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Improvement of physical properties and phenolic compounds of egg noodles by banana pulp and peel flour fortification

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Abstract

This study was designed to improve egg noodles fortified with banana pulp (BF) and banana pulp with peel (PF) at 2 levels (40 and 60%) compared with wheat flour egg noodle. The results showed that the amount of banana flour did not affect those qualities of egg noodles. After cooking, fresh noodle had lower a*, b* and hardness but higher phenolic content than dried noodles. The BF egg noodles were more accepted by the consumer than PF egg noodles with 6.75-7.32 mg GAE/100 g phenolic content. While fresh control egg noodle was 4.54 mg GAE/g phenolic content. Therefore, fresh BF egg noodles had more potential to be used to improve the quality of egg noodle commercially.

1. Introduction

Currently, overnutrition is increasing especially an excessive intake of fat and starch. This is due to living in a community where there are many convenient stores; as many people are living a hasty life, they tend to depend more on junk food which if consumed continuously it will cause an imbalance in the body. These problems have led to many studies, research, and food innovations to respond to health commands which focus on the reduction of flour or carbohydrate and fat as well as the supplement of protein, fibre, and useful nutrients. Moreover, being healthy is becoming an interesting trend nowadays, and there are continuous campaigns about taking care of our health. Thus, consumers are seeking alternatives for new and nutritious foods that are also convenient to prepare, too.

Egg noodles are the second popular food to rice and bread which are the main energy sources around ASEAN regions including Thailand, Vietnam, Laos, Myanmar, Malaysia, and Singapore. Noodles are full of carbohydrate from wheat flour. In each country, there is an addition of ingredients which are called differently to make it more specific, and there is also an improvement of properties so that the consumers have more options such as mushroom noodles (Parvin *et al*., 2020), fish gelatin noodles (Wangtueai *et al*., 2020), oat noodles (Guo *et al*., 2020), lotus seed flour noodles (Jirukkakul and Sengkhampan, 2018), rice noodles (Kasunmala *et al*., 2020), chickpea noodles (Sofi *et al*., 2020), pomelo noodles (Reshmi *et al*., 2020), buckwheat noodles (Bai and Zhou, 2021), soy noodles (Rani *et al*., 2019), brown rice noodles (Geng *et al*., 2020), and cereal bran noodles (Levent *et al*., 2020). Additionally, there is also a process to make it a ready-meal or to preserve the food such as by drying so that it can be kept longer, or to produce new flavours to add more variety of choices for the consumers (Yu *et al*., 2020).

It is well known that bananas have high nutritional value. Carbohydrates are easy to digest and suitable for making foods and snacks such as chip snacks, ice cream, jam, wine, bread, smoothies, and flour (Aurore *et al*., 2009). Statistically, bananas are the most planted fruit with 16.8% of the global plantation, in 2013, there were 105 million tons of bananas, and 57.3% of the number was produced in Asia (Vu *et al*., 2018). Banana flour is made of dried raw banana pulp (Jirukkakul, 2016), and the main components are carbohydrate and fibre. Furthermore, there are minerals and antioxidants which are useful for our body (Campuzano *et al*., 2018). Banana flour is popularly used to relieve diarrhoea and to prevent digestive diseases as it contains fibre which can prevent constipation. In addition, banana flour can be used in cooking foods such as snacks (Wang *et al*., 2012), pasta (Zandonadi *et al*., 2012), macaroni (Alvarenga *et al*., 2011), bread (Alcântara *et al*., 2020) etc. Because of the previously mentioned usefulness of banana flour, the amount of production and consumption

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is thus high worldwide resulting in 35% of banana peel waste. Banana peel contains antioxidants including high phenolic compounds (Vu *et al*., 2018). Nevertheless, most of the peel has been abolished by sanitary landfills. Only some are used to extract the antioxidants (Vu *et al*., 2019), edible film (Silva *et al*., 2020), and biodiesel (Han *et al*., 2019; Fan *et al*., 2019). Eshak (2016) made bread from 10% of banana peel powder instead of wheat flour. It was found that the banana peel bread contained 12.52% of fibre and 2.18% of protein, while wheat bread contained 10.7% of protein and 1.42% of fibre. There are more minerals as well, and this is accepted by the consumers' senses. Some of the raw banana is used as an ingredient when preparing food for humans using raw bananas with peels as side dishes, for example with Vietnamese meatball wrap (Nam *et al*., 2010). Hence, the food processing of bananas from raw ones with peel is likely to increase the amount of antioxidants and fibre. However, there needs to be a study about the amount of flour used in each food product because there might be a difference in colour and flavour from banana flour which is made of banana pulp.

This research aims to study the amount of banana flour from the banana pulp (BF) and banana pulp with peel (PF) that can be used as a replacement for wheat flour in egg noodles production from its physical properties, phenolic compounds, and sensory property acceptance from the consumers. It had more advantage with high antioxidant and nutrition than native egg noodle which was the alternative way for healthy food.

2. Materials and methods

2.1 Banana flour preparation

Raw banana (*Musa saptentum* Linn.) in green colours from an organic garden in Khon Kaen, Thailand; the ingredients (egg, wheat flour and salt) to make egg noodles can be found from local markets in Nong Khai, Thailand. Raw cultivated banana pulps are washed; they were separated into peel and unpeel. The peeled banana was made to banana flour without peel (BF) and the unpeeled banana was made to banana flour with peel (PF). The pulps are sliced with a sharp knife into about 2 mm thin pieces, soaked in 0.5% acetic acid for 30 mins to prevent enzymatic browning reaction (Jirukkakul, 2016), dried then baked in a drying oven at 55°C for 12 hrs (JSOF-400W, JS Research, Korea). After that, the dried banana pulps were crushed into powder by a grinder (Cyclotec 1093, FROSS, China) with a 0.5 mm strainer and then stored in a zip-lock bag for the test within 3 days.

2.2 Noodle preparation

Egg noodles were prepared by following Jirukkakul and Sengkhampan (2018): wheat flour was replaced by 40% and 60% of banana flour (both BF and PF). After 15 mins mixing and kneading the ingredients together by hand, it was left resting for 30 mins. Later, the dough was rolled into thin sheets and cut by using a dough rolling machine (Atlas 150, Marcoto design, Italy). Also, some wheat flour was sprinkled to prevent stickiness. Finally, fresh egg noodles from banana flour were obtained then were divided into 2 groups. The first was kept (fresh egg noodles) and the other was dried at 55°C for 8 hrs (dried egg noodles). The fresh and dried egg noodles were ready for physical, chemical, and sensory properties tests.

2.3 Banana flour and noodle analysis

2.3.1 Chemical composition of banana flour

A brief analysis of the components of banana pulp (BF) and banana pulp with peel (PF) banana flour showed that it consists of fat, protein, fibre, and carbohydrates. The analysis was conducted by the following analysis standards of AOAC (2000), and the analysis was repeated three times for each sample.

2.3.2 Total phenolic content of banana flour and noodles

Pulp banana flour (BF) and peel banana flour (PF) and cooked noodles were extracted by 5 mL of 95% ethanol in the water bath at 95°C for 10 mins. The 0.5 mL of extraction was mixed with distilled water at the same content, which was treated with 2 mL of Na_2CO_3 (in 0.1 N NaOH). After 10 mins, then 0.2 mL of Folin-Ciocalteu's reagent (dilute with water 1:1) was used to determine phenolic content, which was expressed as garlic acid equivalents (GAE) (Jirukkakul and Sengkhampan, 2018).

2.3.3 Physical properties of noodles

The analysis of the texture of egg noodles: boil the noodles in hot water (100°C) for 3 mins, soaked in cold water (20°C), and drain. After that, the noodles were analyzed for Texture Profile Analysis (TPA) using a Texture Analyzer (TA-XTS, Stable Micro System, Godalming, UK). The 5 cm long egg noodles strands were plated parallel with 0.5 cm space on a flat metal plate. Samples were compressed with 5.0 g force of P/50R probe (50 mm diameter cylinder aluminium) twice to 50% of the original sample height with 5 mm/s test speed. The three replications were tested. The TPA curve expressed 6 parameters which were hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness. Hardness was the maximum force on the compression graph curve. Adhesiveness was the area under X-axis on the compression graph curve. Springiness was the distance ratio of the first and last compression graph curve. Cohesiveness was the area above the X-axis ratio of the first and last compression graph curve. Gumminess was the multiplier of hardness and cohesiveness. The chewiness was the area above X-axis on the compression graph curve (Guo *et al*., 2020). The analysis processes were repeated three times with the samples, and the data collected was calculated for average numbers and reports.

The colours analysis of the egg noodles was conducted in the following steps: boil the noodles for 3 mins, cool down, and drain. The colours of the egg noodles were analyzed by using a colours meter (JS 555, Colours Techno System, Co. Ltd., China). The analysis was repeated three times. The report of the result was an average value in the system of Hunter Lab L*, a* and b* meaning lightness, redness, and yellowness, respectively.

Cooking properties analysis of the noodles was shown by swelling index and cooking loss. This can be done by weighing egg noodle strands then boiling in water for 5 mins, cooling down by soaking in cold water, draining, and weighing again (AACC, 2000). The water used to boil and cool the noodle strands was volatilized at 105°C. The remainder of the volatilization was weighed as well.

Swelling index (%) = (after-boiled weight of noodle strands/before-boiled weight of noodle strands) × 100

Cooking loss (%) = (weight after volatilization/weight before boiling) × 100

2.3.4 Sensory evaluation of noodles

Sensory analysis from thirty testers occurred to every sample of the egg noodles. The analysis focused on appearance, colours, texture, odour, flavour, and overall acceptance. All samples were compared to the control egg noodles (wheat flour), and the results were shown in scores pattern 1-9 (9 = like very extremely, 8 = like very much, 7 = like moderately, 6 = liked slightly, 5 = neither liked or disliked, 4 = disliked slightly, 3 = disliked moderately, 2 = disliked very much, and 1 = disliked extremely) (Parvin *et al*., 2020).

2.3.5 statistical analysis

All experiments were randomized complete block design (RCBD) and Analysis of variance (ANOVA) was used to determine the significant differences between the samples. The differences in the mean values were determined by using Duncan's Multiple Range Test at $p<0.05$.

3. Results and discussion

3.1 Chemical composition and total phenolic compounds of banana flour

Cultivated banana pulp with peel flour (PF) contains higher protein, fat, ash and phenolic content than banana pulp flour (BF) statistically significantly ($p<0.05$), which showed that there were nutritious values in BF and PF (Table 1). The amount of phenolic compounds of previous research showed as much as in pulp flour (Campuzano *et al*., 2018). The ash and lipid contents of banana flour were similar to the banana flour which was studied by Kumar *et al*. (2019) (ash 2.06% db, and lipid 0.42% db). The amount of ash indicates that there is a correlation between minerals and phenolic compounds. From the experiment and the results by Anyasi *et al*. (2018), who has tested a correlation between essential minerals and phenolic compounds by the application of Pearson's correlation coefficient test, it was found that there was a correlation ($p>0.01$).

3.2 Physical properties of noodle

The hardness of noodles correlates with the swelling power of the flour and the compactness of the internal structure of noodles which represents the anti-compression ability of noodles (Bai and Zhou, 2021). Adhesiveness values represent the work done to pull the compressing plunger away from the noodles. Cohesiveness is a measure of the extent to which noodles structure was disrupted during the first compression. It was the highest in control noodles and fresh noodles but lowest in dried noodles. High cohesiveness indicates a greater degree of polymerization of the amylose fraction (Rani *et al*., 2019). Gumminess and chewiness indicate the texture in the mouth. Good textures of egg noodles are a little hard, have high cohesiveness, low adhesiveness, and high chewiness. For fresh BF and PF egg noodles, gumminess and chewiness were higher than control noodles whereas the springiness, adhesiveness and cohesiveness were not different ($p>0.05$) (Table 2).

Table 1. Chemical composition of banana flour (BF) and banana with peel flour (PF)

Sample	Protein (% db)	Fat (% db)	Fibre (% db)	Ash (% db)	Carbohydrate (% db)	phenolic (mg GAE/g)
BF	$2.98±0.32^b$	$0.45±0.19^b$	7.84±0.25	$2.02±0.58^b$	86.71	$15.18±0.04^b$
PF	$4.93±0.10^a$	$1.39±0.04^a$	7.35±1.93	$3.68±0.03^a$	82.65	$17.43±0.9^a$

Values are expressed as mean±SD. Values with different superscripts within the column are significantly different ($p<0.05$).

Table 2. Texture analysis of noodle from banana flour (BF) and banana with peel flour (PF)

Noodle	Hardness (N)	Springiness	Adhesiveness (N/s)	Cohesiveness	Gumminess (g)	Chewiness (g)
Fresh						
Control	12.99±0.93	0.87±0.09	0.02±0.01	0.73±0.02	960.63±68.99^{bc}	837.92±93.69^{c}
40%BF	14.03±3.26	0.82±0.12	0.03±0.03	0.72±0.03	1325.17±155.83^{a}	1074.38±123.92^{a}
60%BF	14.99±3.69	0.89±0.08	0.05±0.04	0.69±0.0.5	1132.28±125.14^{a}	1000.92±65.33^{ab}
40%PF	15.26±3.69	0.85±0.07	0.05±0.04	0.70±0.05	1074.69±95.00^{b}	913.04±100.53^{b}
60%PF	15.89±3.59	0.94±0.07	0.05±0.04	0.68±0.03	896.34±62.49^{c}	841.27±76.02^{c}
Dried						
Control	16.11±2.28	0.85±0.08^{A}	0.09±0.03	0.63±0.04^{A}	1032.34±134.32^{BC}	868.72±77.24^{A}
40%BF	17.37±4.79	0.68±0.12^{B}	0.09±0.03	0.58±0.03^{B}	1419.11±148.91^{A}	961.95±203.07^{A}
60%BF	19.23±5.60	0.83±0.12^{A}	0.10±0.04	0.57±0.06^{BC}	1086.60±126.20^{BC}	891.94±110.64^{A}
40%PF	20.67±5.86	0.76±0.06^{B}	0.14±0.08	0.53±0.03^{C}	956.71±119.16^{C}	720.54±64.28^{B}
60%PF	21.49±5.89	0.73±0.07^{B}	0.16±0.07	0.45±0.04^{D}	751.13±137.92^{D}	547.34±90.54^{C}

Values are expressed as mean±SD. Values with different lowercase superscripts within the column of the fresh noodles are significantly different ($p < 0.05$) while values with different uppercase superscripts within the column of dried noodles are significantly different ($p < 0.05$)

The amount of BF flour did not affect the physical properties of fresh egg noodles ($p > 0.05$), which corresponds with the result of the texture test of egg noodles. There was no difference between the level of pulp flour and the texture was similar to rice vermicelli (Kasunmala *et al*., 2020). A firm texture defines comparatively fair hardness, high cohesiveness, low adhesiveness and high chewiness (Kasunmala *et al*., 2020). The lowest textural qualities were observed in dried noodles in terms of high adhesiveness, low cohesiveness and low chewiness. The hardness, adhesiveness, gumminess, and chewiness were lower when BF and PF added due to stable matrix structures to wrap starch granules well (Guo *et al*., 2020).

The primary qualities of egg noodles that the consumers can sense are the colours and appearance followed by the odour, flavour and texture in the mouth (Parvin *et al*., 2020). Dried egg noodles had higher values of a* and b* than fresh egg noodles because of heat. PF egg noodles had higher values of a* and b* than BF egg noodles. The change in colours was from the food processing and the pigment of the flour used as a raw material (Sofi *et al*., 2020). Additionally, the cause of the colours change could also be the Maillard reaction between reducing sugars and protein which can be evaluated from higher a* and b* values (Reshmi *et al*., 2020). The colours of both fresh and dried egg noodles are not affected by the amount of banana (Table 3).

The cooking loss represents the amount of soluble matter dissolved in the cooking water during the cooking process of noodles (Kasunmala *et al*., 2020). This value was used to characterize the cooking quality of egg noodles. The noodle with 40% flour showed a lower cooking loss value than that of 60% flour. This might be

Table 3. Colours, swelling index and cooking loss of noodle from banana flour (BF) and banana with peel flour (PF)

Noodle	L*	a*	b*	Swelling index (%)	Cooking loss (%)
Fresh					
Control	56.32±1.81^{a}	3.75±0.43^{c}	11.88±1.06^{a}	224.58±32.00	5.44±0.48^{a}
40%BF	36.97±0.41^{c}	4.34±0.35^{b}	7.83±0.60^{c}	227.63±29.57	3.43±0.46^{b}
60%BF	33.92±1.19^{d}	4.47±0.29^{b}	7.60±0.48^{c}	237.54±13.66	3.79±0.29^{b}
40%PF	47.79±1.32^{b}	5.74±0.22^{a}	9.87±0.28^{b}	273.59±39.26	3.39±0.68^{b}
60%PF	39.14±1.41^{c}	5.33±0.47^{a}	9.14±0.96^{b}	276.34±34.29	4.67±0.74^{ab}
Dried					
Control	63.37±0.62^{A}	4.28±0.48^{B}	13.21±0.90^{A}	238.74±7.37	3.00±0.72^{B}
40%BF	39.46±1.05^{C}	4.19±0.22^{B}	9.14±0.37^{C}	258.18±5.26	5.77±0.32^{A}
60%BF	33.23±5.28^{C}	3.92±0.23^{B}	8.97±0.41^{C}	271.32±41.68	6.04±1.04^{A}
40%PF	44.95±0.74^{B}	5.98±0.64^{B}	12.25±1.08^{B}	275.16±3.58	3.41±0.67^{B}
60%PF	43.40±2.20^{B}	6.14±0.18^{B}	11.22±0.29^{B}	297.34±80.49	4.73±1.44^{AB}

Values are expressed as mean±SD. Values with different lowercase superscripts within the column of the fresh noodles are significantly different ($p<0.05$) while values with different uppercase superscripts within the column of dried noodles are significantly different ($p < 0.05$)

because of the hydrophilic nature of non-starch polysaccharides in fibre sources (Rani *et al*., 2019). Moreover, the increase of cooking loss of noodle upon the increase of BF or PF content was due to the weak formation of starch as well as a reduction of the crystalline structure of starch (Sofi *et al*., 2020). During the dough process, the protein polymerized by chemical bonding, and starch was hydrated and swelled (Bai and Zhou, 2021). Since PF had higher protein content than BF, the swelling index of PF egg noodle was higher than BF egg noodle at the same content level. However, fresh noodles showed lower cooking loss (3.39-4.67%) and swelling index (227.63-276.34%) than dried noodles (3.41-6.04% cooking loss and 258.18-297.34% swelling index). This might be explained by the limitation of water absorption (Sofi *et al*., 2020). The cooking loss of noodle was dependent on the added ingredients. For example, germinated chickpea reduced the cooking loss and water absorption capacity of noodle by minimizing the leakage of amylose (Sofi *et al*., 2020). Fresh egg white could promote a strong protein network due to protein aggregation after adding in oat noodles. This prevents the leakage of solid into the cooking water, resulting in a reduction of cooking loss value (Guo *et al*., 2020).

3.3 Sensory evaluation of noodles

The sensory test of egg noodles in terms of appearance, colours, odour, flavour, texture, and overall preference showed that the outer look of fresh and dried egg noodles received different satisfaction from consumers ($p>0.05$). Fresh egg noodles were more preferred, and BF egg noodles are preferred more than PF egg noodles (Figures 1 and 2).

In terms of colours preference, the consumers preferred the colours of BF more than PF egg noodles for both fresh and dried noodles, which corresponded with the colours values evaluated by the colours evaluation machine; PF egg noodles had higher a* and b* values than BF egg noodles, which showed less preference of the consumers when the noodles were red and dark yellow, while there was no difference of BF or PF level in colours in both fresh and dried egg noodles.

There was no effect of 40% and 60% of banana flour on the texture of the egg noodles and also no statistically significant difference among the different types of noodles (control, dried, fresh) ($p>0.05$). When the noodles were dried and hydrated, egg noodles which were made of 40% and 60% of banana flour were not statistically significantly different from control dried egg noodles ($p>0.05$). However, fresh egg noodles were preferred in terms of texture to dried egg noodles, BF egg noodles were preferred to PF egg noodles ($p>0.05$).

In terms of the smell, taste and overall preference, the results were similar, the fresh noodles of control egg noodles and BF egg noodles were most preferred and similar ($p>0.05$). The preference was slightly quite preferred showing that BF egg noodles could add 60% more banana flour, while chickpea flour could replace only 20% of wheat flour in egg noodles production. The more chickpea flour present in the egg noodles, the less was the preference of the consumers (Sofi *et al*., 2020). For fresh PF egg noodles, the preference was neither liked nor disliked to liked slightly, and the dried BF and PF noodles were disliked slightly to neither liked nor disliked.

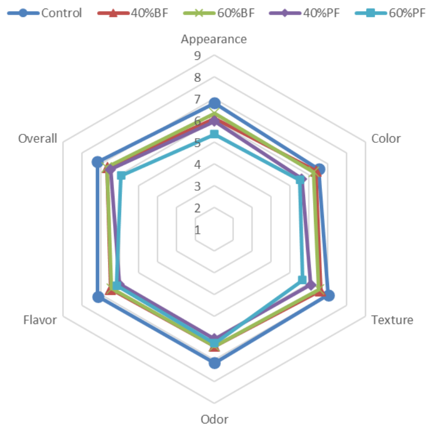

Figure 1. Sensory evaluation of fresh noodle from banana flour (BF) and banana with peel flour (PF)

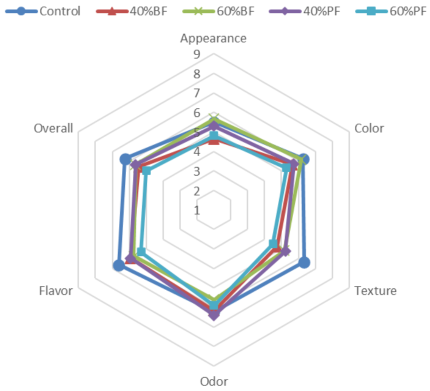

Figure 2. Sensory evaluation of dried noodle from banana flour (BF) and banana with peel flour (PF)

3.4 Chemical composition and total phenolic content of noodles

The BF and PF egg noodles statistically significantly had as many phenolic compounds ($p>0.05$) which was between 6.75-7.32 mg GAE/100 g (Figure 3). When heated, the phenolic compounds were significantly lower ($p>0.05$) but still higher than control dried egg noodles (4.54 mg GAE/g), egg noodles from 6 kinds of wheat flour (4.53-4.89 mg GAE/g) (Yu *et al*., 2020), and egg noodles from 4 cereal brans (rice, rye, wheat and oat) (0.86-1.20 mg GAE/g) (Levent *et al*., 2020). This showed that BF could be used instead of wheat in some part of egg noodles because the antioxidant or specifically phenolic compounds were higher than in egg noodles. When analyzing the chemical components of the fresh BF egg noodles, it was found that ash content was higher (2.00% db) than in control egg noodles (1.70% db) and was close to 30% banana noodles (*Musa acuminate* x *Balbisiana Colla* cv. Awak) (Choo and Aziz, 2010). If banana flour could be a complete substitute for wheat flour, the amount of fat will be zero and the amount of fibre will increase 4 times (Zandonadi *et al.*, 2012).

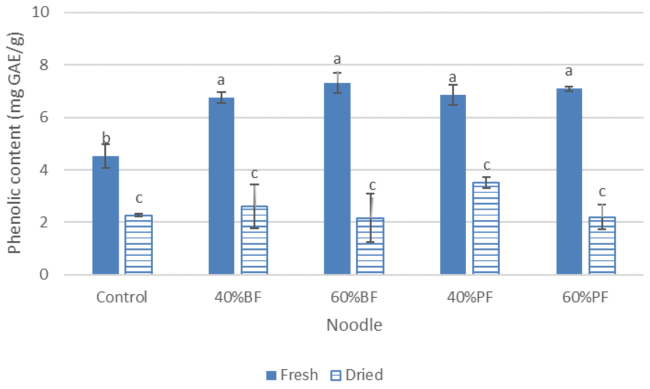

Figure 3. Phenolic content of noodle from banana flour (BF) and banana with peel flour (PF)

4. Conclusion

The physical properties and sensory texture showed that the amount of banana flour did not affect those qualities of the egg noodles. The BF egg noodles were more accepted by the consumers than PF egg noodles, and fresh egg noodles were more accepted than dried egg noodles. Fresh egg noodles had lower a*, b* and hardness but higher in phenolic compounds than dried egg noodles. Therefore, BF egg noodles have more potential to be used to improve the quality of egg noodles commercially.

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