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Combination of Oven and Microwave-assisted Drying Technique for Production of Ready-to-Eat Dried Rice

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Abstract

A combination of oven and microwave was introduced with the purpose of preparing well-balanced dried ready-to-eat dried rice samples. The parameter condition was investigated (oven temperature; 70 and 90 °C, time; 70, 130 and 180 min, microwave power; 450 and 750 W and time; 1, 2, 3, 4 and 5 min). From the study, increasing in moisture content and rehydration capability was obtained when the drying conditions were increased. However, the color product was changing as the color difference was improved whereby the samples with lower water activity have lower microorganism growth (0.4-0.5 wa). The nutrient obtained were in the range of 55.5-65.9% for carbohydrate, 6.4-9.3% for protein, 65.9-17.3% for fat and 3.4-3.5 for ash content, respectively. It can be concluded that the use of oven and microwave in this study is acceptable for preparing ready-to-eat dried rice.

1. Introduction

Ready-to-eat foods (RTE) were introduced with the purpose of helping the victims or people with food that is with minimal preparation. It can be animal or plant derived food that is already cooked, frozen and processed or requiring minimal preparation such as reheating or boiling before reaching the consumers. RTE foods are normally packaged in airtight sealed solutions and manufactured for a longer period. RTE foods can be found in the market in the form of frozen or chilled, retort, canned and dried RTE meals. It also can be presented in the form of meat and poultry products, cereal as well as vegetable-based products. Study [1] reported that RTE foods also can be used as functional foods for specific-proposed food products such as space, military, elderly, emergency functional foods, immune-compromised patient foods as well as domestic consumption. However, it is reported that the existing ready-to-eat (RTE) foods nowadays are lacking sufficient nutritional balance. To solve the problem, RTE foods were manufactured by adding the largest amount of salt and food additives to preserve the taste that is satisfying consumers' demand. Consequently, the nutritional foods that are supposed to be health benefits resulted in totally wasting due to failure to meet standard requirement nutritional level. As a result, the food is subjected to be prepared under specific treatment and conditions that will improve their quality unconditionally.

Food that can satisfy a wide range of processing treatment and conditions can have a better-quality nutrient with a good shelf-life product. In particular, the thermal and non-thermal processing methods were introduced [2]-[3]. The example of thermal processing methods is including ohmic heating, microwave heating and radio frequency whereby for non-thermal processing methods are high pressure processing, light pressure homogenizations, pulsed electric fields, ultrasound and ionizing irradiation, respectively. On the other hand,

there is also combination of thermal process with conventional process methods to prepare the food that is stable and rich with nutrient and sensory equalities [4]-[6]. However, among the thermal methods, microwave technology has been widely used in the food industries especially for cooking, drying, pasteurization and preservation of food materials [7]-[8] due to electromagnetic waves that will interact with heat in situ causing quick distribution to the food. The allowable frequencies for food industry are between 915 MHz and 2454 MHz. In addition, microwave technology is not only generating shorter drying time with lower energy consumption especially for stabilizing moisture content, but it also can preserve the quality and nutritional characteristics of products produced [9]. This is probably due to the energy supplied from microwave power by electromagnetic field that can be directly emergence to the material which in turn resulting in rapid heating and reducing thermal ingredient and shorter processing time [10]-[11]. Furthermore, study [12] reported that electromagnetic heat that is developed inside the sample can create a large amount of vapour pressure difference that resulted in porous structure which can help for good rehydration capability especially for dried rice. Whereby, the high drying efficiency that is produced from microwave also suitable for drying heat-sensitive materials such as fruit and vegetables equivalent to freeze- and spray drying methods [13]-[14]. Furthermore, Fan and colleagues [9] reported that microwave treatment on rice starch also can preserve the chemical bonds and chemical groups of the products without destroying its physicochemical structure.

Oven or hot air drying is the oldest method that has been widely used for food preservation due to its uniformity, hygienic characteristic and rapid drying product that can extend the shelf life of the products [15]. However, the heating from the oven alone can cause colour changing and affect the structure [16].

In this study, the effect of drying conditions of oven drying (temperature and time) and microwave technology (power level and time) on the properties of ready-to-eat dried rice was investigated. The properties of acceptable final dried rice samples in terms of moisture content, colour, rehydration capability, texture evaluation, water activity, proximate compositions and sensory evaluation were also observed.

2. Materials and Methods

2.1 Materials

White fragrant rice, minced chicken, mixed vegetables, cooking salt and mixed spices were obtained from the local supermarket. Chloroform, methanol, sodium sulfate, hydrated copper sulphate, potassium hydroxide solution, potassium sodium tartrate and Bovine Serum Albumin (BSA) (lyophilized powder ≥ 96%, 2-8, agarose gel) were purchased from Sigma Aldrich and Fisher Scientific. All chemicals were used without purification.

2.2 Dried Rice Preparation

For sample preparation (dried rice), all parameters that are applied for cooking were operated in fixed conditions. White fragrant rice (200g), minced chicken (38g), mixed vegetables (100g), salt and spices were mixed and gently stirred in the electric cooker (Wing, Malaysia). This mixture was cooked for 18-20 min and warmed for 15 min to increase the degree of gelatinization [12]. The ratio of mixture to water (1:2.5) was obtained from study [17]. After finished cooking, the rice was dried in the oven (WGL, China) under two different temperatures (70 and 90 °C) at different drying time (70, 130 and 180 min). The rice was further dried in the microwave R30AOS (Sharp, Japan) at different power levels (450 and 750 W) and varied the drying time (1, 2, 3, 4 and 5 min). The dried rice was stored in an airtight container prior to further analysis.

2.3 Moisture Content Determination

Moisture content determination was carried out according to the method described by study [18]. Dried rice samples were measured directly using moisture analyzer, MX-50 (AND Company, Japan). The analyzer was set up at temperature 178 °C of 2 g sample test for each analyzing.

2.4 Rehydration Measurement

Rehydration ratio was measured by referring to [19]. In 2.5 g of dried rice samples, about 1:30 (w/w) ratio of distilled water was added. The experiment was carried out under room temperature and soaked for 5 min. Within 5 min, the excessive water was drained using Whattman paper. Rehydrated dried samples were weighed with laboratory analytical balance and calculated according to equation below;

$$RR = \frac{(W2-W1)\,X\,100}{W1} \tag{1.0}$$

Where W1 represents the weight of dried matter (kg) and W2 represents the weight of the rehydrated material (kg).

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2.5 Color Analysis

Color analysis was carried out by referring to the method [20]. The colors of dried rice were measured using portable colorimeter, BC-10 (Konica Minolta, USA). Color analysis was determined based on Hunter system of which L measures were used to determine the whiteness value of color ranging from black (0) to white (100). Chromaticity coordinates a measure the red color when it is positive and green color when it is negative whereby chromaticity coordinate b measures yellow color when it is positive and blue color when it is negative. The color difference was calculated based on equation below;

$$\Delta E = \sqrt{(\Delta L + \Delta a + \Delta b)} \tag{2.0}$$

2.6 Water Activity Determination

Water activity for dried rice was determined using water activity meter, 4TE (AquaLab, USA). A total of 2 g of dried rice samples were placed in sample container and measured using a water activity meter. The value of water activity was displayed on the screen in the unit of aw.

2.7 Texture Evaluation

Texture evaluation was also included. The analysis was carried out based on method [21] with little modifications using textural analyzer (CT3, USA). About 3 g of dried rice sample was placed on the plate of 6cm diameter and deformed with 75% strain using TA 11/1000 cylindrical-type probe of 35 mm diameter. The test was performed at 1.0 mm/s of pre-test speed and 1.0 mm/s of post-test speed. The hardness of dried rice samples obtained was recorded.

2.8 Nutrient Composition

Protein, fat, and ash values were also required in order to calculate the amount of carbohydrates contented in the dried rice samples. This is due to the equation measurement that is referred to [22]. The equation for carbohydrate is as follow;

$$Carbohydrate\ (\%) = 100 - (protein\ concentration - fat - ash) \tag{3.0}$$

To determine protein concentration, Biuret method was performed according to [23]. A standard stock solution of Bovine Serum Albumin, BSA (2 mg/ml) was also included. Standard curve was prepared based on 8 different measurements (data not shown). For sample preparation, 0.1 g of dried rice samples was dissolved in 1 L of distilled water. The samples were homogenized thoroughly using ultra-turvex 25 Janke and Kunkel homogenizer to disrupt and release proteins into solution, followed by vortex for 10 sec. Care was taken when 2 ml of biuret reagent was added into every sample test tubes. All the test tubes were covered and briefly vortex to ensure all the mixtures were greatly homogenized. The test tubes were allowed to stand at room temperature for 25-30 min. The measurement of protein concentration was taken using spectrophotometer at the wavelength of 540 nm.

Fat content determination was obtained by referring to method [22]. A total of 5 g of dried rice samples were mixed vigorously with 100 mL chloroform/methanol under the ratio of 2:1 v/v. The mixture was shaken for 20 min, followed by addition of distilled water and continued shaking for 5 min. After separated, the chloroform phase was filtered using sodium sulfate then the residue was collected further with evaporation using rotary evaporator at temperature of 45 °C. The left residue was then continued to dry in the oven at 104 °C for 1 hour and allowed to cool in desiccator. The extracted crude fat was recorded.

To determine ash content (%), the moisture-free cooked samples were determined using muffle furnace at 525 °C for 24 h [24]. A total of 2 g of grinded M2H samples were weighted into a tarred crucible. The crucibles were placed in a cool muffle furnace. The dried rice samples were ignited at 525 °C for 2 hours. The muffle furnace was switched off and waiting to open once the temperature was dropped preferably to a lower temperature. The ash content obtained was calculated based on following equation;

$$\%\ Ash\ (dry\ basis) = \frac{wt.after\ ashing - tare\ wt.of\ cricible)}{(original\ sample\ wt\ \times dr\ matter\ coefficienct)} \times 100 \tag{4.0}$$

2.9 Statistical Analysis

All the experiments were performed in duplicate. The data obtained was analyzed using analysis of variance (ANOVA) in data analysis of Microsoft Excel. The T-tests students were carried out to determine significance differences of the data and set up the probability level at $p < 0.05$.

3. Results and Discussion

3.1 Moisture Content of Ready-to-Eat Dried Rice from The Oven

The effect of drying temperature (70 and 90°C) and drying time (70, 130 and 180 min) of the oven was observed on prepared dried rice samples (Fig. 1). The moisture content of the samples from the oven decreases as the temperature and drying time increases. This trend can be observed from the figure depicted in Fig. 1. In the early stage of drying, the moisture content of dried rice was found to be about 64.0 to 59.6% wt. after drying at 70 and 90 °C for 70 min. During this stage, it was also observed that the surface of dried rice was totally saturated with moisture. However, after some time of drying, the moisture content gradually decreased as the temperature and drying time increased. The maximum moisture content reduction was observed approximately 60% when the temperature and drying time were 90°C and 180 min, respectively. This is perhaps due to higher heat transfer and driving force which might cause the moisture to form the core to force itself towards the material surface [25]-[26] at higher temperature. Moreover, the appearance of dried rice kernels was cracked and ruptured as the temperature increases from 70 °C to 90 °C and drying time from 70 min to 180 min, respectively. The ruptured internal open structures leading to the tremendously reduced moisture content on the outer layers. Statistical student T-test also shows that oven temperature and drying time have significantly affect the moisture content of prepared dried rice ($p < 0.05$).

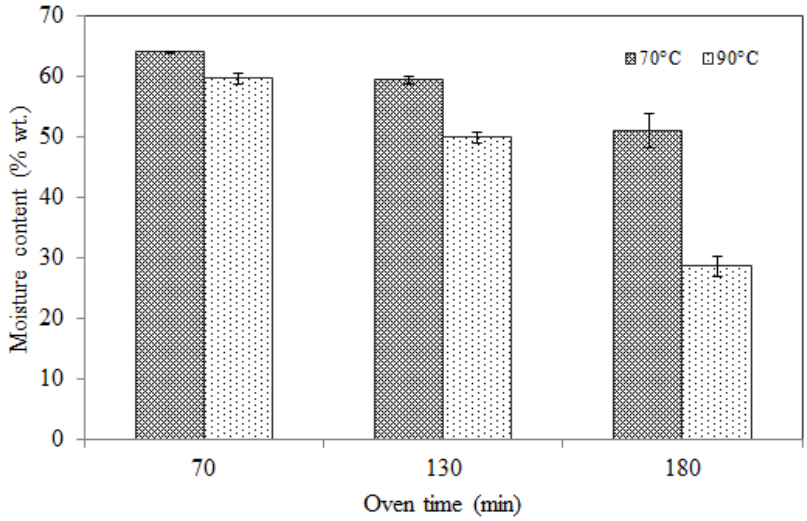

Fig. 1 *The effect of oven temperatures and drying times on moisture content of prepared dried rice*

3.2 Moisture Content of Prepared Dried Rice from The Microwave

The effect of microwave power and drying time on different oven temperature of prepared dried rice was depicted in Fig 2. The microwave power of 450 W was represented by Fig. 2(a) whereby the power of 750 W was represented by Fig. 2 (B), respectively. From figure 2, the moisture content of prepared dried rice gradually decreased as the microwave power and drying time increased. It can be seen from the reduction of moisture content from 57 to 5% wt after drying at 750 W compared to microwave power of 450 W. Statistical T-test shows that the moisture content was decreased significantly ($p < 0.05$) after drying for 70, 130 and 180 min in microwave oven. Researchers [27]-[28] revealed that at higher microwave power, largest internal heat might form create a flux of rapidly escaping water vapours which in turn open the pore of structure and create a large and hollow structure which at the end allowing for high drying rate and easy rehydration.

However, the moisture content in comparison to different group shows no significant different ($p > 0.05$) as the value of reduction is not consistent. For example, as the temperature of the oven accelerated to 90°C for 180 min, at microwave power of 750 W, the moisture content observed started to show no consistent and varied in value. This phenomenon happened perhaps due to the present of remaining water at sorption site of dried rice samples which allowing to some difficulty to remove the remaining moisture on the surface [29]. However, to complete the drying process, it will be more practical to use a microwave oven during the declining rate period or at a lower moisture content [19]-[30]-[31]. This agrees with [22] which suggested that freshly cooked rice must be dried to 6-12 g/100 g dry basis moisture content to obtain the instant or dried rice products. This lower moisture content was very important to ensure that the product is sufficiently dried to minimize microbial growth and extend product shelf life. From observation, at moderate and high conditions of oven temperature and drying time with high microwave power, dried rice samples were successfully achieved the desired moisture content as recommended for instant or dried cooked rice.

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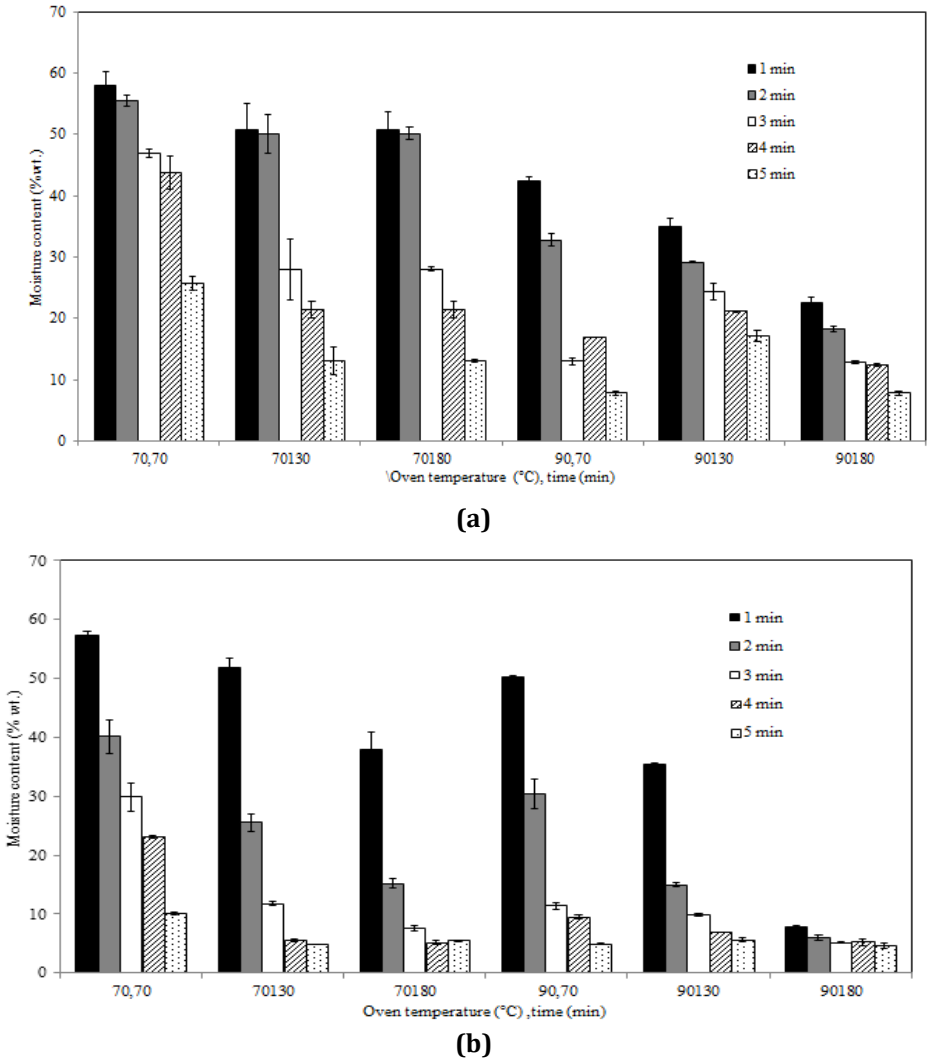

Fig. 2 *The effect of different microwave power on prepared dried rice. (A) 450 W; (B) 750 W*

3.3 Rehydration Capability of Prepared Dried Rice

The rehydration capability of prepared dried rice samples for different microwave power and drying time with combination of different oven temperature and drying time was tabulated in Table 1. The results obtained were calculated and have been converted to the percentage unit as can be seen in the table. In general, the percentage of rehydration capability of prepared dried rice was increased as both parameter conditions were increased. It can be related to the results obtained after 5 min of drying. The rehydration value is about 18 to 41% for temperature 70°C and 21 to 51% for temperature 90°C at all accelerated oven drying time. Water intake for prepared dried rice was also found higher during 5 min of drying. As the oven temperature and drying time were increased, rehydration capability of prepared dried rice was also increased (from 26 to 68% within 15 min). However, better rehydration capability was obtained when the power is 750 W compared to 450 W. This is perhaps due to the larger internal heat that is achieved when the power is higher. The opening pores of structure from high power can prevent the shrinkage on the samples resulting in good rehydration properties [31]-[33]. Moreover, the larger and hollow structure in the center formed due to high drying temperature allowing easy rehydration [25]. Studies [34]-[12] reported that higher rehydration occurred in more porous structure of dried rice. However, after 15 min drying, the rehydration values showed no significant different ($p > 0.05$) at 90 °C, 180 min for both power levels 450 and 750 W, corresponding to the increasing in intermittent drying time.

Interestingly, a study found that lower moisture content has better rehydration capability of prepared dried rice. This agrees with [28] which stated that rehydration rate of instant rice in combination of microwave-hot air drying was increased as microwave power level and air temperature were increased.

3.4 Color Analysis for Prepared Dried Rice

Color analysis for ready-to-eat dried rice was expressed in the form of L-, a- and b- values which represented different color of samples. The results for color analysis of dried rice samples after different drying power of microwave were depicted in Fig. 3 and 4, respectively. From figure, it is noted that L- value of dried rice samples was significantly decreased ($p < 0.05$) from 58.5 ± 1.5 – 27.7 ± 0.2 for microwave power 450 W to 49.7 ± 0.4 - 16.8 ± 0.9 for microwave power 750 W indicating that there is significantly darken for color samples after drying with higher amount of microwave power. This agrees with total color difference (ΔE) which shows that increasing in total color difference of prepared dried rice with increasing in microwave temperature and drying time.

From the results, it is noted that the combination of oven drying (T = 90 °C) with drying time = 180 min, microwave power = 750 W and intermittent drying time = 4 and 5 min have resulted in darkening and slightly increased in total color difference compared to lower drying conditions T = 70 °C with drying time = 70 min, microwave power = 450 W even though lower drying time has higher reduction in moisture content of dried rice samples. However, at drying conditions (T = 70 °C) and drying time = 180 min and oven temperature = 90 °C and drying time = 70 min for both power level 450 W and 750 W, it was found that the colour changing is moderated. This is perhaps due to the different composition in dried rice samples which influence the drying conditions. For example, at certain part of preparing dried rice samples, there is fastest effect of heating that is causing non-uniform colouration inside the samples. Consequently, there is a part in dried rice samples that is seen overheating (Fig. 5). However, this finding seems in agreement with study by [18]-[28] which found that the heating exposure from microwave and longer drying time on dried cooked rice had caused a more intense browning in colour samples. Studies [20]-[22] also revealed that the browning formation or darker in color of food products might also influence by enzymatic and non-enzymatic browning reaction and the destruction of pigments in the vegetables. This phenomenon can be considered as different components that has different thermal resistant capacity. Study [32] reported that high temperature level that is exceeded 100 °C has less significant effect to the colour difference of dried cooked rice.

Table 1 *Rehydration capabilities of prepared M2H (microwave power of 450 W and 750W)*

Drying Condition[1]	Microwave Power (W)						
		450			750		
	MWT	5 min	10 min	15 min	5 min	10 min	15 min
70,70	1	18±2$^{a, a, a}$	23±4$^{a, a, a}$	26±4$^{a, a, a}$	20±3$^{a, a, a}$	27±3$^{b, a, a}$	29±1$^{b, a, a}$
	2	20±1$^{a, a, a}$	26±0$^{b, b, a}$	29±1$^{c, a, a}$	29±1$^{a, b, a}$	36±2$^{b, b, a}$	39±1$^{b, b, a}$
	3	27±1$^{a, b, a}$	31±7$^{a, c, a}$	36±0$^{b, b, a}$	39±4$^{a, b, a}$	48±6$^{a, b, a}$	53±2$^{a, c, a}$
	4	28± 2$^{a, b, a}$	36±2$^{b, c, a}$	38±2$^{b, b, a}$	44±2$^{a, c, a}$	53±2$^{b, c, a}$	56±2$^{b, c, a}$
	5	34±2$^{a, b, a}$	44±3$^{b, c, a}$	48±4$^{b, b, a}$	44±4$^{a, c, a}$	58±4$^{b, c, a}$	63±3$^{b, c, a}$
70,130	1	22±2$^{a, a, a}$	29±3$^{a, a, a}$	32±4$^{a, a, a}$	25±3$^{a, a, a}$	32±5$^{a, a, a}$	36±5$^{a, a, a}$
	2	23±1$^{a, a, a}$	29±0$^{b, a, a}$	32±0$^{c, a, b}$	43±0$^{a, b, b}$	57±2$^{b, b, b}$	61±2$^{b, b, b}$
	3	35±7$^{a, a, a}$	47±1$^{a, b, b}$	49±3$^{a, a, a}$	44±2$^{a, b, a}$	57±0$^{b, b, a}$	64±0$^{c, b, a}$
	4	37±6$^{a, a, a}$	49±6$^{a, b, a}$	55±5$^{a, b, b}$	43±1$^{a, b, a}$	57±1$^{b, b, a}$	65±0$^{c, b, b}$
	5	41±3$^{a, b, a}$	55±2$^{a, b, a}$	62±2$^{b, b, a}$	41±3$^{a, b, a}$	56±2$^{b, b, a}$	64±3$^{b, b, a}$
70,180	1	28±1$^{a, a, b}$	38±0$^{b, a, b}$	42±3$^{c, a, b}$	33±4$^{a, a, a}$	44±5$^{a, a, a}$	49±5$^{a, a, b}$
	2	37±2$^{a, a, b}$	48±1$^{b, b, b}$	53±0$^{c, b, c}$	41±3$^{a, a, b}$	54±3$^{b, a, b}$	60±3$^{b, a, b}$
	3	41±4$^{a, a, b}$	56±4$^{b, b, b}$	62±2$_{b, c, b}$	38±4$^{a, a, a}$	53±4$^{b, a, a}$	60±4$^{b, a, a}$
	4	39±4$^{a, a, a}$	52±2$^{b, b, b}$	58±1$^{b, c, b}$	43±2$^{a, a, a}$	58±2$^{b, a, b}$	64±2$^{b, a, b}$
	5	41±1$^{a, a, a}$	55±2$^{b, c, a}$	62±2$^{b, c, a}$	41±1$^{a, a, b}$	53±1$^{b, a, a}$	60±0$^{c, a, a}$
90,70	1	21±1$^{a, a, b}$	23±1$^{a, a, b}$	26±1$^{b, a, b}$	25±5$^{a, a, a}$	31±5$^{a, a, a}$	35±4$^{a, a, a}$
	2	22±0$^{a, b, a}$	28±1$^{b, a, a}$	31±5$^{b, a, a}$	34±4$^{a, b, a}$	43±5$^{a, a, c}$	48±5$^{a, a, a}$
	3	25±5$^{a, b, a}$	31±5$^{a, a, a}$	33±4$^{a, a, a}$	41±0$^{a, b, a}$	54±0$^{b, b, a}$	61±0$^{c, b, a}$
	4	36±7$^{a, b, a}$	43±9$^{a, b, a}$	46±7$^{a, b, a}$	43±1$^{a, b, a}$	56±1$^{b, b, a}$	63±0$^{c, b, b}$
	5	44±2$^{a, b, a}$	56±2$^{b, b, a}$	62±0$^{b, b, a}$	40±0$^{a, b, b}$	55±0$^{b, b, a}$	62±0$^{c, b, a}$
90,130	1	41±0$^{a, a, c}$	56±2$^{b, a, c}$	61±3$^{b, a, c}$	32±6$^{a, a, a}$	42±7$^{a, a, a}$	47±7$^{a, a, b}$
	2	42±0$^{a, a, b}$	58±5$^{b, a, b}$	62±3$^{b, a, d}$	41±7$^{a, a, a}$	56±4$^{a, a, c}$	61±2$^{a, a, b}$
	3	43±1$^{a, a, b}$	59±4$^{b, a, b}$	66±6$^{b, a, b}$	38±1$^{a, a, a}$	54±0$^{b, a, a}$	61±0$^{c, a, a}$
	4	43±1$^{a, a, b}$	61±4$^{b, a, b}$	66±6$^{b, a, b}$	40±1$^{a, a, a}$	55±1$^{b, a, a}$	63±2$^{c, a, b}$
	5	56±2$^{a, a, a}$	61±7$^{b, a, a}$	68±3$^{b, a, a}$	41±1$^{a, a, b}$	57±0$^{b, a, b}$	64±0$^{c, a, a}$
90,180	1	35±1$^{a, a, d}$	53±6$^{b, a, c}$	59±4$^{b, a, c}$	45±2$^{a, a, b}$	59±1$^{b, a, b}$	66±5$^{b, a, b}$
	2	44±1$^{a, b, c}$	57±1$^{b, a, b}$	63±2$^{b, a, d}$	46±4$^{a, a, b}$	60±0$^{b, a, b}$	66±2$^{c, a, b}$
	3	44±0$^{a, b, c}$	58±1$^{b, a, b}$	64±2$^{c, a, b}$	48±2$^{a, a, a}$	61±5$^{b, a, a}$	67±3$^{b, a, a}$
	4	46±3$^{a, b, b}$	59±2$^{b, a, b}$	65±1$^{b, a, b}$	49±2$^{a, a, b}$	62±1$^{b, a, b}$	68±2$^{b, a, b}$

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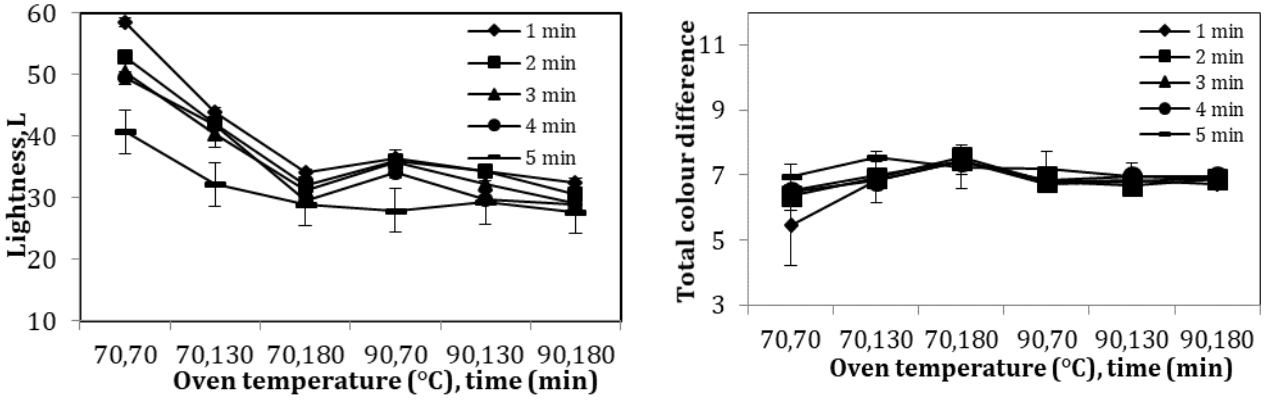
5	50±3[a, b, b]	60±5[b, a, b]	66±2[b, a, b]	51±2[a, a, a]	63±0[b, a, c]	68±2[b, a, a]

[1] oven drying at temperature (°C)
[a, b, c, d] different letters indicated significant differences (P < 0.05)
[a, b, c] different letters indicated significant differences (P < 0.05)

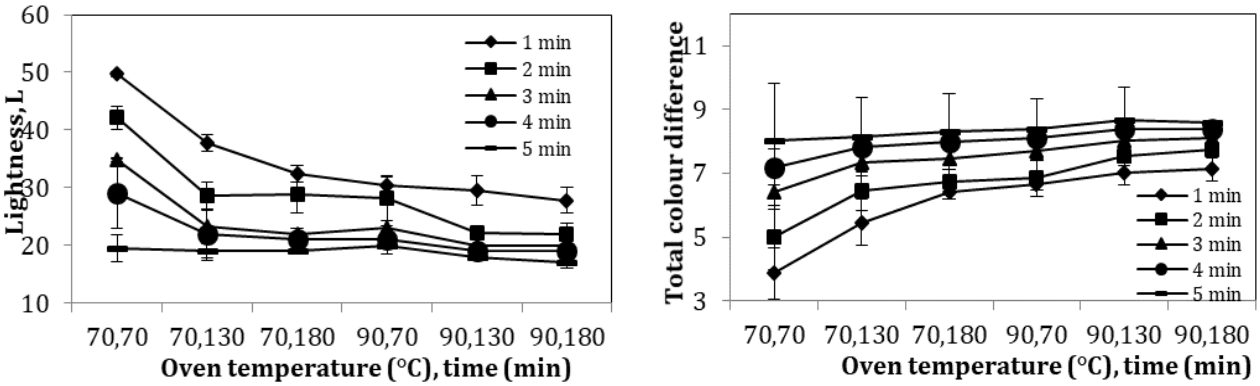
3.5 Water Activity (aw) of Prepared Dried Rice

From all the tests previously, only selected samples with good performance will be selected for water activity analysis onwards. The results obtained were tabulated in Table 2. From table 2, it found that overall results for water activity obtained by all the samples were relatively acceptable and less than 0.6aw. Study [35] reported that lower value for water activity might help in reducing the contamination especially caused by microorganisms since lower value (0.6) of water activity will retard the microorganism growth. However, statistical t-test shows that microwave oven drying and drying time have less significantly affected the water activity of selected samples.



(a) **(b)**

Fig. 3 *Color analysis for prepared dried rice at microwave power of 450 W*



(a) Lightness, L **(b) Total color difference (ΔE)**

Fig. 4 *Color analysis for prepared dried rice at microwave power of 750 W*

(a) Even distribution in color **(b) Over-heating in color**

Fig. 5 *Example of color different of prepared dried rice after drying in microwave drying*

(a) Dried rice at microwave drying time 3 min and power level at 450W
(b) Dried rice at microwave drying time 3 min and power level at 750W

Table 2 *Water activity and texture analysis of prepared M2H foods*

OVEN	MICROWAVE		WATER ACTIVITY (a_w)[1]	HARDNESS (N)[2]	
TEMPERATURE (°C)	DRYING TIME (min)	POWER LEVEL (W)	DRYING TIME (min)		
90	130	450	4	0.4436±0.0345[a]	28.91 ± 8.45[a]
90	180	450	4	0.4462±0.0302[a]	40.89 ± 6.14[a]
90	180	750	2	0.5055±0.0044[a]	20.74 ± 8.26[a]

[1]Mean values in rows with different letters indicated significant differences (P > 0.05)
[2]Mean values in rows with different letters indicated significant differences (P < 0.05)

3.6 Texture Evaluation for Prepared Dried Rice

Texture evaluation with respective hardness of the selected samples was recorded in Table 2. From the results, the hardness of dried rice sample was harder when drying conditions (90 °C, 180 min, 450 W, 4 min) compared to condition (90 °C, 130 min, 450 W, 4 min) and (90 °C, 180 min, 750 W, 2 min), respectively. However, lower hardness values (20.74 N ± 8.26) were found when drying conditions are at 90 °C, 180 min, 750 W, 2 min that is two times lower than hardness value of conditions (90 °C, 180 min, 750 W, 2 min). Moreover, the hardness of prepared dried rice at oven drying time (i.e. 180 min) was higher than short drying time (i.e. 130 min). However, when comparing the hardness between different microwave power applied, the hardness of prepared dried rice samples treated at 750 W with short period drying time has low value compared to 450 W. This agrees with [26] which stated that increasing in microwave power will cause lower fracture density and hardness of dried foods which similar to the freshly cooked rice. This is since higher microwave power will penetrate the large internal heat in the interior and creates a flux of rapidly escaping water vapors and therefore, causing expansion and opening of pores in the structure of dried food products [22]-[27]. Statistical t-test shows that drying conditions have no significant influence (P > 0.05) to the prepared dried rice.

3.7 Nutrient Composition in Prepared Dried Rice

Nutrient composition for prepared dried rice under different temperature and power and drying time was tabulated in Table 3. From table, it is determined that in general, the composition for carbohydrates was about 57.02 to 65.96% wt., protein 6.49 to 7.77% wt., fat 17.35 to 19.68% wt., and ash 3.40 to 3.53% wt., respectively. From all the conditions, prepared dried rice samples under oven temperature of 90°C, drying time 130 min, microwave power 450 W and drying time 4 min was found to have higher protein, fat and ash contents compared to other conditions. However, highest carbohydrate content was observed for the dried rice samples under oven temperature of 90°C, drying time 180 min, microwave power 750 W and drying time 2 min (65.9%

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wt.), followed by dried rice samples of the same condition oven with 450 W and 4 min of microwave condition (64.71% wt.) and dried rice samples under 90°C and 130 min oven condition with the same microwave condition (57.02% wt.), respectively. A large amount of carbohydrate in prepared dried rice for all conditions was obtained due to highest amount of carbohydrate in rice [36] indicating that the rice is a good source for carbohydrate, and it is recommended in ready-to-eat foods as it provides more energy required in human body. According to statistical analysis, these results showed that drying conditions for this study has significantly ($P < 0.05$) affected the nutrient compositions for prepared dried rice samples.

Table 3 *Nutrient compositions of prepared M2H foods*

Oven		Microwave		Carbohydrate (%)	Proteins (%)	Fat (%)	Ash (%)	Total Energy (Kcal)
Temperature (°C)	Drying Time (Min)	Power Level (W)	Drying Time (Min)					
90	130	450	4	57.02±1.21^{a}	7.77±0.20^{a}	19.68±1.33^{b}	3.53±4x10^{-4b}	221.46
90	180	450	4	64.71±1.35^{b}	6.49±0.36^{b}	17.35±0.95^{b}	3.4±1.2x10^{-3b}	240.35
90	180	750	2	65.96±1.49^{b}	6.8±1.55^{b}	17.80±0.22^{b}	3.5±1.0x10^{-4b}	244.12

$^{a, b}$Mean values in rows with different letters indicated significant differences ($P < 0.05$)

4. Conclusion

The synergistic effect of oven-microwave during preparation has led to successfully preparing a well-balanced ready-to-eat (RTE) dried rice. At temperature 90°C of oven with drying time of 130 and 180 min and microwave power of 450 and 750W with drying time in the range of 3 to 5 min, it has significantly affected the moisture content of dried rice samples. Rehydration capability of dried rice is increased when oven-microwave temperature and drying time increased. The pale-yellow color of dried rice was obtained as the drying temperature and the time for drying was changing. Nevertheless, high power level of microwave for example 750 W and longer drying time that is more than 5 min did not suitable for drying dried rice samples. In terms of water activity, studies found that at lower value of water activity (0.6aw), dried rice samples were found to have a longer shelf-life compared to others. As for nutritional matters, dried rice sample has successfully retained approximately 57.02-65.9% wt. of carbohydrates, 6.49-7.77% wt. of protein, 17.35-19.68% wt. of fat and 3.4-3.53% wt. of total ash indicate that the parameter condition used in this study does not tremendously reduce the nutrient inside ready-to-eat dried rice samples.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Thaibah Ali, Dayang Norulfairuz Abang Zaidel;* ***data collection:*** *Thaibah Ali;* ***analysis and interpretation of results:*** *Thaibah Ali, Dayang Norulfairuz Abang Zaidel, Ida Idayu Muhamad, Yanti Maslina Mohd Jusoh;* ***draft manuscript preparation:*** *Nurul Asmak Md Lazim, Dayang Norulfairuz Abang Zaidel. All authors reviewed the results and approved the final version of the manuscript.*

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