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Development of noodles using unripe banana flour and evaluation of its cooking characteristics and nutritional profile

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Abstract
Noodles are a common cuisine in many Asian countries. Traditional noodle is manufactured from wheat flour and is deficient in many important nutrients and also cause some allergic reaction with celiac patients. Banana is an important horticultural crop that grown in tropical and subtropical regions and it has strong antioxidant activity, phenolic compounds, dietary fibre, and resistant starch, making it an appealing source for the development of pasta products. Hence the study was undertaken to develop noodle with unripe banana flour. Noodles was developed by incorporating unripe banana flour at different incorporation levels of 5, 10, 15, 20, 25, 30, 35, 40 and 45 per cent and the prepared noodles were organoleptically evaluated. Based on organoleptic evaluation 45 per cent incorporation of unripe banana flour was found to be highly acceptable. The storage stability of developed noodles was assessed by packing in High Density polyethylene (HDPE) and Metalized Polypropylene (MPP) bags and kept at room temperature. The noodles developed with unripe banana flour had 8.49% moisture 8.23% protein, 1.27 fat, 1.95 fibre, 71.11% fibre and 22.04% resistant starch. The results of the cooking quality characteristics of banana flour substituted noodles during storage showed that optimum cooking time 8.45min to 7.30 min, gruel loss 5.31 to 5.67 %, water absorption 200.15 to 204.45ml and rehydration ratio was 2.0 to 2.22. The noodles stored in MPP showed better results in all the of cooking property assessment.

Keywords: Unripe banana flour, pasta products, noodles, storage stability

Introduction
Pasta products are a staple food in many parts of Asian countries. The low cost, ease of preparation, diversity, variety, good sensory quality, and extended shelf life of pasta have contributed to its global adoption. Pasta is a wonderful source of carbohydrates because it is made from wheat. Pasta is extremely popular in many nations due to its deliciousness, nutritional value, and ease of preparation (Lu *et al.*, 2018) [19]. For the production of noodles various type of different type of cereals flour are used even though the semolina obtained from wheat was also used as a best raw material for pasta production (Marti *et al.*, 2014) [22] Semolina pasta has a more yellow colour, which is due to a larger quantity of carotenoids pigments, as well as a higher resistance to overcooking and hardness (Lucisano *et al.*, 2008) [20]. However, common wheat flour is frequently utilised in the making of pastas for cost reasons. Wheat flour has improved water absorption and dough management properties, as well as tenderising and resilience. Because of the presence of gluten protein network formed by the gliadin and glutelin fraction upon water addition, the dough becomes more homogeneous, smoother, and malleable, with less sticky nature dough. Other key nutritional components such as dietary fibre, vitamins, and minerals, which are lost during wheat flour refinement, are said to be missing in traditional noodles (Ritthiruangdej *et al.*, 2011) [26]. Negative living habits or a poor diet are important factors in the development of many health issues that lead to diseases. Noodles have long been regarded as important wheat products used as the primary carbohydrate source. They have a high glycaemic index (GI) because carbohydrate elevate blood sugar levels directly (Ho & Che, 2016) [9] due to the potential of wheat noodles on high glycaemic index contribute for the health hazards associated with obesity, cardiovascular disease, diabetes, and cancer. Low-GI additives could be included in noodle products to lessen their GI (Tangthanantorn *et al.*, 2021) [28].

The banana (*Musa* spp.) is one of the most well-known tropical fruits consumed worldwide Banana flour could be prepared from cooked or uncooked bananas. Banana flour has been used to make a variety of foods, including bread, baby food, pancakes, pastries, dry noodles, and pasta. Unripe bananas are high in carbohydrates and bioactive substances of nutritional value. Several studies have suggested that eating unripe bananas has a positive effect on human health, possibly due to the indigestible components (Anggraeni *et al.,* 2018) [2]. Unripe banana flour is high in fibre and contains minerals such as potassium, iron, calcium, and magnesium, making it a fantastic source of nutrients for overall health (Singh *et al.,* 2016) [27]. According to the literature, green bananas are very rich in the resistant starch type 2 (RS2) 31.28 to 46.50g/100g (Kumar *et al.*, 2019) [16]. Resistant starch is not digested in the stomach or small intestine but is passed on to be fermented by microbiota bacteria in the large intestine, resulting in formation of short chain fatty acids and other organic acids. The lack of glucose delivery by RS is linked to a lower GI of carbohydrates that will facilitate prevention of diabetes obesity and cardiovascular disease. (Garcia-Santos *et al.,* 2019) [3]. Hence, an attempt was made to develop unripe banana flour incorporated noodle.

Materials and Methods

Non-perishable items

Whole wheat flour, salt, gingelly oil, chilli powder, turmeric powder, cumin powder, and pepper powder were purchased and stored in a local department store in Madurai, India. Jan enterprises Chennai supplied commercially accessible Xanthan gum (Food grade), which was utilised as additive in the extrusion of noodles.

Perishable items

Unripe Banana bunches (*Musa acuminata*) were procured from Wholesale banana market, Madurai. At the time of manufacturing of Noodles onion, tomato, salt, green chilies, capsicum, carrot, beans, cabbage, and coriander leaves were purchased from Madurai's Primary vegetable market.

Packaging materials

High Density Polyethylene (HDPE) bags of 200 gauge and Metallized Polypropylene (MPP) bags were purchased from local market Madurai for packing the pasta samples.

Processing of unripe banana flour

Unripe banana bunches were examined carefully for any physical damage, uniform color without any black spots and inferior quality banana and were removed. The good quality banana was selected and peels were removed by hand peeling with the aid of stainless knife. The peeled bananas were cut into 4mm thickness for enabling quick drying and then immersed in water (1: 3 ratio) 0.05% potassium meta bisulphite ($K_2S_2O_5$) and 0.1% citric acid treatment for 10 min to arrest the enzymatic browning as suggested by Kumar *et al.*, 2019 [16]. The banana slices were then dehydrated at a temperature of 55 ± 2 °C using laboratory scale cabinet dryer till the slices turned brittle. The dehydrated slices were ground in a commercial pulverized for 120 seconds and then sieved using 60 mesh sieves (ASTM: 60; 250 µm), collected, cooled and stored in a 250 g HDPE bags at room temperature for further analysis.

Development of unripe banana flour substituted noodles

The basic ingredients for the preparation of control noodles were whole wheat flour, salt and water. For the development of unripe banana flour substituted noodles, flour blends (whole wheat flour 55% and unripe banana flour 45%) were weighed, then salt (2%) and xanthan gum (1%) were added and thoroughly combined. The flour mixtures were then sifted three times to ensure thorough mixing, then sieved and kneaded with the appropriate amount of water. The flour mixtures were fed into the extruder's barrel and kneaded for 30 minutes to ensure that moisture evenly distribution by the extruder shaft. The proper brass die was fixed and then extruded into noodles shape. The extruded noodles were steamed in an idly steamer for 15 minutes after extrusion. Steamed noodles were cooled and dried for four hours at 60°C in a cabinet dryer. To ensure safeguard and preserve the quality of the extruded noodles during the storage the prepared noodles were packed in (P_1) High Density Polyethylene bags (HDPE) of 200 gauge and (P_2) Metalized Polypropylene (MPP) bags. The cooking qualities and chemical characteristics of the noodles were studies before and during storage at 30 days intervals for 90 days storage period.

Cooking qualities of unripe banana flour substituted noodles

Cooking properties of experimented noodles were assessed once in every 30 days throughout the storage period, including cooking time, solid loss, cooked volume and rehydration ratio by the following method as described by Grant *et al.* (2004) [6] and Hundal *et al.* (2007) [11] with slight modification.

Five gram of sample was placed in a boiling test tube (capacity 100 ml, 18.5 cm length, and 1.4 cm diameter). It was then filled with fifty millilitres of water and placed in a boiling water bath.

Cooking time

When the water inside the test tube began to boil, the cooking time was recorded. A few strips were drawn and squeezed between two glass slides every 30 seconds to check for the presence of white core in the product, which indicates an uncooked product, then cooked until no white core was visible between the two glass slides.

Gruel loss

The drained water was dried in a hot air oven set to 110 degrees Celsius. Periodic weighing (at one-hour intervals) was carried out until concordant values were found. The residue was weighed and the percentage of cooking loss/solid loss in noodles was calculated.

Water absorption

The excess water from the cooked product was drained out and the amount of water retained in the sample was recorded and taken as water absorbed. The results of water absorption were expressed as millilitre of water absorbed per 100 g dry matter of the sample.

Rehydration ratio

The rehydration features of pasta products were investigated using Kumar (2013) [17] method with minor changes. The sample was preliminarily soaked in hot water (100^0C) for varied periods and their rehydration characteristics were examined for each period to determine the best time for rehydration. All of the samples were observed for 3, 5, 7, 10, 12, and 15 minutes. The time took for noodles to rehydrate to an appropriate level was recorded. The rehydration ratio results were described as follows:

$$\text{Rehydration ratio} = \frac{\text{Drained weight of the rehydrated noodles}}{\text{Weight of the dehydrated noodles}}$$

Chemical Analysis of unripe banana flour incorporated noodles

The samples of unripe banana flour incorporated noodles were subjected to chemical analysis viz. Moisture, protein, fat, fibre, starch and resistant starch with control sample. The results for all parameter are present in forthcoming tables

Statistical analysis

The data obtained from three time replication on each parameters were subjected to statistical analysis using Factorial Completely Randomized Design (FCRD) design to find out the impact of storage period and packaging materials on the cooking characteristics of the developed noodles using online OPSTAT with the method as described by Gomez and Gomez (1984) [5].

Results and Discussion

Changes in the cooking time of the noodles

The result of the optimum cooking time is given in Table 1. The ideal cooking time is the amount of time it takes for the noodles to absorb water and become elastic before drying. From the table the cooking time of noodles at initial day of storage was 9.50 min and 8.45min for Control (wheat flour) (T_1) and unripe banana flour incorporated noodles (T_2) respectively. The optimum cooking time of experimental noodles was ranged from 7.30 min to 9.50 min. among the two samples banana flour incorporated noodles showed the low cooking time from the starting day of storage and also at the end of 90 days of storage. The significant variation in cooking time among the pasta products is due to the addition of banana flour. The incorporation of unripe banana flour will dilute and reduce the strength of the protein network in the composite mix thus will allow the more moisture absorption simultaneously provide the benefit of heat transfer during cooking thus will facilitate the degrease in cooking time. The optimal cooking time for noodles is controlled by thickness (Huang and Lai., 2010) [10] as well as the gelatinization temperature of the starch used in pasta manufacture (Yadav *et al.*, 2011) [29]. The decrease in cooking time of noodles is beneficial in the way do time saving instant cooking and fuel saving. The noodles packed in Metalized polypropylene (MPP) bags showed lower reduction in cooking time as a result of low moisture and gas permeable nature than the High-Density Polyethylene bags (HDPE).

Anggraeni *et al.* (2018) [2] reported the cooking time of noodles formulated with unripe banana flour in the rage of 10% 20% 30% 40% and 50% showed degrease in cooking time as increase in banana flour ranged from 4 minutes to 2 minutes. Spaghetti prepared with 15% 30% and 45% of unripe banana flour in composite mix showed that the degrease in cooking time when increasing the banana flour concentration in pasts range from 8.6 min 6, 5.1 and four minutes in 15% 30% and 45% of unripe banana flour incorporation respectively (Osorio-Diaz *et al.*, 2014) [24]. Martinez *et al.* (2014) [23] reported the cooking time of pasta made with 15, 30, 40, and 50% (w/w) of amaranth flour incorporation as a result of non-gluten flour of amaranth level increased cooking time degreased from 8 minutes to 4 minutes.

Changes in the gruel loss (%) of Noodles during storage

Table 2 displayed the gruel loss of the developed noodles. The weight of solids leached out of the pasta products after draining the water from the cooked pasta products is referred to as gruel loss it was measured in dry form. As a quality indicator, the weight of solid loss in cooked pasta is used to determine the product's quality. The cooking loss of noodles was ranged from 3.60 per cent to 3.95 per cent, 3.60 per cent to 3.80 per cent for Control (T_1) and 5.31 per cent to 5.67 per cent, 5.31 per cent to 5.52 per cent for unripe banana flour incorporated noodles (T_2) during storage in both the packaging materials. The optimum cooking loss was ranged from 3.60 per cent to 5.76 per cent. During the storage period of 90 days, the percentage of gruel loss was also increased, it may be due to moisture absorption through the microscopic whole of packaging material. On comparing noodles packed in two different packaging materials P_2 had the lower cooking loss. Noodles prepared with whole wheat flour showed lower cooking loss than unripe banana flour supplemented noodles the better result of cooking loss was due to the gluten protein network that was formed during the kneading with water as result of interaction between the gliadin and glutenin and also, the solid loss value was linked with bond formation between amylose and amylopectin. While weakening the amylose binding gluten network the whole structure of the noodles will get weaken and allow the solids leaching from the noodles at the time of cooking (Rayas-Duarte *et al.*, 1996) [25]. Solid loss should not exceed more than 8 per cent for the achievement of good quality pasta (Gull *et al.*, 2015) [7] But in the current study the solid loss was within the safe limit and also not exceeded more than 6 per cent. A similar result of increasing cooking loss from 8.71 to 11.49 per cent was reported while increasing the banana flour due to the interaction of non-glutenous materials interaction with wheat protein(gluten) Ritthiruangdej *et al.* (2011) [26]. A study report by Hernandez-Nava *et al.* (2009) [8] explore that addition of unripe banana flour increases the solid loss also increased due to the high amylose content in banana flour, which will solubilize from the pasta surface during cooking.

Changes in the water absorption (ml/100g) of noodles during storage

Changes in the water absorption (ml/100 g) of noodles during storage is represented in Table 3. The percentage of water absorption indicates how much water the noodles can absorb. From the Table 3, the optimum water absorption was raged from 187.20 ml to 193.10 ml/100g for Control noodles packed in P_1 and 187.20 ml to 190.55 ml/100g for Control noodles packed in P_2 and 200.15 ml to 204.45 ml/100g for unripe banana flour incorporated noodles (T_2) packed in P_1 and 200.15 ml to 202.65 ml/100g for unripe banana flour incorporated noodles (T_2) packed in P_2. The noodles prepared from unripe banana flour showed higher water absorption than the whole wheat flour pasta. The amount of water absorption is directly influenced by the gluten protein content in noodles. The gluten protein in the noodles will denature and establish a bond during the heating process thus will preventing penetration of water at the gelatinization temperature (Kovacs *et al.*, 2004) [15]. The increase in water absorption in unripe banana flour noodles was due to the no gluten protein content and also the addition of unripe banana flour components disintegrates the gluten protein network that will facilitate the increased water absorption. High water absorption capacity of pasta products with unripe banana flour is also due to the high amylose and dietary fibre in it which shows the high-water holding capacity than whole wheat flour pasta (Adebowale *et al.*, 2012) [1]. The water absorption capacity of the experimental pasta products was increased during the storage period in all the samples in two different packaging materials. Among the two packaging materials noodles packed in Metalized polypropylene showed low water absorption. Mabogo *et al.* (2021) [21] reported water absorption capacity and swelling capacity of banana flour (2.85% and 1.14%) had highest value than control (1.25% and 1.88%) due to the loose amylopectin and amylose association in the natural starch association on control flour. Anggraeni *et al.*, (2018) [2] conducted study unripe banana flour on dry noodles development. From the physiochemical characteristic analysis of noodles with 0, 10 and 30 per cent unripe banana flour incorporation the water absorption was increased as 157, 169 and 180 per cent due to the low protein content and high starch content.

Changes in the rehydration ratio of noodles during storage

Changes in the rehydration ratio of noodles during storage is given in Table 5. The maximum time took for adequate rehydration property of noodles in all the treatment was noted as 12.30 minutes. From the table 4 data's the optimum rehydration ratio of the Control noodles ranged from 1.87 to 2.12 and 1.87 to 2.08 for High Density Polyethylene (HDPE) bags (P_1) and Metallized Polypropylene (MPP) bags (P_2). Among the two treatments unripe banana flour treated noodles had high water absorption ratio. While comparing packaging material P_1 had high rehydration ratio than P_2. During storage days the rehydration ratio was increased in all the sample gradually packed in both packaging materials but low level of rehydration ratio was observed in noodles packed in P_2. The water absorption capacity is directly proportionate to the rehydration ratio. The higher rehydration ratio of unripe banana noodles may be due to the high amylose and dietary fibre content (Adebowale *et al.*, 2012) [1]. Iyn, (2013) [12] reported the high rehydration ratio in millet supplemented pasta than control pasta as a result low gluten protein in millet supplemented pasta products. During storage period soya meal maker supplemented noodles had increased rehydration ratio ranged from 1.76 to 1.94 (Kavitha, 2006) [13].

Nutritional composition of noodles

Nutritional composition of noodles is given in Table.5. The moisture content of the control noodles (T_1) and the unripe banana flour incorporated noodles (**T_2**) were found to have the moisture content of 9.63 and 8.49 per cent, protein content 11.90 gram and 8.23gram, Fat 1.60 gram and 1.27gram, Fibre 1.83 gram and 1.95gram, Starch 68.75 gram and 71.11 gram and resistant starch 2.30 and 22.04 respectively.

The instant noodles water content will be influenced by the water content of raw material utilised (22). The trend of lower moisture content was attributable to a decrease in protein content with an increase in unripe banana flour in the noodles, where the gluten network is reduced, making water separation easier after drying. Anggraeni *et al.* (2018) [2] reported similar result on moisture content of noodles supplemented with unripe banana flour. Moisture content of noodles supplemented with unripe banana flour was 9.48 per cent where as in control sample was 9.76 per cent. A same result of decreasing of moisture content in pasta product with unripe banana flour was reported by Ritthiruangdej *et al.* (2011) [26]. Study conducted by Khalil *et al.* (2017) [14] with unripe banana flour at the level of 10, 20 and 30 per cent in substitution with whole wheat flour in bakery products had the protein content of 8.61, 8.06 and 7.9 per cent of protein in bread.

A similar result of increasing banana flour with increased crude fibre content in noodles were reported by Anggraeni *et al.* (2018) [2]. Garcia-Valle *et al.* (2020) [4] reported that higher starch content of spaghetti with whole unripe banana flour (81.92/100g) than wheat semolina spaghetti (76.57g/100g). Salted noodles developed from 20 per cent unripe banana flour showed 10.92 per cent resistant starch but control sample had 3.25 per cent resistant starch (Li *et al.*, 2022) [18].

Table 1: Changes in the cooking time of the noodles

Storage days	T_1		T_2	
	P_1	P_2	P_1	P_2
Initial	9.50	9.50	8.45	8.45
30	9.35	9.40	8.20	8.25
60	9.13	9.35	7.55	8.05
90	8.56	9.30	7.30	7.80

Table 2: Changes in the gruel loss (%) of Noodles during storage

Storage days	T_1		T_2	
	P_1	P_2	P_1	P_2
Initial	3.60	3.60	5.31	5.31
30	3.72	3.66	5.42	5.37
60	3.84	3.73	5.55	5.44
90	3.95	3.80	5.67	5.52

Table 3: Changes in the water absorption (ml/100g) of noodles during storage

Storage days	T_1		T_2	
	P_1	P_2	P_1	P_2
Initial	187.20	187.20	200.15	200.15
30	188.82	188.10	201.55	200.75
60	190.45	189.25	202.60	201.45
90	193.10	190.55	204.45	202.65

Table 4: Changes in the rehydration ratio of noodles during storage

Storage days	T_1		T_2	
	P_1	P_2	P_1	P_2
Initial	1.87	1.87	2.00	2.00
30	1.94	1.92	2.07	2.05
60	2.02	1.99	2.15	2.11
90	2.12	2.08	2.22	2.16

Table 5: Nutritional composition of noodles

Chemical composition	Whole wheat flour Noodles (T_1)	Unripe banana flour incorporated Noodles (T_2)
Moisture content (%)	9.63	8.49
Protein (g)	11.90	8.23
Fat(g)	1.60	1.27
Fibre(g)	1.83	1.95
Starch(g)	68.75	71.11
Resistant starch(g)	2.30	22.04

Conclusion

The results of the cooking quality assessment of banana flour incorporated noodles during storage showed that optimum cooking time 8.45min to 7.30 min, gruel loss 5.31 to 5.67 per cent, water absorption 200.15 to 204.45 ml and rehydration ratio was 2.0 to 2.22. The noodles developed with unripe banana flour had 8.49 per cent moisture 8.23 per cent protein, 1.27 fat, 1.95 fibre, 71.11 per cent fibre and 22.04 per cent resistant starch. The pasta product stored in MPP showed better results in all the parameters the parameters of cooking property assessment. The investigation revealed that the noodles containing unripe banana flour was found to be better in than the wheat flour noodles.

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