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Effect of Microwave Power and Puffing Time on the Quality of Yam Bean Cracker

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Fried crackers have issues with high-fat content, oil absorption, and oxidation during storage. The objective of this research was to study the effect of microwave power and puffing time on the quality of yam bean crackers. The microwave has power settings of 160, 400, and 800 watts, with puffing times for each power setting of 30, 45, and 60 seconds, respectively. The dried semi-product has an initial moisture content of 10 to 12% on a dry basis. The cracker products contained yam bean pulp, accounting for 30 percent of the weight of the cassava starch. The results showed that increasing microwave power and puffing time resulted in a loss of lightness (L*) and an increase in redness (a*), with no significant difference in yellowness (b*) between different microwave powers. Increasing power level and puffing time affected the physical characteristics of the yam bean crackers, resulting in darker-coloured crackers. The expansion ratio ranged from 2.10±0.23 to 5.10±0.30 times the original size of the raw yam bean crackers, with the highest expansion ratio of 5.10±0.30 attained at 800 watts and a puffing duration of 60 seconds. Moisture content and water activity of yam bean crackers decreased with increasing puffing time and microwave power. Yam bean crackers puffed at 160 watts for 30 seconds had the lowest hardness and fracturability values, at 9.23±1.98 N and 5.50±1.66 N, respectively. The yam bean crackers puffed by microwave had a fat content ranging from 0.026 ± 0.054 to 0.201 ± 0.013%, while those puffed by frying had a fat content of 23.33 ± 1.36%.

Keywords: Yam bean, Cracker, Microwave power, Puffing time, Texture.

1. Introduction

Crackers are a popular Thai snack enjoyed by people of all ages and genders. Thai people refer to it as "Khao Kriap." They can be consumed as a crunchy snack or between meals. The main

ingredients used in their production are cassava flour mixed with various other ingredients such as meat, shrimp, fish, vegetables, and various herbs and spices (Nguyen et al., 2013). These ingredients are ground together and cooked to combine flavors, then shaped into various forms, dried, and finally fried or baked before consumption (Chudasama et al., 2019).

In the past 1-2 years, the COVID-19 pandemic has emerged as a significant factor leading to changes in consumer lifestyles, affecting consumption behaviors and increasing awareness of health care, both in daily life and dietary habits. Therefore, making semi-prepared puffed crackers using a microwave oven has become an option to help reduce the fat content of the product. This method involves reducing the puffing time and increasing convenience for consumers (Iyiola et al., 2020).

Microwave technology has revolutionized food processing by offering rapid and efficient heating techniques. Microwave heating of food takes place as electromagnetic energy is converted to thermal energy, causing water molecules and charged ions to become more agitated when exposed to microwaves (Jiang et al., 2018). Microwave heating is desirable in the puffing process because it results in low-fat, nutritious food compared to deep-fat fried items. Dielectric materials absorb microwaves, causing them to transmit energy to the substance, which leads to a quick increase in temperature and mass transfer inside the material (Chandrasekaran et al., 2013).

The ability of materials to absorb microwaves varies depending on their dielectric properties (Marlena Pielak et al., 2022). Generally, materials with a high water content absorb microwaves more easily and convert them into heat energy. Water molecules undergo rotation due to the high-frequency rotation corresponding to the microwave frequency of 2.45 GHz, leading to resonance and alignment in the direction of the electric field. The rapid rotation or vibration results in heat generation at the point where the microwaves contact the food. This rapid heating causes the water to heat up quickly and evaporate, leading to puffing (Boischot et al., 2003; Dash & Das, 2021; Rajha et al., 2021; Guttifera et al., 2022). Therefore, the heat energy generated is used to evaporate moisture in the food without causing structural damage or altering the taste, helping reduce the fat content in crackers (Pompe et al., 2020; Atuonwu & Tassou, 2019). Microwave power directly affects the heating rate of the yam bean crackers during puffing. Higher power leads to faster heating, which can promote more rapid expansion of the product. However, excessively high power may also cause overheating, resulting in undesirable changes in texture and flavor (Peranginangin et al., 1997; Jiang et al., 2018). Therefore, determining the optimal power is essential to achieving the desired puffing characteristics while maintaining product quality.

Puffing time is another critical factor that influences the quality of yam bean crackers. The duration of puffing determines the extent of expansion and the final texture of the product. Short puffing times may result in underdeveloped crackers, while prolonged puffing times can lead to over-puffing and a loss of desirable texture (Maisont & Narkrugsa, 2009; Sompong & Songsermpong, 2022).There have been studies on the effects of microwave power on the physical properties of various types of crackers, such as fish crackers (Chedoloh & Chehmalee, 2019; Chedoloh & Waeno, 2020), seaweed and kale crackers, and shrimp crackers (Nguyen et al., 2013). However, there are no reports investigating the effects of microwave power on the physical properties of yam bean crackers.

Therefore, this research aims to examine the quality of yam bean cracker products made using microwave puffing. This study evaluates the microwave power and length of heating required to make yam bean crackers in a household microwave oven. We might modify these factors to increase the quality of yam bean crackers and advance the development of enhanced food processing methods.

2. Material and Methods

Preparation of Yam Bean Crackers

Yam beans (Pachyrizhus erosus L. Urban) were bought from an agricultural market, Mahasarakham province, Thailand. The fresh yam bean was peeled, washed, and subsequently chopped into tiny pieces. Blend it well using a blender. Apply heat to the finely blended yam bean pulp using an electric stove for a duration of *5* minutes in order to partially convert the starch in the yam bean into a gelatinous state. Subsequently, combine it with the other components. In this investigation, yam bean pulp was utilized as a substitute for *30%* of the weight of tapioca starch. Prepare a mixing bowl and mix tapioca starch, all-purpose flour, seasoning powder, sugar, salt, and powdered black pepper. Combine thoroughly. Once thoroughly mixed, slowly add boiling water at 100 ℃ to the mixing basin. Avoid pouring it all at the same time. Knead the dough with your hands or a wooden spatula. Continue the process until you form a cohesive and uniform dough ball. Produce round sticks from the divided portions of dough. Wrap them in plastic wrap, molding the dough into stick-like shapes. Place the dough in a steamer for 40–60 minutes to enhance the starch gelatinization. Then, it was cooled down at room temperature for 45 min and stored in a freezer overnight at -2 °C. After that, the loaves were cut into slices of 3 mm thickness. The slices were spread uniformly onto steel girds in a far infrared dryer until they reached a final moisture content of 10–12% (d.b.). The semi-yam bean crackers produced were packaged in polyethylene plastic bags and stored at room temperature. The dried slices were puffed by microwave and deep fried in palm cooking oil at 180-200 ºC for 60 seconds using an electric fryer (Nurul et al., 2009).

Microwave puffing operation

The experiment used a standard domestic microwave oven (Model R-270; Sharp, Thailand) with varying power settings of 160, 400, and 800 watts for durations of 30, 45, and 60 seconds at 2,450 MHz. Semi-products were placed on the turntable of the microwave table. Each puffing condition involved baking four pieces of crackers at a time. The puffed crackers were kept in sealed aluminium foil pouches until analysis.

Characterizations of yam bean crackers

Expansion ratio measurement

The expansion ratio of the yam bean cracker was calculated using the sesame seed displacement method (Sompong & Songsermpong, 2022). The sesame seeds were put into a shallow glass cup to fill it. A ruler was used to level the surface of the cup equally around its edge. The quantity of sesame seeds was determined by measuring it with a graduated cylinder and noted as V_1. Six unexpanded yam bean crackers were put in a cup together and filled with

sesame seeds until the cup was full. The cup was tapped to compact the sesame seeds until they had fully filled the spaces between the samples, and a ruler was then used to level the surface. The yam bean crackers were segregated from the sesame seeds. The quantity of sesame seeds was documented as V_2. Six yam bean crackers were inflated in the microwave oven. Their volume was then measured using the same way and recorded as V_3. Expansion ratio was determined using Eq. (1). Each experiment was repeated three times.

Expansion ratio = $(V_1\text{-}V_3) / (V_1\text{-}V_2)$ (1)

where V_1–V_3 is the volume of yam bean cracker after puffing or frying and V_1–V_2 is the volume of yam bean crackers before puffing or frying.

Colour measurement

The colour of the puffed yam bean cracker was assessed with a colorimeter (Hunter Lab, Ultra Scan Pro; USA) utilizing the CIELAB system (L*, a*, b*). In this system, L* represents lightness and darkness (0 = dark, 100 = white), a* indicates greenness (-) and redness (+), and b* signifies blueness (-) and yellowness (+). Each experiment was repeated three times.

Moisture content and water activity

The moisture content of the dried crackers was determined by the hot air oven method (A.O.A.C, 2005). The samples were dried in an oven at 135 °C and weighed after 2 hours until a constant weight was reached. Two grams of cracker were cut into small pieces and spread out in an aluminium can. The weight of the cracker was determined using triplicate measurements. The moisture content was calculated using Eq. (2):

$$MC = \frac{W - W_d}{W_d} \quad (2)$$

Where MC is the moisture content of the puffed cracker (%, dry base), while W represents the mass of the samples before puffing or frying (g), and W_d is the mass of samples after puffing or frying (g).

Water activity in the tested samples was carried out with the AquaLab Water Activity Meter device (Switzerland) at a temperature of 25 °C, in accordance with the guidelines contained in the manufacturer's instructions.

Texture analysis

The firmness and ability to break of the puffed yam bean crackers were assessed with a texture analyzer TA-XT Plus (Stable Micro Systems; UK) equipped with a 25 kg load cell, 0.635 cm diameter spherical probe (P/0.25S), and each sample was placed on the cracker fracture support rig (HDP/CFS). The texture analyzer was configured with a spherical probe (P/0.25S) of 0.635 cm in diameter and equipped with a 25 kg load cell for force/displacement measurement. Testing was conducted on samples using the following parameters: speed of 1 mm/s, trigger force of 5 g, and probe travel distance of 5 mm. The highest force was recorded and expressed as the hardness measured in newtons (N). Fracturability was assessed based on the initial prominent peak during the first compression. Each experiment was repeated three times.

Total fat content analysis

In a Soxhlet extraction apparatus (model: FAT 6, origin: Slovenia, manufacturer: India), 5 g of puffing or frying crackers were extracted over the course of 6 hours using petroleum ether. The petroleum ether completely evaporated from the containers after the ether extract was filtered into them, and the increase in container volume indicated the total fat content (A.O.A.C, 2005). The percent of total fat content is amount of the ether extract per weight of sample, and calculation percent of total fat content was following Eq. (3):

$$\text{Percent of total fat content} = \frac{W_2 - W_1}{W} \times 100 \quad (3)$$

Where W is sample weight (g), W_1 is empty container weight (g), and W_2 represents empty container weight plus fat content (Ether extract) (g).

Statistical analysis

The statistical investigations employed one-way analysis of variance (ANOVA) and Duncan's multiple range test (DMRT). The results provided a confidence interval of 95% for statistically significant differences ($p < 0.05$) using SPSS software (Ver. 20.0). All information was expressed using the mean and standard deviation (SD) values.

3. Results and Discussion

Colour measurement of yam bean crackers

The yam bean crackers were puffed using a microwave oven. Three power levels were tested: 160 watts (low), 400 watts (medium), and 800 watts (high), with each power level having puffing times of 30, 45, and 60 seconds. It was found that increasing the power level and puffing time affected the physical characteristics of the yam bean crackers. More precisely, increased power levels and longer puffing times resulted in darker-coloured crackers. All yam bean crackers were different in terms of appearance, as shown in Table 1.

All yam bean crackers were colour-measured using the parameters L*, a*, and b* (Figure 1a-c). Yam bean crackers were microwaved at power levels of 160, 400, and 800 watts for 30, 45, and 60 seconds, resulting in lightness (L*) ranging from 28.41±11.11 to 65.52±2.12 (Figure 1a). Higher microwave power and longer puffing time led to lower lightness ratings, suggesting a darker colour of the yam bean crackers. Moreover, when puffed at 800 watts for 60 seconds, the yam bean crackers showed a deeper colour and evidence of burning.

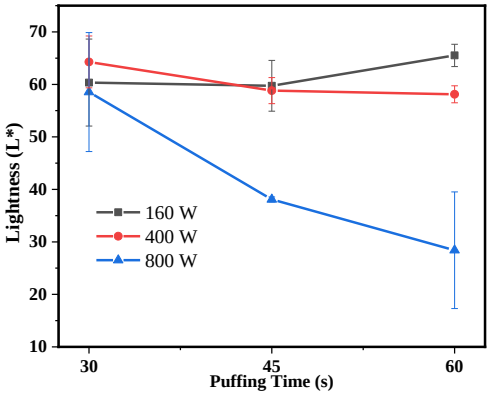
Table 1. Appearance of yam bean crackers with the different microwave power and puffing times

Microwave power (Watt)	Puffing times (second)		
	30	45	60
160			

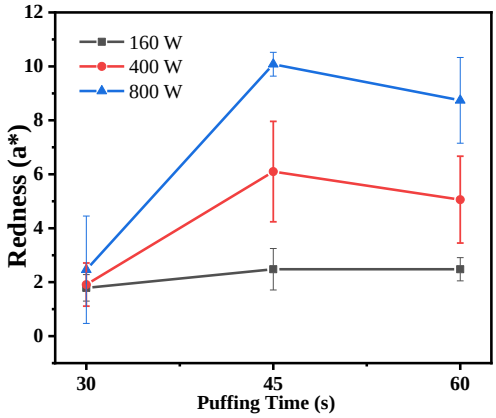
400			
800			

The redness values (a*) ranged from 1.79 ± 0.49 to 10.08 ± 0.44 (Figure 1b). Increasing the microwave power and puffing duration resulted in greater redness values in the yam bean crackers. The maximum redness value was recorded at 800 watts of microwave power and a puffing duration of 45 seconds, measuring 10.08 ± 0.44. The yellowness values (b*) ranged from 16.67±6.11 to 23.81±2.11 (Figure 1c). The yam bean crackers had the lowest yellowness of 16.67 ± 6.11 while puffed in a microwave at 800 watts for 60 seconds. The highest value of yellow colour intensity was recorded at 23.81±2.11 upon applying 400 watts of microwave power for 45 seconds. It is observed that the yellow colour of the power at *160* and *400* watts does not differ significantly. Since microwaved meals normally do not brown, it suggests that their surfaces do not achieve the required temperatures. This result corresponds to the experiment reported by Wattanapreechanont and Songsermpongt (2014), who found that there was no noticeable difference in the colour of the rice cracker as the microwave power rose.

(a)



(b)



(c)

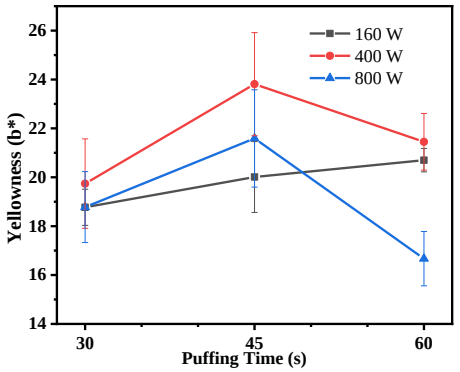


Figure 1. Effect of power microwave and puffing time on colour of yam bean cracker (a) lightness, (b) redness and (c) yellowness

Expansion ratio of yam bean crackers

The effect of power microwave and puffing time on the expansion ratio of yam bean cracker is shown in Figure 2. The expansion ratio ranged between 2.10±0.23 and 5.10±0.30 times that of the original size yam bean crackers. As a microwave power of 160 watts was used, puffing for 30, 45, and 60 seconds resulted in expansion ratios of 2.10±0.23, 2.60±0.11, and 3.20±0.29, respectively, in comparison to the original crackers. Similarly, at 400 watts, puffing durations of 30, 45, and 60 seconds resulted in expansion ratios of 2.60±0.31, 3.50±0.21, and 3.40±0.23, respectively. At 800 watts, the expansion ratios were 3.00±0.27, 4.80±0.26, and 5.10±0.30 for puffing durations of 30, 45, and 60 seconds, respectively. The trend of expansion ratios was to increase with puffing time and microwave power. According to Rahman et al. (2019), the expansion volume increased dramatically as the microwave power level increased. Heat is produced by ionic polarization and dipole rotation since microwaves interact with charged particles and polar molecules. During this heating timing, considerable vaporization occurred inside the sample, leading to the puffing process and expansion of the sample as it was heated (Liu et al., 2010). The study determined that the maximum expansion ratio of 5.10±0.30 was attained with 800 watts and a puffing duration of 60 seconds. Based on the inherent colour properties of yam bean crackers, it is recommended to use a microwave power of 400 watts and a puffing duration of 45 or 60 seconds to avoid excessive browning. Chedoloh and Waeno (2020) investigated the expansion ratio of fish crispy puffed at 1700 watts in a microwave for 30 minutes and observed that the ratio was 2.51-3.39 times that of the semi-product. Supanpayak et al. (2019) reported that sea lettuce crackers showed an expansion ratio of 3.43–4.73 when exposed to 800 watts of microwave power for 25 seconds. Microwave puffing of yam bean crackers involves fast heating that causes water molecules to evaporate quickly, providing pressure that allows the treats to expand effectively. However, the expansion ratio of yam bean cracker depends on several variables, such as moisture content, bulk density, production method, ingredients, and operator techniques. These variables affect the chemical and physical properties in different ways.

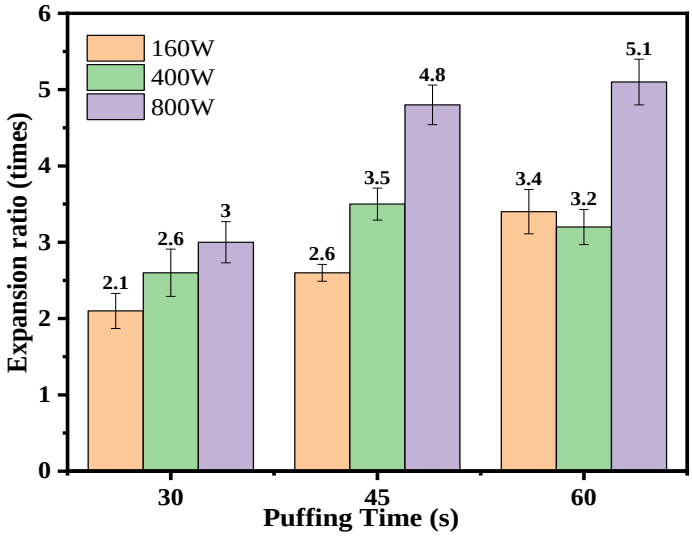


Figure 2. Effect of power microwave and puffing time on expansion ratio of yam bean cracker

Moisture content and water activity of yam bean crackers

After microwave puffing, the yam bean crackers had a moisture content ranging from 3.09±0.01 to 4.81±0.01% and a water activity (a_w) ranging from 0.29±0.001 to 0.383±0.001, as shown in Figures 3a and 3b, respectively. The results showed that yam bean crackers puffed with 800 watts of microwave power for 60 seconds had the lowest moisture content and water activity levels, measured at 3.09±0.01% and 0.29±0.001, respectively. On the contrary, crackers puffed with 160 watts of microwave power for 30 seconds had the greatest moisture content and a_w levels, measuring at 4.81±0.01% and 0.383±0.001, respectively. The moisture content and water activity of yam bean crackers decreased with puffing time, and microwave power increased because higher energy caused more moisture to evaporate. Chedoloh and Chehmalee (2019) found that puffing at 800 watts led to lower moisture levels compared to puffing at 450 and 600 watts. However, the water activity at low power (160 watts) is not significantly different when puffing time increases. Increased microwave power and extended puffing periods lead to differences in the a_w values ($p< 0.05$). Water activity is an important factor in food science, influencing food safety, stability, and quality. The term refers to the amount of water in a food system that is available for microbial and chemical reactions. The moisture level in the final yam bean crackers achieved the Community Product Standards requirement, which states that the moisture content of ready-to-eat crackers should not be more than 4% by weight (Thai Industrial Standards Institute, 2011).

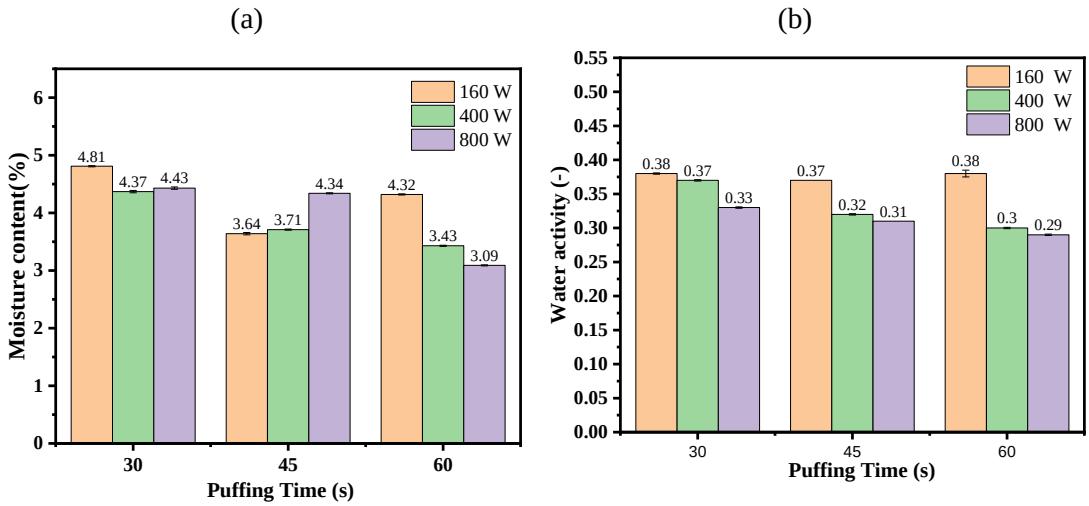


Figure 3. Effect of power microwave and puffing time on (a) moisture content and (b) water activity of yam bean cracker

Texture analysis of yam bean crackers

The measurement of the textural properties of yam bean crackers after microwave puffing includes fracturability and hardness, as shown in Figures 4a and 4b, respectively. The microwave-puffed yam bean crackers showed fracturability values between 5.50±1.66 and 10.55±1.43 N and hardness values between 9.23±1.98 and 19.25±2.20 N. The increase in microwave power and puffing duration had a significant influence on the hardness and fracturability parameters. Yam bean crackers puffed at 160 watts for 30 seconds had the lowest hardness and fracturability values, at 9.23±1.98 N and 5.50±1.66 N, respectively. Conversely, samples processed at 400 watts for 45 seconds showed a maximum hardness of 19.25±2.20 N. At a microwave power of 160 watts, the hardness and fracturability results showed no significant difference between puffing periods of 45 and 60 seconds, although they differed at 30 seconds. When using a microwave power of 400 watts, there was no significant variation in hardness and fracturability between puffing times of 30 and 45 seconds; however, there was a difference at 60 seconds. There was no significant variation in hardness and fracturability at a microwave power of 800 watts as the puffing time increased. The yam bean crackers obtained by deep-frying had a fracturability and hardness value of 8.11±0.80 and 3.17±0.25 N, respectively, which were significantly lower than those established by microwave puffing. The oil absorption in the food structure caused deep-fried crackers to have less fracturability and hardness compared to those produced with a microwave. In comparison, the colour, fracturability, and hardness of yam bean crackers were puffed by deep-frying and microwave-puffing, as shown in Table 2.

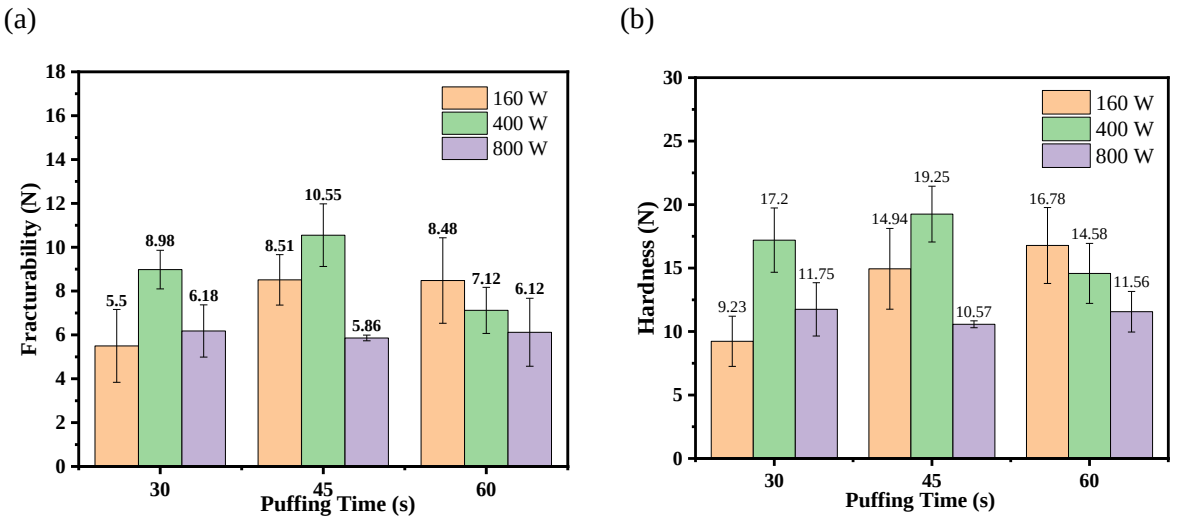


Figure 4. Effect of power microwave and puffing time on texture of yam bean cracker (a) fracturability and (b) hardness

Table 2. A comparison the colour, fracturability, and hardness of yam bean crackers were puffed by deep-frying and microwave-puffing

Method of Puffing	Time (second)	Colour			fracturability (N)	Hardness (N)
		L*	a*	b*		
Deep fried	60	55.91±2.50^{b}	4.71±2.70^{b}	25.06±4.12^{a}	3.17±0.25^{b}	8.11±0.80^{b}
Microwave (400 Watts)	45	58.82±2.48^{a}	6.10±1.86^{a}	23.81 ±2.11^{b}	10.55±1.43^{a}	19.25±2.20^{a}

Values are means ± standard deviation. The same lowercase letters are not a statistically significant difference

($p < 0.05$)

Total fat content analysis

The total fat content of yam bean crackers was subjected to microwave puffing at 160, 400, and 800 watts for 30, 45, and 60 seconds and ranged from 0.026±0.054 to 0.201±0.013% (Figure 5). Variations in microwave power and puffing time resulted in statistically significant differences in fat content. Prolonging the puffing time resulted in the higher fat content. The fried yam bean crackers had a fat level of 23.33±1.36%, which was significantly higher. Table 3 shows the total fat content of yam bean crackers, which were puffed in the microwave and deep-fried.

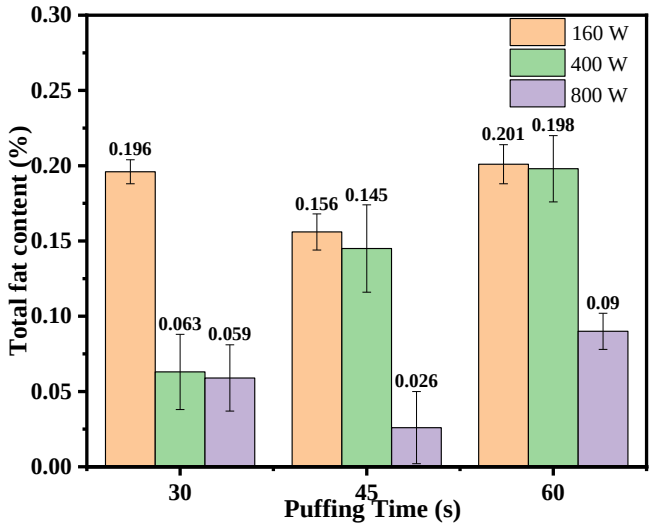


Figure 5. Effect of power microwave and puffing time on total fat content of yam bean cracker

Table 3. The total fat content of yam bean crackers was puffed in the microwave and deep-fried

Microwave power (Watt)	Total fat content *(%)*		
Deep fried	23.33 ± 1.36[a]	23.33 ± 1.36[a]	23.33 ± 1.36[a]
	30 second	45 second	60 second
160	0.196 ± 0.008[b]	0.156 ± 0.012[b]	0.201 ± 0.013[b]
400	0.063 ± 0.135[b]	0.145 ± 0.139[b]	0.198 ± 0.022[b]
800	0.059 ± 0.022[b]	0.026 ± 0.054[b]	0.090 ± 0.012[b]

Values are means ± standard deviation. The same lowercase letters are not a statistically significant difference ($p < 0.05$)

4. Conclusions

This research demonstrated the effect of power microwaves and puffing time on the quality of yam bean crackers using a household microwave oven. At a low microwave power level of 160 watts, as the puffing time increased, the colour values did not differ significantly. At a high power level of 800 watts, a significant colour change in the yam bean cracker as the puffing time increased. Higher microwave power and longer puffing time led to lower lightness ratings, suggesting a darker colour of the yam bean crackers. Moreover, when puffed at 800 watts for 60 seconds, the yam bean crackers showed a deeper colour and evidence of burning. The trend of expansion ratios was to increase with puffing time and microwave power. Based on the inherent colour properties of yam bean crackers, it is recommended to

use a microwave power of 400 watts and a puffing duration of 45 or 60 seconds to avoid excessive browning. Yam bean crackers puffed at 160 watts for 30 seconds had the lowest hardness and fracturability values, at 9.23±1.98 and 5.50±1.66 N, respectively. As puffing time increased, there was no significant variation in hardness or fracturability. Microwave cooking produces a higher hardness compared to deep-frying. Therefore, the results suggested that microwave puffing has the benefit of reducing the total amount of fat applied and shortening the puffing duration of yam bean crackers.

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