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Effect of Gamma Irradiation on Physicochemical Properties and Microbiological Quality of Yellow Noodle with Addition of Rice Bran

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ABSTRACT

Irradiation is principally used as preservation to improve food shelf-life. The effect of gamma irradiation on physicochemical properties and microbiological quality of yellow noodles with addition of rice bran were observed. Wheat flour was replaced with rice bran at different levels (5%, 10%, 15%, 20%). The rice bran yellow (RBY) noodles were exposed to different irradiation doses (4 kGy, 6 kGy 8 kGy) using Cobalt-60. Gamma irradiation significantly decreased the pH, moisture content, hardness, lightness and redness; whereas significantly increased the breaking length of RBY noodles. Total plate count of RBY noodles stored at 8°C was observed on day 0, 3, 5 and 7. No bacterial growth was observed at dose 6 kGy and 8 kGy on day 5 and 7. Micrograph of RBY noodles under SEM at 500x magnification showed that different gamma irradiation dose and replacement of rice bran resulted in small changes on starch granules. Additionally, increment of rice bran showed significant increase in moisture content, breaking length, redness, cooking yield and cooking loss; but significantly decreased the water activity at high dose, hardness, lightness and yellowness. In conclusion, irradiation positively impacted the microbiological quality and incorporation of rice bran gave positive effect on the cooking yield.

Keywords:
gamma irradiation, rice bran, physicochemical properties

1. Introduction

Noodle is a staple food for many Asian countries. Noodles are made in several of contents, formulation and shape [1]. Variety type of noodles which available in a different color, taste, and ingredients composition is easily found in the market. The ingredients composition that contributes

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to the different types of noodles are type of flour, amount and types of alkaline agent. Basically, types of flour that can be used in the making of noodle are rice flour and wheat flour while types of alkaline agent are sodium carbonate and potassium carbonate. Other than that, different processing techniques might result in different types of noodles for instance, fresh, dried, boiled and steamed noodles. In spite of this types of noodles, the commonly noodles that are produced and consumed in Malaysia is yellow alkaline noodles [2].

The processing step used in making yellow alkaline noodles is very simple which requires no complex method, whereas the basic ingredients are easy obtained, namely wheat flour, salt, alkaline salt and water. However, the noodles are very susceptible to spoilage and easy to deteriorate if not stored under refrigeration temperature. Thus, the shelf life of the fresh noodles is short. This is due to water contents and nutrients substances [3]. Basically, the most common spoilage organisms that are present in the fresh noodles are bacteria and followed by yeast and also mold. In industry, high level of wastage occurs because of the short shelf life of fresh noodles [4]. Due to this problem, most of the manufacturer found a solution on how to prolong the shelf life of the fresh noodles by adding some percentage of preservatives into the formulation of the noodles, preferably chemical preservatives such as potassium sorbate, calcium propionate and boric acid [5]. However, these chemical preservatives only prolong the shelf life of the fresh noodles for just a couple more days.

Besides shelf life problem, the yellow noodles are perceived as less nutritious due to high carbohydrate contributed by the wheat flour and contain low protein and dietary fiber. Therefore, several studies on supplementing functional food ingredient in yellow noodles were carried out to boost protein, dietary fiber content and improve the cooking qualities. For instance, a study by Minarovičová *et al.* [6] showed that incorporation of pumpkin powder with wheat flour in making pasta increased water absorption and optimal cooking time of pasta. Other examples of food ingredients with high dietary fiber and suitable for enrichment of noodles are rice bran, oat and whole grain [7].

Rice bran is a by-product of the rice milling process and it is collected from outer layer of the brown (husked) rice kernel. The total weight of rice bran from rice is 10% [8], making it a by-product that is relatively cheap. According to Zullaikah *et al.* [9], 90% of the rice bran production is used for cattle and poultry utilization and the remaining 10% is used for extraction of rice bran oil. Rice bran is functional foods which have many benefits such as rich source of vitamins, minerals, essential fatty acids, dietary fiber and other sterols. It is rich in antioxidant compounds like polyphenols, vitamin E, toco-trienols and carotenoids that help prevent the oxidative damage to DNA and other body tissues [10]. The used of rice bran in food industries is increasing due to its effectiveness in increasing the nutritional quality of the processed foods. Rice bran has high in dietary fiber and it can contribute to the development of value added foods [11]. In addition, Pakhare *et al.* [7] reported that enrichment of noodles with rice bran could help in water absorption capacity, water holding capacity, texture and stabilizing properties of noodles. On the other hand, rice bran also helps in reduction of cholesterol, coronary heart disease and weight loss.

Consequences to the behavior of noodles that are easy to spoiled, gamma irradiation as a method of food preservation, has an excellent potential to improve the safety and extend the shelf life [12]. Gamma irradiation could improve the microbiological quality of the fresh noodles. Cobalt-60 is the most widely used of gamma rays due to the cost and high penetration [13]. Basically, gamma irradiation is a non-thermal processing which can enhance the microbial safety and quality. The use of gamma irradiation on variation of food had been approved by US and other countries due to its safety and powerful action. According to studied by Li *et al*. [5], irradiated noodles at irradiation dose of 4 kGy or higher in total plate count had low threshold limit (10^6 CFU/g). In addition, the best pH and sensory stability were obtained at irradiation dose of 4 kGy. Other studied also showed the same pattern where irradiation dose around 1 to 10 kGy might help in reducing spoilage organism [14].

Therefore, this study is undertaken to study the impact of rice bran enrichment in yellow noodles and exposure of gamma irradiation to yellow noodles on physicochemical properties and microbiological quality of yellow noodles. Besides, the study aimed at finding out the optimum dose of gamma irradiation and the optimum rice bran to be incorporated in yellow noodles that do not adversely affect the quality of yellow noodles.

2. Methodology

2.1 Preparations of rice bran yellow noodles

Preparation of noodles according to Table 1 was carried out as described by Zawawi *et al*. [15] with some modification on the formulation and processing steps. First, the wheat flour was sieved before used. Second, sodium chloride (NaCl) and sodium carbonate (Na_2CO_3) were dissolved in water to form the alkaline solution. The wheat flour was replaced with the rice bran powder at different percentage of 5%, 10%, 15% and 20% (w/w). The wheat flour was mixed with the rice bran at speed 1 for 20 s by using a mixer. While mixing, the alkaline solution was added and the mixture was continually mixed for 1 min at speed 1 followed, by 4 min at speed 2 in order to form a uniform dough. Next, the dough was divided into 4 sections and each section was allowed to pass through two rotating rollers to form a sheet by using noodle machine. The sheets were folded and pass through the rollers 6 times before cutting, by using cutting roll. Then, the noodles were cooked in boiling water (100°C ±0.5°C) for 50 s and the noodles were cooled immediately under tap water for 1 min, drained to remove surplus water and then mixed with cooking oil. Finally, the noodles were packed in polypropylene (PP) and kept at 8°C for further analysis.

Table 1
Formulation of rice bran yellow noodles

Ingredients	Formulation (%)			
	5% RB	10%RB	15%RB	20%RB
Wheat flour	65.97	62.5	59.03	55.56
Rice bran powder	3.47	6.94	10.42	13.89
Sodium carbonate (Na_2CO_3)	0.69	0.69	0.69	0.69
Sodium chloride (NaCl)	0.69	0.69	0.69	0.69
Water	27.78	27.78	27.78	27.78
Cooking oil	1.39	1.39	1.39	1.39

2.2 Gamma irradiation treatment for the rice bran noodles

The gamma irradiation treatment was carried out at the Malaysian Nuclear Agency (Dengkil), Selangor. The exposure of rice bran yellow noodles to gamma rays, by using Cobalt-60 gamma irradiator at 4 different doses 0 (control), 4, 6, and 8 kGy were done. Individual noodles (250 g) were packed and sealed in clean polypropylene (PP) bags and placed inside the cardboard boxes (dimension: 17.6 cm x 27.6 cm x 8.5 cm), which the box function to maximize the dose received. At ambient temperature, the individual cardboard box with packed noodles inside was exposed to gamma irradiation at intended doses and duration of 4 kGy (1.6 h), 6 kGy (2.3 h), and 8 kGy (3.1 h) at a dose rate of 42.8 Gy/min.

2.3 Cooking properties

The method used in the determination of cooking yield was based on the method of Hou [16]. The rice bran yellow noodles (10 g) were cooked in 150 ml boiling water (100°C ±0.5°C) for 120 s by using a hotplate. Then, the cooked rice bran yellow noodles were placed in a plastic strainer in order to remove excess water on the surface of the cooked rice bran yellow noodles. After cooled for 15 minutes, the weight of the rice bran noodles was recorded. The percentages of cooking yields were determined based on the equation (1) below.

$$\text{Cooking yield (\%)} = \frac{Weight\ of\ noodles\ after\ cooking}{\begin{matrix} Weight\ of\ noodles \\ before\ cooking \end{matrix}} \times 100 \qquad (1)$$

In addition, the cooking water that was obtained from the process of cooking yield was transferred into a crucible for determination of cooking loss of the rice bran yellow noodles. Then, the crucibles were placed in the oven at 105°C for 24 h. After 24 h, the crucible was weighed. The percentage of cooking loss were determined based on the equation (2) below.

$$\text{Cooking loss (\%)} = \frac{(Weight\ of\ \ crucibles + weight\ of\ cooking\ water\ ) - weight\ of\ crucible}{\begin{matrix} Weight\ of\ noodles \\ before\ cooking \end{matrix}} \times 100 \qquad (2)$$

2.4 Determination of moisture content

The moisture content of the rice bran yellow noodles was determined by using oven drying method according to AOAC [17]. The rice bran yellow noodles were dried in the oven at 105°C for 24 h. Then, it was cooled in the desiccators. The weight loss during the oven drying method was calculated for the moisture content. The moisture content of rice bran yellow noodles was determined as equation (3) below:

$$\text{Moisture content (\%)} = \frac{Weight\ of\ noodles\ \ before\ drying - weight\ of\ dried\ noodles}{weight\ of\ noodles\ before\ dried} \times 100 \qquad (3)$$

2.5 Determination of water activity

Water activity of the rice bran yellow noodles was determined by using Aqualab Model Series 3 TE (Pullman, Washington, USA) at 25°C.

2.6 Determination of pH

The pH determination of rice bran yellow noodles was measured by referring to the method as described by Ghaffar *et al.* [4]. Approximately 10 g of rice bran yellow noodles was homogenized with 100 ml of distilled water for 5 min. Then, the homogenized sample was filtered by using muslin cloth. The pH of the filtrate was measured using pH electrode (Mettler-Toledo, Inlab Semi Micro Electrode) attached with a pH meter (Mettler-Toledo, S40 SevenMulti). Calibration on the pH meter was done with buffer solution of pH 4.00 and 7.00 prior to measurements.

2.7 Determination of color

Color determination of rice bran noodles was measured according to Hou [16], which used calorimeter (Chroma Meter CR-410). The rice bran yellow noodles were packed tightly in a sealed translucent plastic bag and the readings were taken on each side. Then, the average of the reading was taken and the results were expressed as L*, a* and b* value. Basically, the reading of L* value represented a percentage of light that ranges from 0% (black color) to 100% (white color). In addition, the reading of a* value represented the direction of green color to red color while the value of b* was representing the direction of blue to yellow [18].

2.8 Determination of texture profile analysis (TPA)

For the texture profile analysis, the hardness of the rice bran yellow noodles was determined. The apparatus used for hardness determination was CT3 Texture Analyzer (TexturePro CT V1.4, USA) with 4500 g of load cell and 2.0 mm of speed. The probe used to determine the hardness of the noodles was knife (acrylic clear 8 g, 60 mm wide). The steps involved were by placing 5 strands of noodles on the fixture base table, then the knife cut the strands of the noodles with a distance 20 mm from the probe to the fixture base table. The replicates of 4 for each sample were recorded.

Next, the breaking length of the rice bran noodles was evaluated by using the same texture analyzer but with a different type of probe, namely dual grip assembly. Basically, 1 strand of the noodles were griped at both end with 12 mm of target value and 100 mm of adjust beam. The replicates of 3 for each sample were recorded.

2.9 Determination of Total Plate Count (TPC)

Total plate count (TPC) methods were conducted according to Li *et al.* [5] with some modifications. The irradiated of rice bran yellow noodles were stored at chill temperature (8°C). TPC were determined at day 0, 3, 5 and 7. The rice bran yellow noodles (25 g) was weighed and placed into 225 ml of 0.1% peptone water. Then, the mixture was shaken in a stomacher bag using a stomacher machine (Lab-blender 400, Seward Laboratory, US) for 120 s. After that, serial dilutions were prepared by using 0.1% peptone water. 0.1 ml of the appropriate dilutions was spread plated onto sterile plates which contained plate count agar (PCA), and then incubated at 37°C for 48 h ± 2 h.

2.10 Determination of Scanning Electron Microscopy (SEM)

The SEM was carried out on the rice bran yellow noodle as described by Sung and Stone [19] with some modifications. The SEM was done by using Variable Pressure Scanning Electron Microscope (LEO 1455 SEM, Cambridge, England). Firstly, the rice bran yellow noodles were cut into a small cube with the parameter of 1 cm x 1cm. Then, the cube noodles were placed on the stub using carbon conductive adhesive 502. Next, the samples were observed under magnification of 500 x with an accelerating potential of 20 kV.

2.11 Statistical analysis

Data were statistically analyzed using Minitab 18. One-way analysis of variance was performed and significant differences between the mean values were determined using Turkey’s tests at a significance level of $p<0.05$. The results obtained from the present study are represented as the mean values of three individual replicates ± the standard deviation. Different letters in the figures indicate significant differences in a multiple range analysis for 95% confidence level.

3. Results and Discussion

3.1 Effect of physicochemical properties of RBY noodles

The moisture content of 5%, 10%, 15% and 20% of RBY noodles with different irradiation doses are shown in Table 2. Based on the results obtained, the moisture content of control RBY noodles is higher, as compared to irradiated RBY noodles with significant finding in 10% and 20% rice bran. A similar trend was shown by Gani *et al*. [20] where the moisture content of kidney bean starch was reduced after the irradiation treatment and this was due to the gamma rays that dissolve radiation energy while penetrating the starch. Gamma irradiation damage the wheat starch granules, in a way the compact crystallites of large starch granules were destroyed and some of its bound water molecules turned into free water [21, 22]. The increasing breakage of large starch granules increased the surface area of starch granules and more free water molecules could be adsorbed due to the increased surface area of starch granules. Therefore, most free water molecules are transferred from the inner area to the surface area and vaporized to the environment. These results happen to decrease the moisture content of wheat grain through the effects of both desorption and adsorption. Moreover, RBY noodles were not significantly different in the moisture contents among irradiated RBY noodles with an increase of irradiation dose. This finding validates the study by Gani *et al.* [23] who observed, no significant difference in the moisture content of irradiated starches with the increase of irradiation dose. Thus, it could be explained that wheat of RBY noodles not reaching the equilibrium in constant temperature and relative humidity, by the higher dose of gamma irradiation to decreases in moisture content during both desorption and adsorption [22].

Table 2
Moisture content of rice bran yellow noodles

Dose of irradiation	Moisture content (%)			
	5% RB	10% RB	15% RB	20% RB
0 kGy	$63.19±0.40^{Ab}$	$64.59±0.41^{Ab}$	$64.38±0.20^{Ab}$	$68.247±1.39^{Aa}$
4 kGy	$61.78±0.18^{Ab}$	$62.11±1.56^{Bb}$	$63.45±0.26^{ABab}$	$65.58±0.57^{Ba}$
6 kGy	$62.49±0.87^{Ab}$	$62.66±0.21^{Bb}$	$62.88±0.88^{Bb}$	$65.62±0.29^{Ba}$
8 kGy	$62.21±0.83^{Ab}$	$62.12±0.16^{Bb}$	$63.32±0.^{40ABb}$	$65.78±0.19^{Ba}$

Values denoted with the same capital letter are not significantly different $p<0.05$ among the power of irradiation with the same formulation. Values with the same small letter are not significantly different $p<0.05$ among the RBY noodles formulation with the same power of irradiation. Different letters in the figures indicate significant differences in a multiple range analysis for 95% confidence level.

Besides, there was a significant difference shown in moisture content between the noodle's samples within the same irradiation dose. Based on Table 2, the moisture content of RBY noodles increases gradually with the increased percentage of rice bran at dose 4 kGy, 6 kGy and 8 kGy. The highest percentages of moisture content were observed at 20% of rice bran with different irradiation doses. This may be due to the properties of rice bran which are good in water holding capacity and water absorption capacity [7]. Therefore, a higher amount of rice bran used in the production of noodles caused higher moisture content of noodles. The same trend was reported by Dar *et al.* [24], where they reported that the moisture content of *Chappatis* increased with an increased amount of fibre content. However, Zawawi *et al.* [15] claimed that the higher moisture content in the making of boiled wheat yellow noodles is undesirable. This is because, the gluten level will be higher when the moisture content is higher, indirectly, leads to difficulty in sheeting during the production of noodles.

Water activity is defined as unbound water that presents in food. High water activity contributes to the spoilage of noodles [2]. Usually, the water activity of yellow noodles is around 0.979 [5], thus, it is considered as perishable food. Since irradiation treatment is cold pasteurization, no water activity changes were observed. By referring to Table 3, there was no significant difference in water activity with increasing irradiation dose except on 8kGy with 20% rice bran at 0.897, the lowest reading. This lowest value of water activity (0.897) is within the effective range observed by Lombard *et al.* [26] in the exclusion of gamma irradiation treatment. The level of glycerol as a preservative used in South African Steamed Bread at concentrations 150 and 180 g/kg gave water activity reading 0.908 and 0.880 respectively. Furthermore, Li *et al.* [5] claimed the lowest water activity lowering agent in non-irradiated fresh noodles was 0.900, found in the combination of 3% glycerol, 2% propylene glycol, 0.4% compound phosphate and 3% salt.

Table 3
Water activity of rice bran yellow noodles

Dose of irradiation	Water activity			
	5% RB	10% RB	15% RB	20% RB
0 kGy	0.982±0.0047^{Aa}	0.985±0.0059^{Aa}	0.988±0.00058^{Aa}	0.986±0.005^{Aa}
4 kGy	0.978±0.012^{Aa}	0.987±0.001^{Aa}	0.988±0.001^{Aa}	0.988±0.001^{Aa}
6 kGy	0.988±0.0.00058^{Aa}	0.987±0.00058^{Aa}	0.988±0.001^{Aa}	0.986±0.0021^{Aa}
8 kGy	0.985±0.0021^{Aa}	0.986±0.00058^{Aa}	0.986±0.0053^{Aa}	0.897±0.015^{Bb}

Values denoted with the same capital letter are not significantly different p<0.05 among the power of irradiation with the same formulation. Values with the same small letter are not significantly different p<0.05 among the RBY noodles formulation with the same power of irradiation. Different letters in the figures indicate significant differences in a multiple range analysis for 95% confidence level.

The addition of rice bran at different levels showed no significant difference in water activity. However, at dose 4 kGy and 8 kGy, the water activity trend of the RBY noodles slightly increased with an elevated amount of the rice bran. This trend was agreed by the study of Dar *et al.* [24], who found the water activity of the *Chappatis* was increased with the increased amount of bran supplementation. Dar *et al.* [24] stated water activity was positively correlated to moisture content. Manthey *et al.* [27] claimed that the water activity was correlated with the moisture content level and followed the same trend during storage. Therefore, the following trend agreed to the higher water activity of RBY noodles due to higher moisture content contribution. Nevertheless, a significant difference in decreased water activity with increased 20% rice bran resulted in a drastic drop in the water holding capacity of irradiated RBY noodles at 8 kGy. Azzeh and Amr [28] pointed out wet gluten of irradiated semolina was decreased 23.73% and 20.40% after exposed to 5 and 20 kGy doses respectively which highlighted partial damage to the gluten network structure with a concomitant reduction in water-holding capacity. This claimed supported by Koksel et al. [29] research found slight damage to the gluten structure of durum wheat with increasing radiation dose.

Table 4
pH of rice bran yellow noodles

Dose of irradiation	pH			
	5% RB	10% RB	15% RB	20% RB
0 kGy	8.65±0.12^{Aa}	8.81±0.032^{Aa}	8.79±0.066^{Aa}	8.84±0.055^{Aa}
4 kGy	8.58±0.27^{ABa}	8.72±0.11^{ABa}	8.76±0.12^{Aa}	8.73±0.075^{Aa}
6 kGy	8.54±0.05^{ABa}	8.70±0.045^{ABa}	8.72±.029^{Aa}	8.70±0.036^{Aa}
8 kGy	8.14±0.17^{Bb}	8.39±0.27^{Bab}	8.65±0.17^{Aa}	8.52±0.038^{Bab}

Values denoted with the same capital letter are not significantly different $p<0.05$ among the power of irradiation with the same formulation. Values with the same small letter are not significantly different $p<0.05$ among the RBY noodles formulation with the same power of irradiation. Different letters in the figures indicate significant differences in a multiple range analysis for 95% confidence level.

The range of the pH value in yellow noodles was around 9 to 10 and basically, pH value was influenced by the types and amount of alkaline salt use in the production of yellow noodles [25]. The changes in pH value in RBY noodles are presented in Table 4. There was a significant difference in pH value was observed in RBY noodles with an increment of irradiation dose. The pH values of 5%, 10%, 15% and 20% RBY noodles were decreased with increment of irradiation dose. The same trend was shown in the study by Li *et al.* [5], where the reduction of pH value occurred due to the irradiation treatment. The same pattern was reported by Gani *et al.* [23] where the pH value of the kidney bean starch was decreased as the irradiation dose increased.

Abd Allah *et al.* [30] observed that the reduction of pH value with an increase of irradiation dose is due to the production of formic acid (HCOOH) in wheat starch. This was caused by an internal change inside the starch molecules and oxidation is achieved rapidly in a shorter time for irradiated RBY noodles. Under the influence of gamma rays, the rings in high molecular weight compounds as carbohydrate polymers (starch) split off into C 5 residues, and HCOOH was formed. Furthermore, the moles of formic acid produced was increased 0.08 m, 0.12 m, 0,14 m and 0.16 m along with the reduced of glucose units per end group at 20, 12.5, 10.8 and 6.4 were found at 0 (unirradiated), 0.5 x 10^6 rad, 0.75 x 10^6 rad and 1.0 x 10^6 rad respectively were observed to justify the gradual decrease in pH with increased irradiation dose with significant findings at 8 kGy doses of RBY noodles.

3.2 Textural properties

Table 5 indicates the hardness of RBY noodles with different levels of rice bran which are treated to different irradiation doses. The hardness of the RBY noodles was significantly decreased as the irradiation dose increased. The hardness between control samples and irradiated samples rapidly decreased for 5% and 10% rice bran. Irradiation treatment on the RBY noodles resulted in a reduction of hardness. Based on finding by Koksel *et al.* [29] and Wan *et al.* [31], they found the firmness of irradiated samples was decreased with an increase of irradiation dose. However, a slight decrease of hardness is observed in small degrees as noodles treated with irradiation as observed by Lee *et al*. [35] when noodles were treated at 10 kGy irradiated doses. Researchers claimed, these trends were due to the gamma irradiation damages the gluten content in noodles and weaken the gluten networks [28, 29]. Furthermore, the cause of RBY noodles softening was due to the breakdown of starch in the gluten network after exposed to an increased dose of irradiation at each level. Thus, makes the network less compact [36].

Table 5
Hardness of rice bran yellow noodles

Dose of irradiation	Hardness (N)			
	5 % RB	10 % RB	15 % RB	20 % RB
0 kGy	0.99±0.041^{Ab}	1.30±0.044^{Aa}	0.98±0.025^{Ab}	0.74±0.032^{Ac}
4 kGy	0.73±0.098^{Bb}	0.99±0.042^{Ba}	0.89±0.056^{Aa}	0.64±0.020^{Bb}
6 kGy	0.71±0.026^{Bb}	0.88±0.045^{Ca}	0.76±0.033^{Bb}	0.62±0.04^{Bc}
8 kGy	0.69±0.08^{Bb}	0.83±0.025^{Ca}	0.72±0.099^{Bab}	0.61±0.044^{Bb}

Values denoted with the same capital letter are not significantly different p<0.05 among the power of irradiation with the same formulation. Values with the same small letter are not significantly different p<0.05 among the RBY noodles formulation with the same power of irradiation. Different letters in the figures indicate significant differences in a multiple range analysis for 95% confidence level.

Significant differences were observed in hardness with the addition of different rice bran levels. The hardness of RBY noodles decreased after the addition of 10% rice bran. Further increased the rice bran in noodles resulted in a decrease in hardness. Zawawi *et al.* [15] proved that the addition of defatted kenaf seed flour caused decreased hardness of noodles due to the gliadins and glutenins composition of the protein gluten, who responsible to dough extensibility and strength. A similar trend was shown by Wang *et al.* [32], where the hardness decreased as rice bran percentage increased from 0% to 25%. Bustos *et al.* [33] explained the decreasing trend in hardness was due to the disturbance of bran during the formation of the protein starch matrix. However, Cleavy and Brennan [34] claimed incorporation with high fiber in pasta caused starch leaching and disrupting protein starch network.

Table 6
Breaking length of rice bran yellow noodles

Dose of irradiation	Breaking length (mm)			
	5 % RB	10 % RB	15 % RB	20 % RB
0 kGy	8.80±0.60^{Ba}	10.66±0.83^{Aa}	2.49±0.39^{Bb}	11.63±1.92^{Aa}
4 kGy	6.15±0.73^{Cc}	11.85±0.67^{Aa}	8.95±0.40^{Ab}	10.70±1.61^{Aab}
6 kGy	12.20±0.44^{Aa}	11.85±0.67^{Aa}	9.86±0.78^{Aa}	10.16±1.93^{Aa}
8 kGy	13.03±0.58^{Aa}	11.10±0.55^{Aab}	10.10±0.48^{Ab}	8.91±1.77^{Ab}

Values denoted with the same capital letter are not significantly different p<0.05 among the power of irradiation with the same formulation. Values with the same small letter are not significantly different p<0.05 among the RBY noodles formulation with the same power of irradiation. Different letters in the figures indicate significant differences in a multiple range analysis for 95% confidence level.

Breaking length in yellow noodles is very important which is used as an indicator for good quality of yellow noodles in terms of texture. Higher breaking length is desirable because it will result in elastic noodles. Basically, the breaking length of noodles is influenced by the gluten network strength. RBY noodles shown a significant difference in breaking length, Table 6 with increased irradiation dose. The decreased in breaking length with increasing irradiation dose agreed with the previous studies by Azzeh and Amr [28], in which higher irradiation dose weakens the strength of the gluten network. Thus, a weak gluten network results in decreased breaking length. It was also supported, the gelatinization viscosity of irradiated flour decreased as irradiation dose increased as agreed to increased starch damage thus, increased reducing sugars level [28]. Damaged starch in RBY noodles was susceptible to amylosis, caused a decreased in gelatinization viscosity. Moreover, viscosity characteristics of RBY noodles might change with increased irradiation dose due to the rapid breakdown of gel which occurred more readily. Resultant in reduced intrinsic viscosity of RBY noodles, due to shape modification of RBY noodles granules, together with their configuration along with the decrement in starch chain length after exposure to gamma radiation.

In addition, a significant difference was observed in the breaking length of RBY noodles between different levels of rice bran. Basically, a high level of rice bran caused a decrease in breaking length because rice bran has the ability to absorb and hold water. Therefore, higher rice bran caused the noodles to have a lower breaking length.

3.3 Color of RBY noodles

The effect of adding a different level of both rice bran and irradiation dose on the color of RBY noodles are shown in Table 7-9. The results color of the RBY noodles were expressed in L*, a* and b* value. The L* value, it is representing the lightness which ranges from 0 % to 100 %. Based on the results obtained, the L* value of RBY noodles shows a significant difference between control noodles and irradiated noodles. However, there were no significant differences were observed among the irradiated noodles. This can be supported by Chen *et al.* [37] and Lacroix *et al.* [12] where they reported that the color changes between control and irradiated samples occurred due to oxidative rancidity. They explained that the irradiation was accelerating the process of oxidative rancidity. Furthermore, the decrease in color with an increase in irradiation dose of lasagna [28] and cook rice noodles [38] studied, were found to be supporting the data of research findings. This could be explained by the non-enzymatic browning reaction due to the formation melanoidin pigment or the effect of increasing activity of polyphenol oxidase and other enzymes with increasing irradiation dose. Moreover, Noomhorm *et al.* [38] explained the resulting trend was confirmed due to the Maillard reaction.

Table 7
L* value of rice bran yellow noodles

Dose of irradiation	COLOR (L*)			
	5 % RB	10 % RB	15 % RB	20 % RB
0 kGy	70.67 ± 0.16^{Aa}	65.81 ± 0.62^{Ab}	64.53 ± 1.18^{Ab}	64.02 ± 0.5^{Ab}
4 kGy	68.89 ± 1.11^{Aa}	64.32 ± 0.79^{ABb}	61.81 ± 0.36^{Bc}	60.51 ± 0.38^{Bc}
6 kGy	68.55 ± 0.54^{Bba}	64.65 ± 0.67^{ABb}	61.89 ± 0.10^{Bc}	60.31 ± 0.06^{Bd}
8 kGy	68.76 ± 0.69^{Ba}	64.23 ± 0.031^{Bb}	61.35 ± 0.25^{Bc}	61.39 ± 0.56^{Bc}

Values denoted with the same capital letter are not significantly different p<0.05 among the power of irradiation with the same formulation. Values with the same small letter are not significantly different p<0.05 among the RBY noodles formulation with the same power of irradiation. Different letters in the figures indicate significant differences in a multiple range analysis for 95% confidence level.

Also, a significant difference was found in L* value with the addition of rice bran at 5%, 10%, 15% and 20% rice bran. The L* value of RBY noodles were decreased as the level of rice bran increased. The decreased L* value may cause by the pigment of rice bran which caused the RBY noodles to become darker. The same trend was reported by Wang *et al.* [32], they reported that the lightness of rice pasta was decreased as the rice bran fiber used increased. Thus, the higher the rice bran added, the darker the color of the RBY noodles.

Table 8
a* value of rice bran yellow noodles

Dose of irradiation	COLOR (a*)			
	5 % RB	10 % RB	15 % RB	20 % RB
0 kGy	2.98±0.53^{Ab}	4.05±0.15^{Ba}	3.70±0.16^{Bab}	3.21±0.15^{Bb}
4 kGy	3.55±0.17^{Ab}	4.75±0.12^{Aa}	4.96±0.023^{Aa}	4.41±0.12^{Aa}
6 kGy	3.63±0.070^{Ab}	4.76±0.12^{Aa}	5.01±0.067^{Aa}	4.98±0.12^{Aa}
8 kGy	3.55±0.072^{Ab}	4.59±0.30^{Aa}	4.85±0.13^{Aa}	4.92±0.087^{Aa}

Values denoted with the same capital letter are not significantly different $p<0.05$ among the power of irradiation with the same formulation. Values with the same small letter are not significantly different $p<0.05$ among the RBY noodles formulation with the same power of irradiation. Different letters in the figures indicate significant differences in a multiple range analysis for 95% confidence level.

Next, a* value is representing the redness of the samples [2] as shown in Table 8. There was a significant difference between control noodles and irradiated noodles, where a* value increased gradually from 0 kGy to 4 kGy of irradiation dose. A negative correlation was found between a* and L* value of the RBY noodles. This means that, when the L* value decreased, the a* value will be increased. However, increasing the percentage of rice bran was resulting in increasing of a* value from 5% to 10% at all irradiation doses and 5% to 20% at 8 kGy doses. This can be supported by studies of Dar *et al.* [24] and Wang *et al.* [32] which a* value was increased with an increase of bran addition.

Table 9
b* value of rice bran yellow noodles

Dose of irradiation	COLOR (b*)			
	5 % RB	10 % RB	15 % RB	20 % RB
0 kGy	22.58±0.074^{Aa}	21.57±0.39^{Ab}	18.13±0.45^{Bc}	17.57±0.15^{Ac}
4 kGy	21.65±0.37^{ABa}	20.71±0.52^{Aab}	19.92±0.25^{Ab}	18.18±0.45^{Ac}
6 kGy	21.49±0.52^{Ba}	20.72±0.31^{Aab}	20.10±0.27^{Ab}	18.44±0.36^{Ac}
8 kGy	21.27±0.51^{Ba}	20.86±0.27^{Aab}	19.78±0.45^{Ab}	18.10±0.40^{Ac}

Values denoted with the same capital letter are not significantly different $p<0.05$ among the power of irradiation with the same formulation. Values with the same small letter are not significantly different $p<0.05$ among the RBY noodles formulation with the same power of irradiation. Different letters in the figures indicate significant differences in a multiple range analysis for 95% confidence level.

Generally, b* value is indicating for the yellowness color. If the b* value increased, the color of the noodles is close to yellow while the decreasing value of b* shows the color of noodles is getting darker which close to blue. No significant differences were observed in b* value with an increase of irradiation dose, except observed a significant difference at 5% RB. This may be attributed to the Maillard reaction between sugars and protein residue or transformation of residual phenolics as observed in potato starches [39], non-enzymatic browning on broad bean starch [41] and dry smoke shrimps [42]. However, a significant difference was found in b* value of RBY noodles with different levels of rice bran and the same dose. b* values were decreasing with increasing of rice bran. This can be strengthened by Dar *et al.* [24] which reported that the b* value of *Chappatis* was decreased as the percentage of bran increased. Zawawi *et al.* [15] also reported that when the level of defatted kenef seed flour increased, the b* value was decreased.

On the other hand, Zawawi *et al.* [15] claimed that there is a relation in terms of color with the fiber content in noodles incorporation of defatted kenaf seeds flour. They explained that the dark color in noodles is due to the action of the polyphenol oxidase (PPO) enzymes in the bran together with the fiber found in the bran layer. Many studies have proved that the incorporating of fiber content in food may result in decreasing the value of L* (lightness) and b* (yellowness) and also increasing the value of a* (redness) [43, 44].

3.4 Cooking quality of RBY noodles

Cooking loss is used to measure the solid substances that are lost during the cooking process [40]. Cooking loss is commonly used as an indicator of yellow noodle's quality. Basically, high cooking loss in noodles is undesirable. According to Susanna and Prabhasankar [45], good quality yellow noodles have a low percentage of cooking loss. The effect of rice bran addition in yellow noodles with a different level on cooking loss and cooking yield are shown in Table 10. The cooking loss of RBY noodles was slightly increasing at 5%, 10% and 15% rice bran which 4.27%, 4.30% and 4.33% respectively. But, cooking loss increased rapidly to 4.87% when 20% of rice brans were added. The same trend was shown by Wang *et al.* [32] where the cooking loss of rice pasta increased as the addition of rice bran fiber increased. According to Bustos *et al.* [33], when the concentration of the bran is low, fiber will disperse and be incorporated into the starch matrix. However, if the concentration of the bran used is high, the bran particles might disrupt the starch matrix and the starch granules become swelling and ruptured. Thus, a high level of rice bran causes high cooking loss in RBY noodles.

Table 10
Cooking quality of rice bran yellow noodles

Formulation	Cooking Quality	
	Cooking yield (%)	Cooking loss (%)
5 % RB	171.37 ± 0.72^{A}	4.27 ± 0.95^{A}
10 % RB	174.03 ± 0.65^{B}	4.30 ± 0.41^{A}
15 % RB	185.64 ± 0.75^{C}	4.33 ± 0.29^{A}
20 % RB	191.53 ± 0.68^{D}	4.87 ± 1.01^{A}

Values denoted with the same capital letter are not significantly different p<0.05 among the power of irradiation with the same formulation. Different letters in the figures indicate significant differences in a multiple range analysis for 95% confidence level.

Cooking yield is the ratio of the weight of the noodles after and before cooking in percentage. The measurement of cooking yield is to analyze the ability of noodles to absorb water. Based on Table 10, significant differences in cooking yield were observed where the percentages of cooking yield were increased as the addition of rice bran increased. The percentage of cooking yield at 5%, 10%, 15% and 20% rice bran were observed which are 171.37%, 174.03%, 185.64% and 191.53% respectively. The increasing trend of cooking yield in RBY noodles as the level of the rice bran increased was due to the properties of rice bran which possessed good water holding capacity and water absorption capacity. This trend can be supported by Zawawi *et al.* [15] where the highest percentage of cooking yield was presented by the noodles that contain a high amount of defatted kenaf seed flour.

3.5 Microbiological quality

The total plate count of RBY noodles after stored at 8°C for 7 days are presented in Table 11. According to the results obtained, the bacterial growth was started on day 3 for samples at 0 kGy, whereas the irradiated noodles at 4 kGy showed bacterial growth below the limitation amount on day 5 and the colony count is decreased as increased in percentage of rice bran up to 15%. Normally, the level of the colony that indicates as the limitation for human consumption is around 10^6 CFU/g. However, at doses 6 kGy and 8 kGy, the inhibition of bacteria in RBY noodles were effective with no bacteria growth up to day 7. Li *et al.* [5] reported an irradiation dose of fresh noodles at 6 kGy and 8 kGy were resulting in the same effect.

Based on the results in Table 11, the irradiated RBY noodles were safe to consume even after day 7 at all levels of rice bran percentage. This is because the bacteria count in the irradiated RBY noodles were below 10^6 CFU/g. Above 10^6 CFU/g, the samples are not safe to consume and need to be discarded [4, 12]. The effects of gamma irradiation on RBY noodles were effective in killing the microbes and were able to extend the RBY noodles over 7 days at temperature 8°C. Li *et al.* [5] also claimed gamma irradiation was effective in inhibition of bacterial growth in fresh noodles, but, the effectiveness is depending on the dose of irradiation.

Table 11
Total plates count of the rice bran yellow noodles after stored at 8°C for 7 days

Sample	Total colony count (log CFU/g)			
	Day 0	Day 3	Day 5	Day 7
5%, 0 kGy	<1	3.59±0.11	4.53±0.12	5.30±0.025
5%, 4 kGy	<1	<1	3.20±0.17	3.52±0.45
5%, 6 kGy	<1	<1	<1	<1
5%, 8 kGy	<1	<1	<1	<1
10%, 0 kGy	<1	3.46±0.15	4.83±0.087	5.20±0.066
10%, 4 kGy	<1	<1	3.39±0.36	3.63±0.056
10%, 6 kGy	<1	<1	<1	<1
10%, 8 kGy	<1	<1	<1	<1
15%, 0 kGy	<1	3.49±0.61	4.80±0.11	5.42±0.037
15%, 4 kGy	<1	<1	1.20±2.08	4.11±0.19
15%, 6 kGy	<1	<1	<1	<1
15%, 8 kGy	<1	<1	<1	<1
20%, 0 kGy	<1	3.58±0.57	5.0067±0.085	5.39±0.095
20%, 4 kGy	<1	<1	<1	4.021±0.166
20%, 6 kGy	<1	<1	<1	<1
20%, 8 kGy	<1	<1	<1	<1

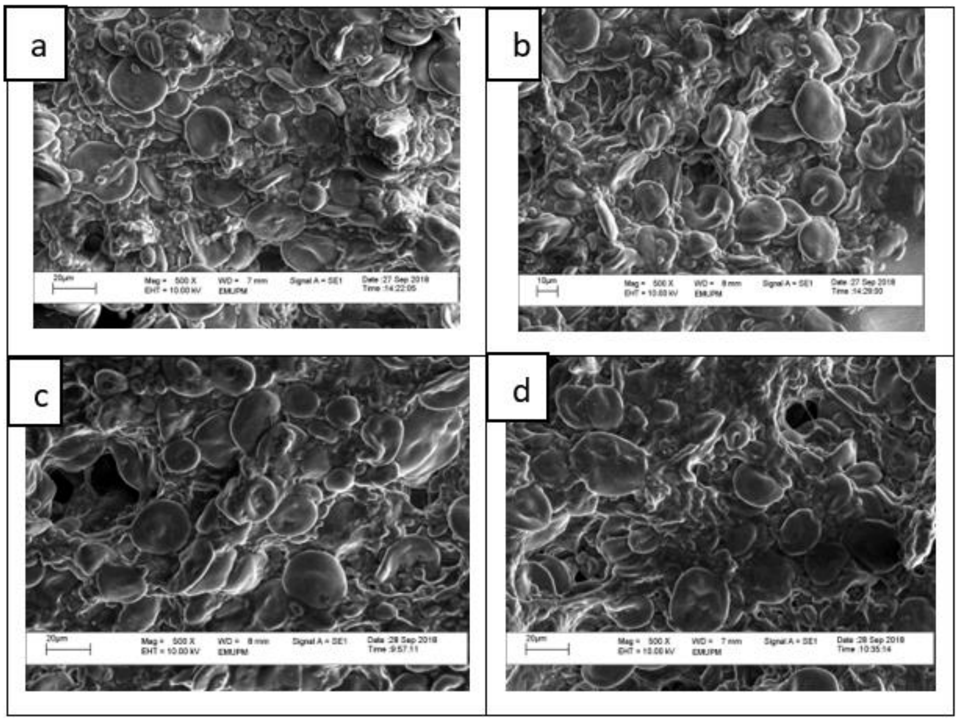
Despised the use of salt which may play a lowering agent of water activity in the formulation, it did not seem to give a positive effect on the water activity over control and irradiated RBY noodles, which determine the growth factor of microorganisms. However, claimed made by Lacroix *et al.* [12] and FDA [46], food irradiation can increase the shelf life and improve the food safety of several products, and the occurrence of foodborne diseases. Gamma irradiation dose, damage the DNA and/or protein of microorganism cells and caused swelling and breakings along the chain. Furthermore, the damage in DNA was large and makes it difficult or impossible to be repaired, to be replicate and leads to the death of irradiated microorganisms [47, 48]. On the other hand, a significant increase in water activity with increased of rice bran percentage was proven safe to consume after RBY noodles been irradiated at doses 6 kGy and 8 kGy. Thus, the RBY noodles can extend the shelf up to day 7 with bacteria count below 10^6 CFU/g at temperature 8°C.

3.6 Microstructure of cross section in RBY noodles

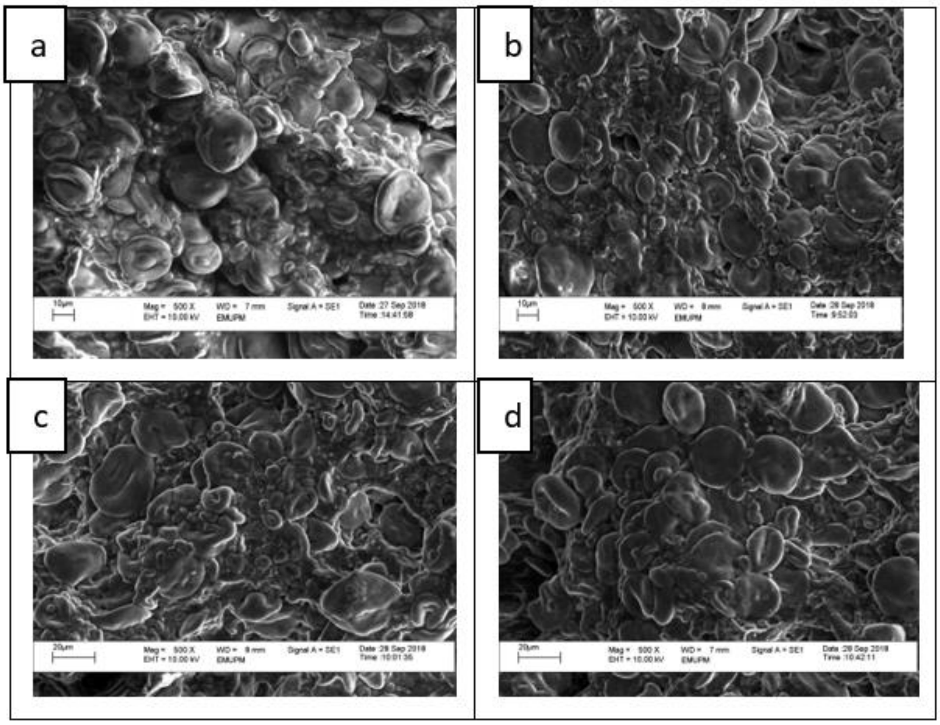
Micrograph taken from scanning electron of wheat starch granules in RBY noodles is presented in Figure 1. The wheat starch granules had spherical and oval in shape. Basically, there are two types of wheat starch granules which are type A and type B [49]. For type A, the size of the granule is large which more than 10 µm while, for type B, the size of the granule is small which less than 10 µm [50].

Based on the results obtained, the samples of RBY noodles with an increasing level of rice bran at 0 kGy contains a balance size of starch granules in which the amount of starch granules types A is equal to the amount of starch granules type B. Thus, the structures were in-shape and emerged or lifted. On the other hand, the starch granules with higher irradiation dose and a higher level of rice bran added show imperfection in terms of structures. For instance, the shape of the starch granules become elongated and dented at irradiation dose 8 kGy and 20% of rice bran. Lee *et al.* [35] found the irregular shapes and crack granules were affected as the irradiation dose increases which might relate to the resistance starch contents. Thus, small and large granules appear to be imperfect shaped might be ruptured of the starch granules by increasing gamma irradiation as observed by Lee *et al.* [35] and supported by the research finding in breaking length and hardness.

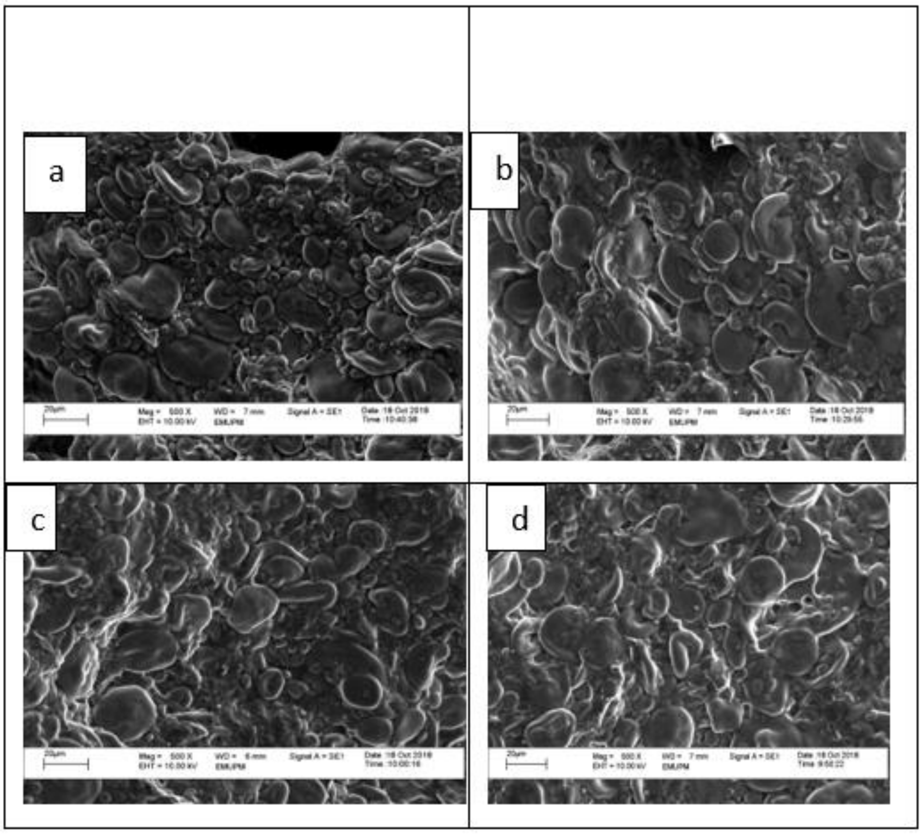
However, both shapes of every dose irradiated starch granules, compared to non-irradiated, were found swelling at every ratio of rice bran added. The presence of gamma rays that dissolve radiation energy while penetrating the starch and damaging the wheat starch granules could be an explanation for the finding. Through gamma irradiation, the compact crystallites of large starch granules were destroyed, making the chemical bonds in starch molecules become unstable and break down. Thus, the increasing breakage of large starch granules, increased the surface area of starch granules and more free water are transfer from inner to surface of area [21, 22]. A research found by Azzeh *et al.* [28], and Koksel *et al.* [29] also claimed the break down situation of starch granules after asserting irradiation dose is applied. Therefore, it exhibits amorphous regions which starch granule rapidly becomes 50-100 times bigger in volume [49].



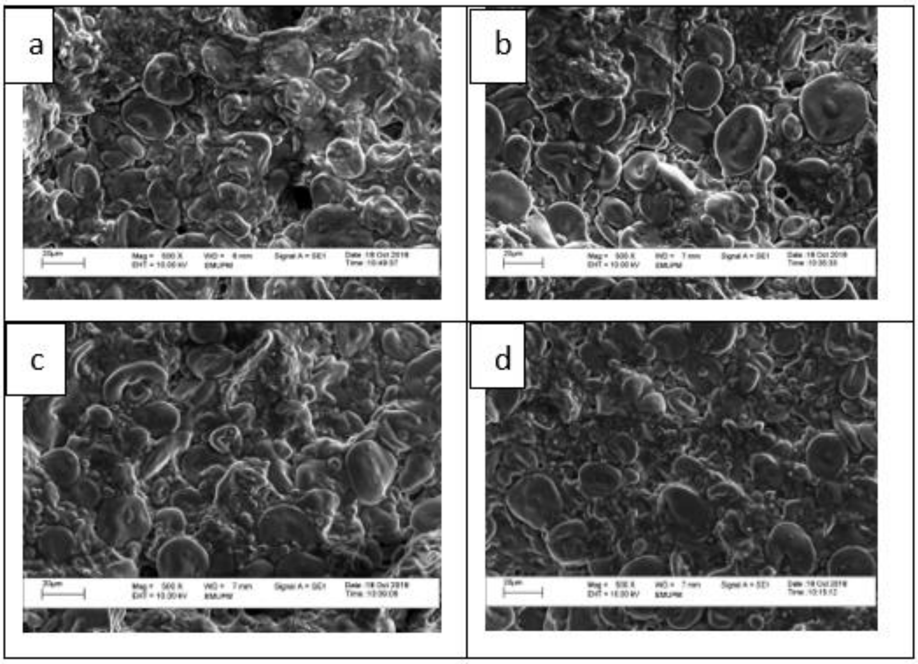
A) 5%



B) 10%



C) 15%



D) 20%

Fig. 1. Morphology of cross section A)5%, B)10%, C)15%, D)20% rice bran yellow noodles for different dose of irradiation a) 0 kGy b) 4 kGy c) 6 kGy d) 8 kGy at 500 x magnificent

4. Conclusions

This study showed gamma irradiation has strong disinfection potential on RBY noodles especially at dose 6 kGy and 8 kGy where no microbial growth was recorded compared to control and 4 kGy. Based on the results obtained, the shelf life of the irradiated RBY noodles could be extended more than 7 days with a storage temperature of 8°C. In addition, increased irradiation dose significantly decreased the pH, moisture content, hardness, lightness and redness. However, further increased irradiation dose caused a significant increase in the breaking length of RBY noodles at 5%, 10% and 15% rice bran, with an exception for 20% rice bran where the breaking length was decreased as irradiation dose increased. The different gamma irradiation dose treatment and addition of rice bran resulted in small changes in the starch granules. Increased percentage of rice bran caused a significant increase in the moisture content, breaking length, redness, cooking yield and cooking loss; and a significant decrease in the hardness, lightness and yellowness.

In view of this, the best irradiation dose in this study was 6 kGy while the best percentage of rice bran added in yellow noodles was 10% rice bran. At minimum 6kGy doses of gamma irradiation exposure are required to extending the shelf life of RBY noodles up to 7 days at 8°C. Thus, a higher irradiation dose would cause a rapidly increased cooking loss and decrease in breaking length with 15% and 20% rice bran at the same dose or 8kGy, event with 10% rice bran. Besides, the potential of having slightly higher moisture content causes difficulty in the sheeting process during the production of RBY noodles. Compared to 5% rice bran, the 10% rice bran contributes a significantly higher cooking yield, among highest breaking length, a significant increase in hardness with slightly lower in water activity, a significant decrease in lightness and a significant increase on redness. Moreover, no significant difference found between 5% and 10% rice bran in pH, breaking length, yellowness, and micrograph.

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