. Vimercati, W.C.; Macedo, L.L.; Araujo, C.D.S.; Maradini Filho, A. M.; Saraiva, S.H., Teixeira, L.J.Q., Effect of storage time and packaging on cooking quality and physicochemical properties of pasta with added nontraditional ingredients. *Journal of Food Processing and Preservation* **2020**, *44*(9), e14637
30. Balmurugan, M.; Saravanakumar, R.; Kanchana, S.; Vellaikumar, S.; Mini, M.L.; Haripriya, S., Development of noodles using unripe banana flour and evaluation of its cooking characteristics and nutritional profile, *Pharma Innovation* **2022**, *11*(5), 954-959.