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Quality assessment and sensory evaluation of green banana starch enriched instant noodles

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ABSTRACT

In this study, instant noodles (INs) were prepared by partially replacing wheat flour with green banana starch, which has a functional ingredient called resistant starch (RS). The starch was isolated from green banana, and was incorporated in the formulation as a source of resistant starch. Four different formulations were developed, and investigated the effects of the addition of banana starch on the nutritional composition, and functional properties of formulated instant noodles. The quality of the developed products was determined by moisture, ash, fat, protein, carbohydrate, crude fiber, enery, resistant starch, minerals, functional properties, and sensory attributes. Instant noodles with no banana starch had the highest moisture, ash, fat, protein, crude fiber, and energy contents but the lowest carbohydrate content. Among these, moisture, fat, protein, crude fiber, and carbohydrate content were varied significantly ($p \leq 0.05$). The results showed that with the increase of banana starch percentage, the RS content increases significantly ($p \leq 0.05$), and found 0.81 and 8.67 g/100 g respectively for control, and 11.75 % banana starch containing instant noodles. The functional properties exhibited that with the increase of the banana starch percentage in formulation, the water absorption capacity, oil absorption capacity, and rehydration rate increases significantly ($p \leq 0.05$) but swelling index was not varied significantly ($p > 0.05$). The nine point hedonic scale based sensory evaluation results involving ten panelists showed that 11.67 % wheat flour supplemented with banana starch was highly accepted with desirable properties. Therefore, banana starch containing instant noodles can open up a new dimension for food product manufacturers to formulate green banana starch enrich food products which can improve RS consumption with potential health benefits.

1. Introduction

Noodles are a traditional Asian meal comprised of flour, water, eggs or veggies, and are typically cooked in boiling water. The consumption of noodles has risen due to shifts in dietary preferences, population growth, and development or urbanization. Moreover, the ease of preparation, relatively low cost, and long shelf life make noodles more popular day by day. Noodles can be classified into various types based on their processing methods, such as fresh, dried, boiled, steamed, and instant noodles. IN is distinct from other noodle varieties because they undergo extra processing steps like steaming, frying, or drying (Zhang et al., 2016). Instant noodles containing a significant amount of resistant starch (RS) could be beneficial for human well-being because of the characteristics of RS, such as its complex structure, and ability to

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interact with the intestinal microbiota (Guo et al., 2023; Wang et al., 2023). The production of short-chain fatty acids by RS in the colon seems to have a significant impact on safeguarding against colon cancer, diverticulitis, and hemorrhoids (Li & Hu, 2023; McNabney & Henagan, 2017). Recently, there has been a growing interest in the development of RS through a variety of sources, and exploring diverse methods to enhance its presence in food.

The green banana (Musa paradisiaca) is extensively produced, and eaten in tropical, and sub-tropical areas (Marta et al., 2022). There are several reports on the preparation of flour from bananas, and their utilization (Khoozani et al., 2019; Pico et al., 2019; Zaini et al., 2022). However, green banana flour offers several distinct benefits, such as significant amount of total starch (73.4 %), resistant starch (17.5 %), and dietary fiber (14.5 %) (Juarez-Garcia et al., 2006). The resistant starch, and dietary fiber helps to lower the blood sugar level as they are mostly undigested, and unabsorbed carbohydrate (Slavin, 2013). In a previous study, Choo et al. (2010) reported that 30 % wheat flour substituted by green banana flour in noodles formulation significantly increased the total dietary fiber, total starch, and resistant starch, and lower the carbohydrate digestibility rate, and reducing the glycaemic index of the noodles. Therefore, flour from green bananas is incorporating with food items like cookies for slow digestion (Khoozani et al., 2020), and high fiber content (Hung, 2013) could be a novel approach in the economic plan. It contains a substantial quantity of fiber, and RS, which are classified as functional components. The content of RS in food items can be raised by supplementing them with particular starch preparations used as an additive to raw material in the technical process (Alsaffar, 2011).

Hernandez-Nava et al. (2009) developed spaghetti by substituting semolina with different percentage of banana starch and evaluated the physical and chemical parameters such as chemical composition, resistant stach content, texture profile, cooking loss, and sensory attrivutes. Protein, fat, and ash contents were all diluted by the addition of banana starch, while moisture content remained unaffected. Conversely, when the amount of banana starch in the spaghetti rose, the quantity of RS increased dramatically ($p \leq 0.05$). In another study, Aparicio-Saguilan et al. (2007) formulated cookies enrich with resistant starch powder extracted from autoclave-treated lintnerized banana starch. The formulated products were examined with respect to their chemical constitution, accessible starch (AS), resistant starch, and in vitro starch digestion rate. The *in-vitro* digestibility study of this research revealed that banana starch can be a potential raw materials for bakery products containing slowly digestible starch.

Hence, the aim of this study was to optimize the formulation to develop instant noodles enrich in banana starch, and evaluate its physicochemical, functional, and sensory properties.

2. Materials and methods

2.1. Raw materials, ingredients and chemicals

The raw green banana (Musa paradisiaca) was collected from the Bangladesh Agricultural Research Centre, situated in Gazipur, Dhaka. To prevent the enzymatic reaction, and other physical variables of the quality of the bananas, they were processed as soon as possible after picking, and starch was extracted by alkaline steeping method (Marta et al., 2022). Other ingredients such as wheat flour, salt, oil, and, egg were procured from New Market, Dhaka-1205, Bangladesh. The reagents, and chemicals consumed in this research were of analytical/reagent grade.

2.2. Formulation of instant noodles

The ingredients except water were mixed in a 500 mL stainless steel jar, and warm water was added to make the dough which was then kneaded for 20 min. The dough was moved to a pasta machine (ATLAS 150, MARCATO S. P. A., VIA ROSSIGNOLO, 12, ITALY), resulting in the noodles product. The raw noodles were then steamed for 5 min at 100 °C. Afterward, the noodles were subjected to a cabinet dryer for 5 h at 68 °C. After being cooled and dried, the prepared instant noodles were packed in food grade polythene bags. 100 % wheat flour based noodles was served as a control. The formulation is depicted in Table 1.

2.3. Proximate composition analysis

To determine nutritional compositions such as moisture, ash, crude fat, protein, and crude fiber, standardized test protocol was followed (AOAC, 2005). Carbohydrate, and energy content was calculated by following the Food energy - methods of analysis, and conversion factors method (FAO, 2003).

2.4. Mineral content analysis

The mineral sample was prepared by following the reported methods in an article with slight modification (Miah et al., 2023). In order to dehydrate silica, the ash was dissolved in 40 mL of 10 % HCl, and heated over a water bath for one hour. Deionized water was added to dissolve the soluble salt, and filter into a 50.0 mL volumetric flask using Whatmann No. 1 filter paper. Mineral content of the samples were determined by flame emission spectrophotometer (JENWAY, PFP7, Ireland), UV–vis spectrophotometer (Analytikjena, SPECORD 205, Germany), and atomic absorption spectrophotometer (AAS) (VARIAN AAS 240 FS, USA).

2.5. Resistant starch content analysis

AOAC official method was adopted to determine the RS content of each formulated products (AOAC, 2002.02). The blank was 0.1 mL of pH 4.5 sodium acetate buffer and 3.0 mL of GOPOD (glucose oxidase-peroxidase) reagent. Standard calibration curve was prepared by mixing ranging D-glucose solution with 3.0 mL of GOPOD. The absorbance of the resultant mix solution was measured at 510 nm using a UV–Vis spectrophotometer. RS content (% dry basis) was calculated as follows:

$$RS\ (mg / 100g) = C_c \times V_f \times (162 / 180) \times 100 / M_c$$

Where, C_c is the concentration from calibration plot, V_f is the final volume, M_c is the moisture content and 162/180 is the factor to convert free D-glucose as determined.

2.6. Functional properties analysis

Water absorption capacity (WAC), oil absorption capacity (OAC), rehydration rate (RR), and swelling index (SI) were determined by following the method reported in the previously published work (Chintong, 2022; Meenu et al., 2022; Hadiyanto et al., 2019).

2.7. 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 ten members of Institute of Food Science and Technology (IFST), Bangladesh Council of Scientific and Industrial Research, Dhaka, Bangladesh. To perform this test, the method reported by Olorunsogo et al. (2019) was employed. Nine point hedonic scales was used, where 9 like extremely, and 1 represents dislike extremely. The panelists were asked to grade for appearance, flavour, taste, texture, and overall acceptability. The optimal ratio of banana starch in the noodles was investigated using sensory qualities in comparison to the control noodles.

Table 1
Formulation pattern of instant noodles.

Ingredients	Weight of raw materials (g and %)							
	IN_0 (g)	IN_0 (%)	IN_1 (g)	IN_1 (%)	IN_2 (g)	IN_2 (%)	IN_3 (g)	IN_3 (%)
Wheat flour	100	58.75	90	52.88	85	49.94	80	47.00
Banana Starch	–	–	10	5.88	15	8.82	20	11.75
Egg	15	8.81	15	8.81	15	8.81	15	8.81
Oil	15	8.81	15	8.81	15	8.81	15	8.81
Water	40	23.51	40	23.51	40	23.51	40	23.51
Turmeric powder	0.2	0.12	0.2	0.12	0.2	0.12	0.2	0.12
Total	170.2	100	170.2	100	170.2	100	170.2	100

IN_0 = 0 % banana starch (BS) containing instant noodles; IN_1 = 5.88 % banana starch (BS) containing instant noodles; IN_2 = 8.82 % banana starch (BS) containing instant noodles, and IN_3 = 20 % banana starch (BS) containing instant noodles.

2.8. Statistical analysis

Statistical, and graphical analysis were performed using Microsoft Excel (Office 2016), and SPSS software (version 22.0, IBM Inc, Chicago, USA). Results are presented as mean ± standard deviation (SD). The different letter as superscript in the table and figure denotes significant difference. The one-way analysis of variance (ANOVA) was performed to determine the significance of differences. In all cases, $p \leq 0.05$ were considered significant.

3. Results and discussion

3.1. Proximate composition analysis of formulated products

The measured proximate content data viz., moisture, ash, protein, fat, crude fiber, carbohydrate, and energy of the developed products were presented in Table 2. The analysis results showed that instant noodles with no banana starch had the highest moisture (9.50 g/100 g), ash (1.56 g/100 g), fat (12.60 g/100 g), protein (10.50 g/100 g), crude fiber (1.65 g/100 g), and energy contents (423.94 Kcal/100 g) but carbohydrate content was found lowest (66.32 g/100 g) among the four formulation. However, as the amount of banana starch added to formulation, a decreasing trend was noticed because the starch contained negligible amounts of fat, protein, and, minerals (Garcia-Santos et al., 2019). The only thing that separates the control from the other three formulations is the high fat, and protein content, which is due to the higher percentage of wheat flour in this formulation. Also, from the tabulated data it is revealed that when wheat flour is replaced by different percentage of banana starch there was no significant difference ($p > 0.05$) was observed in the ash, and energy content. Whereas, the moisture, fat, protein, and crude fiber content were found decreased with the increase of banana starch content in the formulation (9.50 to 6.45 g/100 g), (12.60 to 10.53 g/100 g), (10.50 to 9.12 g/100 g), and (1.65 to 1.40 g/100 g) respectively, and the change was significant ($p \leq 0.05$). The carbohydrate content was found significantly higher ($p \leq 0.05$) for IN_3 (71.13 g/100 g) when compared with IN_0 (66.32 g/100 g). A decline in protein content, and an increase in banana starch in the noodles were the main causes of the trend of reduced moisture content. The similar result was reported for noodles supplemented with green banana flour, and the moisture was found decreased from 9.76 % to 9.48 % respectively for control, and 30 % unripe banana flour enriched dried noodles (Anggraeni et al., 2018). Hence, from proximate analysis data it can be concluded that wheat flour replaced by banana starch instant noodles had changed the nutritional value significantly.

3.2. Mineral content analysis

Minerals are essential for many body functions or metabolism like improving bone density, lower blood pressure, nervous signals, neural development, utilization of oxygen, enzymatic systems, and contraction of muscles. (Mbaeyi-Nwaoha et al., 2022; Penalver et al., 2022). The micronutrient content such as Na, Mg, K, Ca, Fe, Mn, Cu, Zn, and P were analyzed, and presented in the Table 3. The results showed that all studied minerals except potassium showed decreasing trend between control, and formulated products. Statistical analysis revealed that there was no significant difference ($p > 0.05$) in the potassium content between the IN_3 instant noodles, and the control group, which increased from 423.09 to 427.03 mg/kg. The sodium content was found 61.54 mg/kg for control whereas 58.54 mg/kg was found for IN_3, and the decrease amount was not statistically significant ($p > 0.05$). No significant change ($p > 0.05$) was also observed for magnesium, and iron content of the control, and banana starch enrich instant noodles. The calcium, and phosphorous contents of control, and banana starch

Table 2
Proximate analysis of formulated products.

Test Parameter	IN_0	IN_1	IN_2	IN_3
Moisture (g/100 g)	9.50±0.15[a]	7.61±0.06[b]	7.07±0.12[b]	6.45±0.11[b]
Ash (g/100 g)	1.56±0.05[a]	1.53 ±0.08b[a]	1.49±0.03[a]	1.47±0.01[a]
Fat (g/100 g)	12.60 ±0.10[a]	11.04 ±0.11[b]	10.83 ±0.08[b]	10.53 ±0.09[b]
Protein (g/100 g)	10.50 ±0.06[a]	9.92 ±0.05[ab]	9.27±0.02[b]	9.12±0.01[b]
Carbohydrate (g/ 100 g)	66.32 ±0.39[a]	68.73 ±0.23[ab]	69.92 ±0.45[ab]	71.13 ±0.29[b]
Crude fiber (g/100 g)	1.65±0.14[a]	1.50±0.13[b]	1.49±0.16[b]	1.40±0.07[c]
Energy (kcal/100 g)	423.94 ±1.07[a]	415.03 ±1.13[a]	414.13 ±1.21[a]	415.85 ±1.09[a]

Different letters within the same row (identical test parameter) denote significant differences by Tukey's test ($p \leq 0.05$) in the mean value ($n = 3$). The result was expressed on a dry weight basis. IN_0 = 0 % BS; IN_1 = 5.88 % BS; IN_2 = 8.82 % BS, and IN_3 = 11.75 % BS.

Table 3
Mineral content analysis of control and formulated products.

Test Parameter	IN_0	IN_1	IN_2	IN_3
Na (mg/kg)	61.54±0.13[a]	59.49±0.09[a]	59.15±0.17[a]	58.54±0.11[a]
Mg (mg/kg)	185.64 ±0.14[a]	184.18±0.17[a]	184.64 ±0.12[a]	184.52 ±0.22[a]
K (mg/kg)	423.09 ±0.18[a]	425.35±0.14[a]	425.67 ±0.17[a]	427.03 ±0.18[a]
Ca (mg/kg)	309.26 ±0.06[a]	297.21 ±0.03[ab]	283.31 ±0.09[b]	281.19 ±0.08[b]
Fe (mg/kg)	23.78±0.21[a]	23.02±0.05[a]	22.69±0.16[a]	22.50±0.11[a]
Mn (mg/kg)	2.79±0.01[a]	2.63±0.02[a]	2.39±0.01[b]	2.27±0.08[b]
Cu (mg/kg)	0.75±0.03[a]	0.59±0.05[b]	0.67±0.04[c]	0.53±0.03[b]
Zn (mg/kg)	2.89±0.05[a]	2.53±0.0[b]	2.39±0.05[b]	2.42±0.02[b]
P (mg/kg)	515.00 ±0.15[a]	507.00±0.18[a]	498.90 ±0.11[a]	483.20 ±0.19[b]

Different letters within the same row (identical test parameter) denote significant differences by Tukey's test ($p \leq 0.05$) in the mean value ($n = 3$). The result was expressed on a dry weight basis. IN_0 = 0 % BS; IN_1 = 5.88 % BS; IN_2 = 8.82 % BS, and IN_3 = 11.75 % BS.

containing instant noodles were found in between 309.26–281.19 mg/kg, and 515.00–483.20 mg/kg respectively, and the difference was statistically significant ($p \leq 0.05$). Similar results were also observed for copper, zinc, and manganese content. In a previous study, Choo et al. (2010) reported that 30 % green banana flour enriched instant noodles magnesium, potassium, and calcium content 604.1, 3604.8, and 831.0 mg/kg respectively. Akubor et al. (2023) discovered that incorporation of unripe banana, and cowpea flours in noodles formulation increased the sodium (26.80–36.40 mg/100 g), and phosphorus (155.25–187.50 mg/100 g) content whereas calcium (103.00–89.60 mg/100), and magnesium (42.80–37.60 mg/100 g) contents were found decreased. Another study revealed that 10 % banana peel powder containing instant noodles have 2212.9, 573.5, 5296.0, 165.4, 11.1, 7.7, and 792.7 mg/kg potassium, calcium, sodium, iron, manganese, zinc, and phosphorous content respectively (Pasha et al., 2022). The increased amount of minerals was for the minerals enriched supplemented flour. Therefore, the mineral contents of wheat flour instant noodles decreased with the increased percentage of banana starch in formulation due to having lower percentage of mineral containing wheat flour. Though minerals exhibited significant difference ($p \leq 0.05$) except potassium among control, and banana starch enriched instant noodles, a significant increase of resistant starch suggested the development of banana starch supplemented instant noodles, which may exert potential health benefits.

3.3. *Resistant starch content of control and banana starch enriched products*

The resistant starch (RS) was measured, and presented in the Fig 1. The resistant starch content was significantly different in between the samples ($p \leq 0.05$). From the figure, it is shown that with the increase percentage of banana stach in the formulation, the content of RS content were found higher. The RS content was found 0.81 % for IN_0 sample whereas 4.97 %, 6.26 % and 8.67 % were found respectively for IN_1, IN_2, and IN_3 and, this results were significantly higher ($p \leq 0.05$) than the control. This behaviour was directly matched with the previous literature. A group of researcher reported that green banana flour has 48.88 %−54.2 % resistant starch (Das et al., 2022; Islam et al., 2024; Moongngarm et al., 2014). In an another study, Marta et al. (2022) reported that the RS percentage of banana starch was 65 %−98 %. So, the RS in the products is just for the wheat flour supplementation of banana starch in formulation. Also, RS is a desirable property for food since it has potential physiological health benefits as well as exhibits functional properties (Miah et al., 2023).

3.4. *Functional properties analysis*

Water absorption capacity (WAC), and oil absorption capacity (OAC) indicates the amount of water/oil that noodles can absorb. The WAC was found in the range of 1.21–1.78 g/g for control and banana starch enriched instant noodles (Fig. 2A**)** and WAC of the control sample differs significantly ($p \leq 0.05$) from that of the IN_2 and IN_3 formulated products. Hence, noodles with high percentage of banana starch exhibited higher water absorption capacity. The WAC is directly related to the gluten protein content of instant noodles, and during the heating process the gluten protein is denatured, and restrict the penetration of water at the temperature at which gelatinization start (Jekle et al., 2016). These results is supported by the protein content in proximate analysis part where there was a decreaing trend with the increase of banana starch percentage. In case of OAC, similar trend was observed for both control, and banana starch enriched products i.e., with the increase of banana starch, the OAC increased, and they are significantly different ($p \leq 0.05$) with each other. The maximum (3.94 g/g) OAC capacity was found for IN_3 product, and lowest (2.33 g/g) for control sample. Similar results was also found in a research for noodles samples (2.78 g/g) reported by Akubor et al. (2018). In another study, soy enriched functional noodles OAC was reported 2.70 g/g (Rani et al., 2019). Therefore, low protein content causes the starch granules to become free within the protein matrix, which access to water easily penetrate, and maximizes the swelling, which is a crucial feature for high-quality noodle formulations (Miah et al., 2023).

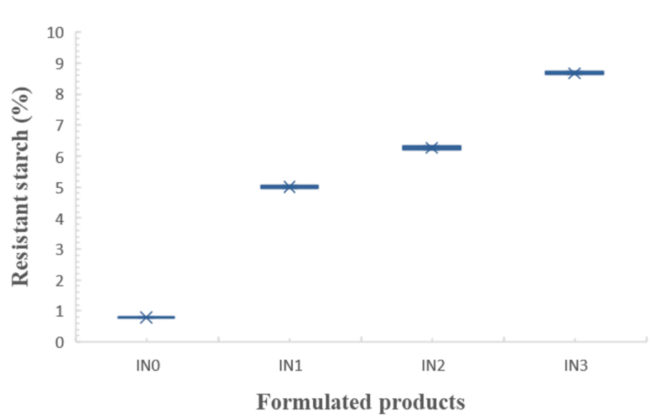

Fig. 1. RS percentage of formulated instant noodles. (IN_0 = 0 % BS; IN_1 = 5.88 % BS; IN_2 = 8.82 % BS and IN_3 = 20 % BS).

The swelling index of noodles is a measure of how much water was absorbed by the protein, and starch during cooking, which was then used to hydrate the protein, and gelatinize the starch, and this way resist the easy breakdown of the noodles (Omeire et al., 2014). In this study, the swelling index value was found in the range of 3.55–3.76 (%), and there were no significant difference ($p > 0.05$) between the samples (Fig. 2B). High swelling index is a requirement for good quality noodles (Hadiyanto et al., 2019). The rehydration rate (RR) is directly proportionate to the WAC (Balmurugan et al., 2022). So, as high as the water absorption capacity, the more the rehydration rate. The high RR in IN_3 may be for the higher percentage of amylose, and resistant starch from higher amount of banana starch (Adebowale et al., 2012). The maximum RR value was observed for IN_3 formulated products, and the value was 128.79 %, and least one for control sample (125.67).

3.5. *Sensory evaluation*

Fig. 3 represents the sensorial attributes, and overall acceptability of the control, and banana starch containing instant noodles. To get the best formulation chosen by the panelists, the hedonic scale test was performed. The analysis was conducted on cooked noodles. The results revealed that on a 9-point hedonic scale, each noodles sample received a minimum score of 7, which is considered acceptable. As per the study, the addition of different percentage of banana starch in the formulation to make noodles had no significant difference on all the sensory parameters. For control sample, maximum score (7.50) was found for color whereas noodles with the 11.75 % banana starch showed the best sensory results in terms of flavor (7.70), taste (7.96), texture (7.80), and overall acceptability (7.50) attribute. So, the panellists favoured noodles with modest amounts of banana starch. In the majority of studies looking into composite flour, it was discovered that adding more composite flour resulted in a lower acceptance score (Izzreen et al., 2023). Therefore, it could be concluded that 11.75 % banana starch containing instant noodles can be a potential alternative wheat flour based formulation for the development of instant noodles.

4. Conclusion

The prospect of this study was the utilization of banana starch as a functional ingredient in food production. The results reveal that as the proportion of BS increased, the fat, protein, crude fiber, energy, and mineral contents of instant noodles decreased. Subsequently, carbohydrate content increased and the difference was significant ($p \leq 0.05$).

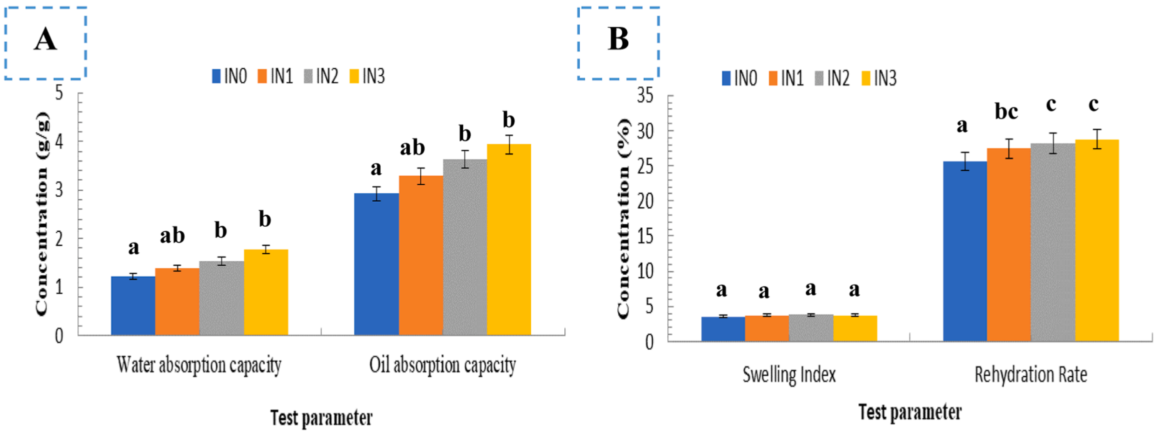

Fig. 2. Functional properties (**A**) water absorption capacity, and oil absorption capacity, and (**B**) swelling index, and rehydration rate of developed instant noodles. Different letters within the same test parameter denote significant differences by Tukey's test ($p \leq 0.05$) in the mean value ($n = 3$). (where, $IN_0 = 0$ % BS; $IN_1 =$ 5.88% BS; $IN_2 = 8.82$ % BS, and $IN_3 = 20$% BS).

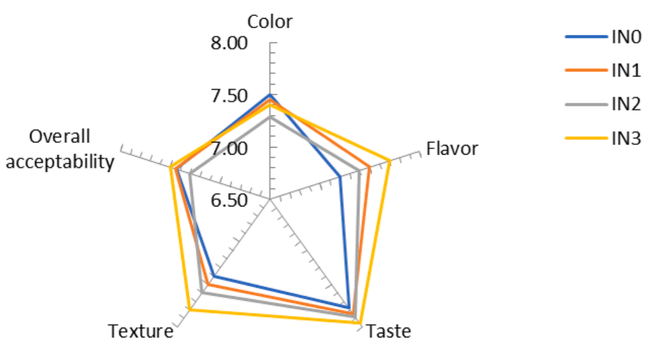

Fig. 3. Effect of banana starch (%) on sensory attributes of developed products. (where, $IN_0 = 0$ % BS; $IN_1 = 5.88$ % BS; $IN_2 = 8.82$ % BS, and $IN_3 = 11.75$ % BS).

Though the addition of banana starch in the formulation of instant noodles slightly reduce the nutritional value but significantly increase ($p \leq 0.05$) the health beneficial functional component known as resistant starch. In addition, the incorporation of banana starch also improved the functional properties of the developed products. The sensory analysis data indicated that instant noodles prepared from 11.75 % banana starch were preferred over others developed instant noodles. This implies that banana starch could be supplemented. The future works will be examined the in vitro, and in vivo digestibility of starchy foods with high RS flour to ascertain how it affects the glycaemic index of the food products in a setting similar to the human digestive system.

CRediT authorship contribution statement

Md. Faridul Islam: Writing – original draft, Supervision, Investigation. **Shariful Islam:** Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Data curation. **Md. Abdus Satter Miah:** Writing – review & editing, Supervision, Resources, Project administration, Investigation, Funding acquisition, Conceptualization. **Mohammad Nazrul Islam Bhuiyan:** Writing – review & editing. **Nusrat Abedin:** Supervision, Methodology, Investigation, Conceptualization. **Md. Mahmudul Hassan Mondol:** Writing – review & editing, Writing – original draft. **Sayeda Sultana:** Formal analysis, Data curation. **Khan Md. Murtaja Reza Linkon:** Supervision, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

Ethical statement—studies in humans and animals

Before recruiting, the theme of the research was briefed to the subjects, then data was collected from the agreed volunteers. No personal question, no invasion or no supplementation was done by the researcher to the subjects, and it was ensured that their personal identification will not be used in this research report, and they have right to withdraw themself from this research any time. Approval was taken from the Department of Nutrition and Food Technology, Jashore University of Science and Technology, Bangladesh.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.afres.2024.100431.

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