STORAGE STABILITY OF HIGH RESISTANT STARCH RICH UNRIPE BANANA FLOUR INCORPORATED NOODLES

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I.   ABSTRACT

Noodles are a common cuisine in many Asian countries in recent years. Traditional noodles are made from wheat flour and which lacking in several vital elements and can trigger allergic reactions in those with celiac disease. The banana is a significant crop for the production of pasta products because of its high antioxidant activity, phenolic compounds, dietary fiber content, and resistant starch. Banana is being cultivated in tropical and subtropical climates. Therefore, an attempt was made to develop noodles using flour made from high resistant starch rich unripe bananas. 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 the organoleptic assessment, 45% of unripe banana flour incorporated noodles was found to be highly acceptable.The storage stability of the developed high resistant starch richnoodles was evaluated by putting them in two types of bags made of metalized polypropylene (MPP) and high density polyethylene (HDPE), then storing them at room temperature. The noodles developed with unripe banana flour had 8.49% moisture, 8.23% protein, 1.27 fat, 1.95 fiber, 71.11% fiber, and 22.04% resistant starch. The ideal cooking time for banana flour incorporated noodles was found to be 8.45 to 7.30 minutes, while the ideal gruel loss ranged from 5.31 to 5.67%. The optimal water absorption was found to be 200.15 to 204.45 milliliters, and the rehydration ratio was found to be 2.0 to 2.22. The noodles kept in MPP exhibited superior performance in every evaluation of their cooking properties.

Index Terms – Pasta products , Noodles , Unripe banana flour , Resistant starch, Storage stability

II.   INTRODUCTION

Products made from pasta are a staple diet in many Asian nations. Pasta's widespread popularity can be attributed to its inexpensive cost, ease of preparation, diversity, variety, good sensory quality, and long shelf life. Because pasta is made of wheat, it's an excellent source of carbohydrates. Due to its deliciousness, nutritional content, and simplicity of preparation, pasta is incredibly popular throughout the world (Lu et al., 2018). Although semolina from wheat is the ideal raw material for making pasta, many types of cereal flour are utilized to produce noodles

(Marti et al., 2014). Because semolina pasta contains more carotenoids and is more resistant to hardness and overcooking, it has a yellowercolor (Lucisano et al., 2008).However, due to budgetary constraints, pasta is often made with regular wheat flour. Wheat flour offers enhanced qualities for managing dough, absorbing water, tenderizing, and resilience. The gluten protein network, which is created when water is added and consists of the gliadin and glutelin portion, makes the dough less sticky and more uniform, smooth, and flexible. Traditional noodles are claimed to be lacking in other important nutritional elements such dietary fiber, vitamins, and minerals, which are lost during the refining of wheat flour (Ritthiruangdej et al., 2011).

Poor food and negative lifestyle choices play a major role in the emergence of numerous health problems that eventually become diseases. Noodles are the main source of carbohydrates and have long been recognized as significant wheat products. They have a high glycaemic index (GI) because carbohydrates immediately raise blood sugar levels (Ho & Che, 2016). Additionally, wheat noodles may increase the risk of health problems related to obesity, diabetes, cardiovascular disease, and cancer because of their high GI. To lower the GI of noodle products, low-GI additives could be added (Tangthanantorn et al., 2021). One of the most popular tropical fruits consumed worldwide is the banana (*Musa spp.*). Cooked or raw bananas banana flour could be very well used to develop novel food products. Many meals, such as bread, baby food, pancakes, pastries, dry noodles, and spaghetti, have been made with banana flour. Unripe bananas are rich in nutritionally significant bioactive compounds and carbohydrates. Owing to their indigestible components, a number of research have indicated that eating unripe bananas is beneficial to human health (Anggraeni et al., 2018).

Unripe banana flour is an excellent source of nutrients for general health because it is high in fiber and contains minerals including potassium, iron, calcium, and magnesium (Singh et al., 2016). Green bananas are extremely rich in resistant starch type 2 (RS2), ranging from 31.28 to 46.50g/100g (Kumar et al., 2019). In the large intestine, resistant starch is fermented by microbiota bacteria instead of being broken down in the stomach or small intestine, where it produces various organic acids and short chain fatty acids. A lower GI of carbohydrates is associated with the absence of glucose transport by resistant starch, which may help prevent diabetes, obesity, and cardiovascular disease. (Garcia-Santos and associates, 2019).

III. Materials and Methods

3.1 Non-perishable Items

Whole wheat flour, salt, gingelly oil, pepper powder, turmeric powder, cumin powder and chilli powder were purchased from nearby Lakshmi Department store in Madurai. Commercially available food-grade xanthan gum was bought from Jan Enterprises Chennai and the same was used as an additive during the noodle extrusion process.

3.2 Perishable Items

Unripe banana bunches (*Musa acuminata*) were procured from the wholesale Banana Market, Madurai.Onion, tomato, salt, green chilies, capsicum, carrot, beans, cabbage, and coriander leaves were purchased from Central Vegetable market, Madurai at the time of preparation of noodles.

3.3 Materials for Packaging

High Density Polyethylene (HDPE) bags (200 gauge thickness) and Metallized Polypropylene (MPP) bags were bought from Ramani Packaging, Madurai to pack the noodles samples for storage study.

3.4 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. After choosing a banana of superior quality, the peels were manually peeled using a stainless knife. After peeling and chopping the bananas into 4mm thick pieces to facilitate rapid drying, they were treated for 10 minutes with in a 1:3 water solution containing 0.05% potassium meta bisulphite ($K_2S_2O_5$) and 0.1% citric acid to prevent the enzymatic browning process, as recommended by Kumar et al., 2019. After that, the banana slices were dried in a laboratory scale cabinet dryer at 55 ± 2 °C until they became completely dried and brittle. The dehydrated slices were ground into powder using pulverizing machine for 120 seconds.Then they ground powder was 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.

3.5 Development of Unripe Banana Flour Substituted Noodles

Whole wheat flour, salt, and water were the main components used to make the control noodles. For the development of unripe banana flour incorporated 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 mixture was then well blended. After ensuring complete mixing with three rounds of sifting, the flour combinations were sieved and mixed with the right amount of water. To make sure that the extruder shaft distributed moisture equally, the flour mixes were put into the barrel of the extruder and kneaded for 30 minutes.

After the appropriate brass die was adjusted, the noodles were extruded. In an idle steamer, the extruded noodles were steam-cooked for 15 minutes after extrusion. Steamed noodles were cooled and dried for four hours at 60°C in a cabinet dryer.The prepared noodles were packed in (P_1) 200 gauge HDPE bags and (P_2) Metalized Polypropylene (MPP) bags in order to protect and preserve the quality of the extruded noodles during storage. Over the course of a 90-day storage period, cooking qualities and chemical characteristics of the noodles were studied both before and during storage at 30 days of intervals.

3.6 Cooking Qualities of Unripe Banana Flour Substituted Noodles

Throughout the storage period, the cooking properties of the experimented noodles were evaluated once every 30 days. This included measuring the cooking time, solid loss, cooked volume, and rehydration ratio using a slightly modified version of the method by Grant *et al.* (2004) and Hundal*et al.* (2007).One hundred milliliter boiling test tube (18.5 centimeters in length, 1.4 centimeters in diameter) was filled with five grams of sample. Thenit was filled with fifty millilitres of water and placed in a boiling water bath.

3.7 Cooking Time

The cooking time was noted when the water in the test tube started to boil. Every 30 seconds, a few strips noodles were drawn and squeezed between two glass slides to check for the presence of white core, an indication of an undercooked product. The product was then cooked until the white core was no longer visible between the two slides.

3.8 Gruel Loss

The drained water was dried in a hot air oven set to 110 ^{0}C .Weighing was done periodically (every hour) until concordant values appeared. The percentage of cooking loss/solid loss in noodles was determined by weighing the residue.

3.9 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.

3.10 Rehydration Ratio

The rehydration features of pasta products were investigated using Kumar (2013) method with minor changes.To ascertain the ideal time for rehydration, the sample was first soaked in hot water (100^{0}C) for different period of time. Then, the sample's rehydration features were assessed at 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:

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

3.11 Chemical Analysis of Unripe Banana Flour Incorporated Noodles

Control (T_1) and unripe banana flour incorporated noodle (T_2) samples were analyzed chemically for moisture, protein, fat, fiber, starch, and resistant starch, along with a control sample. The results for all parameter are present in forthcoming tables.

3.12 Statistical Analysis

The data obtained from three time replication on each parameterswere statistically analyzed using the Factorial Completely Randomized Design (FCRD) design to determine the effect of storage duration and packaging materials on the cooking characteristics of the developed noodlesGomez and Gomez (1948).

IV.   Results and Discussion

4.1 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.

According to the table, the cooking times of noodles on the first day of storage were 9.50 minutes for the Control (wheat flour) noodles (T_1) and 8.45 minutes for the noodles made with unripe banana flour (T_2) respectively. Among two samples, noodles prepared with banana flour incorporation had lower cooking times for both on the

first day of storage and at the end of the storage period (90 days). The ideal cooking time for the experimental noodles ranged from 7.30 to 9.50 minutes.The addition of flour made from unripe bananas will weaken and dilute the protein network in the composite mix, allowing for more absorption of moisture while also facilitating heat transfer during cooking, which will shorten the cooking time. Noodle thickness (Huang and Lai, 2010) and the starch used to make pasta's gelatinization temperature determine the ideal cooking time for noodles (Yadav et al., 2011).

Table 1. Changes in the Cooking Time (min) of Noodles during Storage

Storage days	T_1		T_2		T_3		T_4	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
Initial	9.50	9.50	8.45	8.45	9.10	9.10	8.43	8.43
30	9.35	9.40	8.20	8.25	8.50	9.00	8.18	8.23
60	9.13	9.35	7.55	8.05	8.25	8.45	7.53	8.06
90	8.56	9.30	7.30	7.50	8.00	8.25	7.28	7.47

Factors	C.D.	SE (d)
A	0.015	0.007
B	0.010	0.005
A X B	0.021	0.010
C	0.015	0.007
A X C	0.029	0.015
B X C	0.021	0.010
A X B X C	0.041	0.021

Treatment details

T_1 :   Wheat flour

T_2 :   Wheat flour 60g + Unripe Banana flour 50g+ Xanthan gum 2g

Noodles packed in metalized polypropylene (MPP) bags demonstrated a lower reduction in cooking time due to their low moisture content and gas permeable nature than those packed in high-density polyethylene (HDPE) bags. This reduction in cooking time is advantageous for time-saving instant cooking and fuel-saving.

According to Anggraeni et al. (2018) [2], when unripe banana flour was added to noodles, the cooking time decreased by 10%, 20%, 30%, 40%, and 50%. The range of cooking times for banana flour increases was from 4 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 pasta 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). According to Martinez et al. (2014) [23], the cooking time of pasta prepared with 15, 30, 40, and 50% (w/w) amaranth flour incorporation decreased from 8 minutes to 4 minutes due to the non-gluten flour of amaranth level.

4.2 Changes in the Gruel Loss (%) of Noodles during Storage
Table 2. Changes in the Gruel Loss (%) of Noodles during Storage

Storage days	T_1		T_2		T_3		T_4	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
Initial	3.60	3.60	5.31	5.31	5.50	5.50	5.33	5.33
30	3.72	3.66	5.42	5.37	5.62	5.56	5.45	5.39
60	3.84	3.73	5.55	5.44	5.74	5.63	5.54	5.46
90	3.95	3.80	5.67	5.52	5.86	5.70	5.66	5.53

Factors	C.D.	SE(d)
A	0.003	0.002
B	0.002	0.001
A X B	0.005	0.002
C	0.003	0.002
A X C	0.006	0.003
B X C	0.005	0.002
A X B X C	0.009	0.005

Treatment details

T_1 : Wheat flour

T_2 : Wheat flour 60g + Unripe Banana flour 50g+ Xanthan gum 2g

Table 2 displayed the gruel loss of the developed noodles. Gruel loss, which is the weight of solids that remain after the pasta products are completely cooked and the water is drained, is measured in dry form. The product quality is assessed using the weight of solid loss in cooked pasta as a quality indicator. The range of the cooking loss for the noodles during storage in both types of packing materials was 3.60 percent to 3.95 percent, 3.60 percent to 3.80 percent for the Control (T_1) and 5.31 percent to 5.67 percent, 5.31 percent to 5.52 percent for the unripe banana flour incorporated noodles (T_2). The ideal cooking loss was found to be between 3.60 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). Solid loss should not exceed more than 8 per cent for the achievement of good quality pasta (Gull *et al.,* 2015). 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)

4.3 Changes in the Water Absorption (ml/100g) of Noodles during Storage

Table 3 shows variations in the water absorption (ml/100 g) of noodles during storage. The amount of water that the noodles can absorb is shown by the percentage of water absorption. The optimal water absorption was determined by comparing the Control noodles packed in P_1 and the Unripe Banana Flour incorporated noodles (T_2) packed in P_1 and P_2 respectively. The results showed that the Control noodles' optimal absorption ranged from 187.20 ml to 193.10 ml/100g and the Unripe Banana Flour incorporated noodles (T_2) packed in P_2 from 187.20 ml to 190.55 ml/100g. Compared to pasta made with whole wheat flour, the noodles made with unripe banana flour exhibited a higher water absorption rate. Noodles gluten protein composition has a direct impact on how much water they absorb. When the noodles heat up, the gluten protein denatures and forms a link, which stops water from penetrating at the gelatinization temperature (Kovacs et al., 2004).

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

Storage days	T_1		T_2		T_3		T_4	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
Initial	187.20	187.20	200.15	200.15	195.52	195.52	199.70	199.70
30	188.82	188.10	201.55	200.75	197.45	196.48	201.95	200.65
60	190.45	189.25	202.60	201.45	199.48	197.80	203.49	201.78
90	193.10	190.55	204.45	202.65	200.69	199.03	205.97	203.15
Factors	C.D.				SE(d)			

A	3.140	1.571
B	2.220	1.111
A X B	4.441	2.222
C	3.140	1.571
A X C	6.280	3.143
B X C	4.441	2.222
A X B X C	8.881	4.445

Treatment details

T_1 : Wheat flour

T_2 : Wheat flour 60g + Unripe Banana flour 50g+ Xanthan gum 2g

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).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) reported that 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.

4.4 Changes in the Rehydration Ratio of Noodles During Storage
Table.4. Changes in the rehydration ratio of noodles during storage

Storage days	T_1		T_2		T_3		T_4	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
Initial	1.87	1.87	2.00	2.00	1.88	1.88	1.99	1.99
30	1.94	1.92	2.07	2.05	2.05	2.03	2.05	1.03
60	2.02	1.99	2.15	2.11	2.12	2.07	2.14	2.10
90	2.12	2.08	2.22	2.16	2.19	2.11	2.20	2.15
Factors	**C.D.**			**SE(d)**				
A	0.006			0.003				
B	0.005			0.002				
A X B	0.009			0.005				
C	0.006			0.003				
A X C	0.013			0.007				
B X C	0.009			0.005				
A X B X C	0.018			0.009				

Treatment details

T_1 : Wheat flour

T_2 : Wheat flour 60g + Unripe Banana flour 50g+ Xanthan gum 2g

Changes in the rehydration ratio of noodles during storage are given in Table 4. 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 rehydration ratio is directly correlated with the water absorption capacity. According to Adebowale et al. (2012), the high amylose and dietary fiber content of unripe banana noodles may be the cause of their greater rehydration ratio. According to Iyn (2013), millet-supplemented pasta had a higher rehydration ratio than control pasta, which led to lower gluten protein levels in the resulting pasta products. Noodles supplemented with soy meal manufacturer showed a higher rehydration ratio during storage, ranging from 1.76 to 1.94 (Kavitha, 2006).

4.5 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 (Marti et.al.,2014). 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.

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

Similar findings on the moisture content of noodles added with unripe banana flour were reported by Anggraeni et al. (2018). Noodles supplemented with flour made from unripe bananas had a moisture content of 9.48%, compared to 9.76% in the control sample. Ritthiruangdej et al. (2011) found the similar decrease in moisture content in pasta products made with unripe banana flour.According to a study by Khalil et al. (2017) , bread containing unripe banana flour at 10, 20, and 30% protein content instead of whole wheat flour had a protein content of 8.61, 8.06, and 7.9%.Salted noodles developed from 20% unripe banana flour showed 10.92 percent resistant starch, but the control sample had 3.25 percent resistant starch (Li et al., 2022). Anggraeni et al. (2018) reported a similar result of increasing banana flour with increased crude fiber content in noodles. Garcia-Valle et al. (2020) reported that higher starch content of spaghetti with whole unripe banana flour (81.92/100g) than wheat semolina spaghetti (76.57g/100g).

V. CONCLUSION

The best cooking time for noodles made with banana flour was found to be between 8.45 and 7.30 minutes, while the best gruel loss ranged from 5.31 to 5.67 percent. The noodles' water absorption was found to be between 200.15 and 204.45 milliliters, and the rehydration ratio was found to be between 2.0 and 2.22. The noodles made with unripe banana flour had 22.04 percent resistant starch, 1.27 fat, 1.95 fiber, 71.11 percent fiber, 8.49 percent moisture, and 8.23 percent protein. The noodles stored in MPP showed better results in all the parameters of cooking property assessment.The results of the experiment showed that the unripe banana flour noodles performed better than the wheat flour noodles.

VI. ACKNOWLEDGEMENT

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