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Storage Behaviour of Resistant Starch Rich Functional Macaroni Developed using Green Banana Flour

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ABSTRACT: Pastais a predominant carbohydrate source, which led developing chronic illnesses like obesity, cardio vascular disease and diabetes. Hence, unripe banana flour at 25, 35, 45, and 55 per cent was used to develop macaroni and they were organoleptically evaluated. Macaroni with 45 percent unripe banana flour was found to be best for various organoleptic attributes than all other samples and it was subjected to storage study. The Developed macaroni had 8.30 to 6.67 minutes of optimum cooking time, gruel loss was 3.62 to 5.69 percent, water absorption was 182.40 to 201.80 ml, and the rehydration ratio was 1.82 to 2.19.The ideal resistant starch concentration ranged from 2.29 to 22.38 percent. The macaroni packed in Metalized Polypropylene (MPP) had better cooking characteristics than High-Density Polyethylene (HDPE). The unripe banana flour macaroni with high resistant starch is a beneficial one for controlling the life-threatening chronic diseases.

Keywords: Unripe banana flour, Macaroni, Storage stability, Resistant starch.

INTRODUCTION

Even though pasta was 1st tried to introduce in Italy around 13th century effective equipment and quality ingredients were not readily accessible till 20th century. Most macaroni is now made on uninterpreted, larger capacity injected moulded parts that uses an auger extrusion concept which encompasses of extrusion and kneading in single run. Pasta fabrication involves processing of noodles, spaghetti, dry macaroni and other **(**Walsh *et al*., 1997**).**

Adverse lifestyle choices play a critical role in the development of a wide spectrum of diseases. Pasta is historically considered as important wheat products used as predominant carbohydrate source which led to elevated blood sugar levels due to high glycaemic index. This is significant contributor to the risk of developing chronic illnesses like cancers, obesity, cardio vascular disease, diabetes and other **(**Tangthanantorn *et al*., 2021**).** In today's fast paced world, with change in dietary pattern and hectic life habits it becomes clear that a healthy gastro intestinal tract is a critical one in determining the quality of life (Ritthiruangdej *et al.*, 2011. Pasta products serves as an essential part in human nourishment due to their ease, pleasant taste and low cost. They are simple to cook, store, manage and excellent boosting diet in terms of nutritional quality by partially or completely replacing wheat flour with other sources like cereals, pulses, banana and other resistant starch foods **(**Flores-Silva *et* *al.,* 2015). Due to growing demand for this product, necessitating ongoing study for increasing quality (Takacs *et al.,* 2008). According to the researchers study, sugars are gradually released from pasta throughout digestion, resulting in a continual rise in postprandial blood glucose and insulin response. Pasta is reported to have a low glycaemic index (0 to 55) and medium (56 to 69) in reference to bread (Agama-Acevedo *et al.,* 2009).

Unfortunately, due to insufficient post-harvest treatment, there is an excess production and substantial amounts of fruit are wasted during commerce. As a result, new business models for bananas as a food ingredient are being considered (Ovando-Martinez *et al.,* 2009). Unripe bananas are high in starch, banana flour includes 61.3-76.5g/100g of starch and 6.3-15.5g/100g of fibre respectively (Tribess *et al.,* 2009). Banana flour is rich source of vitamins like A, C, E, K and minerals may be potassium, calcium, phosphorus etc (Biernacka *et al.,* 2020). Banana flour has a distinct aroma, flavour, and appearance. Additionally, it works nicely with water. It has expansion and translucent characteristics when heated, and gelatinization when frozen. Banana flour also has a high level of amylose, which gives it cooking qualities (Oupathumpanont, and Wisansakkul, 2021).The resistant starch found in unripe bananas is a form of starch that is not digested in the small intestine but is fermented by bacteria in the large intestine, resulting in short chain fatty acids and other organic acids. Resistant starch is associated with lower glycaemic index of carbohydrates and not produces glucose in the body. Lower glycaemic index linked to weight and diabetes management (Tangthanantorn *et al.,* 2021). Because customers are unlikely to consume enough veggies and other fibre rich foods on their own, supplementing pasta with unripe banana flour can help them to achieve nutritional benefits and it exhibit some anti-oxidant properties (Agama-Acevedo *et al.,* 2009). Uncooked or cooked bananas can be used to make banana flour. Many of the products like baby foods, macaroni, bread and pancakes have been developed by incorporating with banana flour. Unripe bananas are high in bioactive compounds and carbohydrates which are nutritionally beneficial. Unripe banana flour had low rate of carbohydrate enzymatic hydrolysis and may useful in expanding spectrum of low glycaemic index meals to customers (Ritthiruangdej *et al.,* 2011).

MATERIALS AND METHODS

Non-perishable items. Whole wheat flour, salt, gingelly oil, chilli powder, turmeric powder, cumin powder, and pepper powder were procured from local department store in Madurai. Jan Enterprises Chennai provided food-grade Xanthan gum, which was used as an additive for performing the role as gluten on maintaining the rheological and textural properties of the extruded macaroni.

Perishable items. Unripe banana bunches (*Musa acuminata*) were obtained from Madurai's wholesale banana market. Onion, tomato, salt, green chilies, capsicum, carrot, beans, cabbage, and coriander leaves were purchased at Madurai's primary vegetable market when the macaroni was processed.

Packaging materials. For wrapping the pasta samples, 200-gauge High Density Polyethylene (HDPE) bags and Metallized Polypropylene (MPP) were purchased from the local whole sale packaging store Madurai.

Processing of unripe banana flour. Unripe banana bunches were selected after being carefully scrutinised for any physical damage, uniform colour without any black patches, and poorer quality bananas were excluded. The best banana was chosen, and the skins were removed by hand with the help of a stainless knife. The selected bananas were peeled and cut into 4mm thickness for quick drying and then immersed in water (1: 3 ratio) 0.05 percent potassium meta bisulphite ($K_2S_2O_5$) and 0.1 percent citric acid treatment for 10 minutes to stop enzymatic browning (Kumar *et al.,* 2019). The banana slices were then dehydrated in a laboratory size cabinet dryer at a temperature of 55 °C until they became brittle. The dehydrated slices were ground for 120 seconds in a commercial pulveriser, then sieved using 60 mesh sieves (ASTM: 60; 250 m) collected and stored at room temperature for further analysis in 250 g HDPE bags.

Development of unripe banana flour substituted Macaroni. Whole wheat flour, salt, and water were the primary constituents in the control macaroni (T_1). Flour blends (whole wheat flour 55%, unripe banana flour 45%) were weighed, then salt (2%), and xanthan gum (1%) were added and well blended together to develop unripe banana flour replaced macaroni (T_2).

The flour mixtures were then sieved and kneaded with the necessary amount of water after being sifted three times to guarantee proper mixing. The flour mixtures were fed into the extruder's barrel and kneaded for 30 minutes to ensure that the extruder shaft distributed moisture evenly. The correct brass die was then fixed, and the macaroni were extruded. After extrusion, the extruded macaroni was steamed for 15 minutes. Steamed macaroni was cooled and dried in a cabinet dryer for four hours at 60°C. The prepared macaroni samples were packed in (P_1) High density Polyethylene bags (HDPE) of 200 gauge and (P_2) Metalized Polypropylene (MPP) bags to assure the safety and quality of the extruded macaroni during storage. The storage stability and resistant starch content of Macaroni were investigated before and during storage at 30-day intervals for a period 90 days.

Cooking qualities of unripe banana flour incorporated macaroni. The following approach, as described by Grant *et al.* (2004); Hundal *et al.* (2007) was used with slight modification to analyse the cooking parameters of the developed macaroni once in every 30 days throughout the storage period, including cooking time, solid loss, cooked volume, and rehydration ratio.

In a boiling test tube, five grams of macaroni was placed (capacity 100 ml, 18.5 cm length, and 1.4 cm diameter) and was filled halfway with water and placed in a boiling water bath.

Cooking time. The cooking time was recorded when the water inside the test tube began to boil. Every 30 seconds, a few pieces were drawn and squeezed between two glass slides to check for the presence of a white core in the product, which implies an uncooked product, and then cooked until no white core was evident between the two glass slides.

Gruel loss. The drained water was dried in a hot air oven at a temperature of 110 degrees Celsius, Weighing was done on a regular basis (at one-hour intervals) until concordant values were established. Weighing the residue and calculating the amount of cooking loss/solid loss in macaroni.

Water absorption

The surplus water from the cooked product was drained off, and the amount of water left in the sample was measured and recorded as water absorbed. Water absorption data were given as millilitres of water absorbed per 100 grammes of dry matter in the sample.

Rehydration ratio. Kumar (2013) technique was used to study the rehydration properties of pasta products with slight modifications. To find the ideal time for rehydration, the sample was preliminarily immersed in hot water (1000°C) for various times and their rehydration features were studied for each period. For 3, 5, 7, 10, 12, and 15 minutes, all of the samples were observed. The amount of time it took for the macaroni to rehydrate to the proper level was recorded. The results of the rehydration ratio results were described as follows:

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

Resistant starch content. The resistant starch content of pasta products was analysed and described according to the method given by McCleary and Monaghan (2002).

Statistical analysis. The data collected were statistically analysed as suggested by Gomez and Gomez (1984). The data of three replications was analysed using a Factorial Completely Randomized Design (FCRD) design to see how the storage period and packaging materials affected the cooking qualities of the developed macaroni.

RESULTS AND DISCUSSION

Changes in the cooking time(min) of the macaroni during storage. Table 1 shows the results of changes in the cooking time of the macaroni during storage. The time which was taken for the cooking of control(T_1) macaroni was 8.3 min. there was gradual reduction in the cooking time was observed in the cooking time during storage from 30 to 90 days. There was a slight variation was observed between the packaging materials P1 and P2. Cooking time was found to be reduced from 8.30min to 8.20min and 8.25, 8.13, 8.28 and 8.02 and 8.11min for control macaroni packed in P1and P2 respectively. Similarly, the initial cooking time of unripe banana flour incorporated macaroni was 7.55min and were found to be reduced to 7.34 and 7.45, 7.11 and 7.34 and 6.57 and 7.22 respectively during 30, 60 and 90 days of storage respectively.

Table 1: Changes in the cooking time(min) of the macaroni during storage.

Storage period (days)	T_1		T_2	
	P_1	P_2	P_1	P_2
0	8.30	8.30	7.55	7.55
30	8.20	8.25	7.34	7.45
60	8.13	8.28	7.11	7.34
90	8.02	8.11	6.57	7.22

T1 100% whole wheat flour, T2 55%whole wheat flour+ 45% unripe Banana flour, P1 High density Polyethylene, P2 Metalized Polypropylene.

Factors	C.D.	SE(d)
A	0.007	0.003
B	0.007	0.003
A × B	0.009	0.005
C	0.009	0.005
A × C	0.013	0.007
B × C	0.013	0.007
A × B × C	0.019	0.009

Unripe banana flour dilutes and weakens the protein network in the composite mix, allowing for more moisture absorption as well as heat transfer during cooking, thus will facilitate in shortening of cooking time. (Rayas-Duarte *et al.*,1996).

Cooking time of noodles made with unripe banana flour in the range of 10, 20, 30, 40, and 50 percent indicated decrease in cooking time as increase in banana flour varied from 4 minutes to 2 minutes, according to Anggraeni *et al.* (2018). Spaghetti cooked with 15 percent, 30 percent, and 45 percent unripe banana flour in composite mix demonstrated that the degrease in cooking time when increasing the banana flour concentration in pasts ranged from 8.6 minutes, 5.1 minutes, and four minutes, respectively (Osorio-Daz *et al.,* 2014).

Changes in the gruel loss (%) of Macaroni during storage. The changes in gruel loss(%) of macaroni during storage is given in Table 2. The gruel loss of the macaroni was 3.62% in T_1 and 5.33% in T2 at initial day of storage. the changes in the gruel loss of the macaroni were also studied for every 30 days of interval upto 90 days for both control(T_1) and raw banana flour incorporated macaroni(T_2). The initial and final gruel loss were 3.62 and 3.96% for T_1 packed in P_1 and for sample packed in P2 was 3.62 and 3.80%. Similarly, the initial gruel loss of 5.33 was found to be increased to 5.69 and 5.33 packed in P_1 and P_2 for raw banana flour incorporated macaroni. The increase in cooking loss when the banana flour incorporation was correlate with fact that the overall structure of the noodles will deteriorate when the amylose binding gluten network weakens, allowing solids to leach from the noodles during cooking (Rayas-Duarte *et al.*, 1996). In order to get good quality pasta, solid loss should not exceed 8%. (Gull *et al.*, 2015). However, the solid loss in the current investigation was within the safe range and did not exceed 6%. Due to the interaction of non-glutenous components with wheat protein, a similar finding of increased cooking loss from 8.71 to 11.49 percent was discovered while increasing banana flour (gluten) Ritthiruangdej *et al.* (2011). The inclusion of unripe banana flour increases solid loss due to the high amylose content in banana flour, which will solubilize off the pasta surface during cooking, according to Hernandez-Nava *et al.*, (2009).

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

Storage period (days)	T_1		T_2	
	P_1	P_2	P_1	P_2
0	3.62	3.62	5.33	5.33
30	3.73	3.67	5.44	5.39
60	3.86	3.73	5.56	5.46
90	3.96	3.80	5.69	5.53

T1 100% whole wheat flour, T2 55% whole wheat flour+ 45% unripe Banana flour, P1 High density Polyethylene, P2 Metalized Polypropylene.

Factors	C.D.	SE(d)
A	0.003	0.002
B	0.003	0.002
A × B	0.004	0.002
C	0.004	0.002
A × C	0.006	0.003
B × C	0.006	0.003
A × B × C	0.009	0.004

Changes in the water absorption (ml/100g) of macaroni during storage. Changes in water absorption of macaroni during storage is given in Table 3. The changes in the water absorption of control(T_1) and raw banana incorporated macaroni was 182.40 and 195.15ml. A slight increase in the water absorption capacity was observed in both T_1 and T_2 throughout the storage period. The water absorption capacity of the control (T_1) macaroni packed in P_1 and P_2 was 187.90 ml and 185.88 ml at the end of the 90 days of storage period. The raw banana flour incorporated macaroni was also found to be increased from 195.15 ml to 201.8 and 199.25ml packed in P_1 and P_2 after 90 days of storage. The gluten protein composition in macaroni has a direct impact on how much water is absorbed. During the heating process, the gluten protein in the noodles denatures and forms a link, blocking water penetration

at the gelatinization temperature (Kovacs *et al.*, 2004). The high-water absorption capacity of pasta products made from unripe banana flour is owing to the high amylose and dietary fibre content, which demonstrates that it can contain more water than whole wheat flour pasta (Adebowale *et al.*, 2012).

Due to the loose amylopectin and amylose association in the natural starch association on control flour, Mabogo *et al.* (2021) found that banana flour (2.85 percent and 1.14 percent) had the maximum water absorption capacity and swelling capacity than control (1.25percent and 1.88 percent). Unripe banana flour was studied on the creation of dry noodles by Anggraeni *et al.* (2018). The low protein content and high starch content of noodles with 0, 10, and 30% unripe banana flour incorporation improved water absorption by 157, 169, and 180 percent, respectively, according to the physiochemical characteristics study.

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

Storage period (days)	T_1		T_2	
	P_1	P_2	P_1	P_2
0	182.40	182.40	195.15	195.15
30	184.23	183.10	197.20	196.15
60	186.35	184.55	199.11	198.05
90	187.90	185.88	201.80	199.25

T1 100% whole wheat flour, T2 55%whole wheat flour+ 45% unripe Banana flour, P1 High density Polyethylene, P2 Metalized Polypropylene.

Factors	C.D.	SE(d)
A	0.012	0.006
B	0.012	0.006
A × B	0.017	0.008
C	0.017	0.008
A × C	0.024	0.012
B × C	0.024	0.012
A × B × C	0.034	0.017

Changes in the rehydration ratio of macaroni during storage. Table 4 shows changes in the rehydration ratio of macaroni during storage. In all of the treatments, the maximum time required for satisfactory rehydration of macaroni was 12.30 minutes The rehydration ratio of the control (T_1) ranged between 1.82 to 2.07 and 1.82 to 2.01 for macaroni samples packed in P_1 and P_2. The rehydration ratio of the T_2 was ranged from 1.95 to 2.19 and 2.12 for sample packed in P_1 and P_2 at 90 days of storage. All samples packaged in both packaging materials gradually improved their rehydration ratio, however macaroni packed in P_2 had a low rehydration ratio. According to Iyn, (2013), millet supplemented pasta has a higher rehydration ratio than control pasta, resulting in lower gluten protein in millet supplemented pasta products. The rehydration ratio of soya meal maker enriched macaroni increased from 1.76 to 1.94 after storage (Kavitha, 2006).

Table 4: Changes in the rehydration ratio of macaroni during storage.

Storage period (days)	T_1		T_2	
	P_1	P_2	P_1	P_2
0	1.82	1.82	1.95	1.95
30	1.89	1.84	2.02	1.97
60	1.97	1.93	2.10	2.06
90	2.07	2.01	2.19	2.12

T1 100% whole wheat flour, T2 55% whole wheat flour+ 45% unripe Banana flour, P1 High density Polyethylene, P2 Metalized Polypropylene.

Factors	C.D.	SE(d)
A	0.003	0.002
B	0.003	0.002
A × B	0.004	0.002
C	0.004	0.002
A × C	0.006	0.003
B × C	0.006	0.003
A × B × C	N/A	0.004

Changes in the Resistant Starch (RS) content of macaroni during storage days. Resistant starch content variation and its changes during storage of macaroni was documented in Table 5. The initial resistant starch content of control(T_1) and (T_2) unripe banana flour incorporated macaroni were found to be 2.29 and 22.02 at the initial day of storage. At the end of the storage the resistant starch content of the control(T_1) and unripe banana flour incorporated macaroni(T_2) were found to be increased to 2.43 to 2.41 and 22.38 and 22.36 packed in HDPE and MPP at the end of the 90thday of storage. The results reported in these table shows that resistant starch content of unripe banana flour supplemented macaroni had high resistant starch than the whole wheat flour macaroni. Optimum resistant starch content of the developed macaroni products was ranged from 2.29 to 22.38g/100g. Increasing of resistant starch was due to molecular reassociation or retrogradation of gelatinised and fragmented amylose during storage (Dhital *et al.*, 2010).

Study on Dry fresh and dry noodles development from unripe banana flour at the level of 10, 20, 30 and 40per cent incorporation reported increasing the banana flour proportion increased resistant starch content in noodles. The resulted resistant starch content at this level of addition was 9.54, 13.37, 18.03 and 23.31 per cent but in the case of control sample 5.565 of resistant starch was observed (Tangthanantorn *et al.*, 2021). Salted noodles developed from 20% unripe banana flour showed 10.92% resistant starch but control sample had 3.25% resistant starch (Li *et al.*, 2022).

Table 5: Changes in the Resistant Starch (RS) content of macaroni during storage.

Storage period (days)	T_1		T_2	
	P_1	P_2	P_1	P_2
0	2.29	2.29	22.02	22.02
30	2.33	2.30	22.27	22.25
60	2.38	2.36	22.33	22.31
90	2.43	2.41	22.38	22.36

T1 100% whole wheat flour, T2 55%whole wheat flour+ 45% unripe Banana flour, P1 High density Polyethylene, P2 Metalized Polypropylene.

Factors	C.D.	SE(d)
A	0.007	0.003
B	0.007	0.003
A × B	0.010	0.005
C	0.010	0.005
A × C	0.014	0.007
B × C	0.014	0.007
A × B × C	0.019	0.009

CONCLUSION

The cooking quality assessment of banana flour included macaroni during storage revealed that the optimum cooking time was 8.30 to 6.67 minutes, gruel loss was 3.62 to 5.69 percent, water absorption was 182.40 to 201.80 ml, and the rehydration ratio was 1.82 to 2.19. The optimum resistant starch content was2.29 to 22.38% percent. All of the cooking property assessment factors showed that macaroni held in MPP performed better. The experiment discovered that macaroni made with unripe banana flour performed better than wheat flour macaroni.

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Conflicts of Interests. None.

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