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Research article

Formulation of crispy chicken burger patty batter: Properties and storage qualities

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Abstract: This study formulated the batter systems for crispy chicken burger patties using wheat flour-based batter and rice flour-based batter with the ratios of 2:2:1:1 and 2:1:2:1 (wheat flour/rice flour: corn flour: crispy flour: spicy flour). The crispy chicken burger patties were evaluated in terms of proximate compositions (moisture, ash, fat, protein, and carbohydrate contents) and sensory analysis. Crispy chicken burger patties made from rice flour-based batter with a formula ratio of 2:2:1:1 (RFBB1) were found to exhibit the lowest moisture and fat compositions but the highest protein composition. The sensory properties were evaluated using the 9-point hedonic scaling method in terms of overall acceptability, appearance, taste, crispness, juiciness, and color, which revealed that RFBB1 exhibited the best acceptability scores for all attributes. Then, the storage qualities of crispy chicken patties packed using different types of packaging materials (low-density polyethylene (LDPE), medium-density polyethylene, and high-density polyethylene) and stored at different temperatures (−18, 4, and 25 °C) for 12 days were investigated in terms of color and texture. Regardless of the types of packaging materials and storage temperature, the hardness of crispy chicken burger patties decreased over time but crispness increased due to the reduction in moisture content. In terms of hardness and crispness, the RFBB1 was best packed in LDPE packaging material and stored at either cold or frozen temperatures.

Keywords: batter; crispy burger; formulation; packaging; proximate composition; sensory analysis

1. Introduction

Demand for battered food products has been increasing dramatically throughout the world due to their palatability. Thus, in collaboration with a manufacturing company, a new product, which is crispy chicken burger patty, is being developed whereby different batter coating formulations are investigated for the production of crispy chicken burger patties. This new battered and deep-fried product is developed from an existing burger patty. To the best of knowledge, no work has been conducted to investigate different batter coating formulations for the crispy chicken burger patties and no work have been done to produce crispy burgers using patties; instead, many of the work use chicken breasts as a substitution for patties to produce crispy burgers.

To obtain the intended product and the customers' satisfaction, many elements must be addressed, including the choice of ingredients for the batter coating, the formulation used in batter preparation, acceptable packaging, and appropriate storage conditions [1]. The crispy burger patty should have a soft and deformable interior surrounded by a dry, firm, and crunchy crust. The final structure of the crispy burger patties is strongly dependent on the compositions of the core and crust after processing, particularly the water content and coating material composition [2]. The desired results can be obtained by employing an appropriate deep-frying method that is influenced by the frying operation, frying time, and frying temperature [3]. The outer layer of the crispy burger patties is the part that is exposed to high temperatures (hot oil in the deep fryer) during deep-frying, which dehydrates it and thus, provides a crispy crust that is a crucial sensory quality factor [2].

The different batter coating formulation ratios using either rice flour-based or wheat flour-based with extra ingredients such as corn flour, crispy flour, spicy flour, and eggs for the production of crispy chicken burger patties are worth to be investigated to achieve desirable products. Rice flour has been utilized in batter systems since it is a healthier alternative with fewer calories for people who are gluten intolerant [4]. It also has appealing desirable properties, such as crispy and light texture, that make it ideal for a variety of applications, including batters. It has been reported that rice flour can be a substitution for wheat flour in a batter to assist reduce oil absorption while frying. Rice flour is more effective at reducing fat absorption than wheat flour but has a lower ability to thicken the batter [5]. Jackson et al. [6] have evaluated consumer preferences for rice flour and wheat flour-fried chicken nuggets and found that consumers did not differ in their liking of rice and wheat-fried chicken nuggets.

Several studies have revealed that the strongest quality attributes for burger patties are flavor, appearance, juiciness, texture, and healthiness [7–9]. At the customer level, the healthiness, appearance, and eating quality of a food product have similar weights in the formation of quality expectations before a purchase, but eating quality stands out as the most decisive criterion that shapes the quality experience, satisfaction, or dissatisfaction, and future purchase [10,11]. Therefore, understanding consumers' perception of crispy chicken burger patty attributes is vital to ensure acceptance of the product.

Meanwhile, food packaging is an important factor in the food industry to maintain product quality during storage while ensuring consumers' safety and convenience [12]. Plastic-type packaging is the most commonly used packaging material for small-medium businesses (SMEs) that produce deep-fried foods because it is not only capable of preserving food from moisture, gases, bacteria, and insects, but it is also inert, lightweight, and inexpensive. Low-density polyethylene (LDPE), high-density polyethylene (HDPE), medium-density polyethylene (MDPE), and polyethylene terephthalate (PETE or PET) are examples of such packaging.

The storage quality of the crispy chicken burger patties is dependent on both the packaging material and the storage temperature at which they are kept. Good packaging is very much important because the packaging does not only function to keep and protect the content but also as a medium to attract and educate the consumers about the product [12]. Food packaging can also help to extend the shelf-life of food by conserving the product from deterioration, retaining the beneficial effects of processing, and maintaining the quality and safety of the food [13]. Furthermore, storage temperatures also play an important role in maintaining the quality of the product during storage. For instance, food quality will deteriorate very quickly if not stored at proper temperatures. Food shelf-life, if stored at room temperature is usually lower than that stored in the refrigerator and freezer due to enhancement in bacteria and mold growth. Therefore, proper packaging materials and storage conditions are essential to be investigated in maintaining the quality of crispy chicken burger patty produced.

The aim of this work has been directed to investigate different batter coating formulation ratios which were 2:2:1:1 and 2:1:2:1 (wheat flour/rice flour: corn flour: crispy flour: spicy flour) for the production of crispy chicken burger patties. Sensory analysis which includes overall acceptability, appearance, taste, crispness, juiciness, and color of crispy chicken burger patties using the 9-point hedonic scaling method was conducted to ensure the acceptance of the consumers towards the developed product and to determine how the consumers like their crispy chicken burger patties to be. Apart from that, proximate compositions such as moisture, ash, fat, protein, and carbohydrate contents of crispy burger patties at different formulations were also determined because they would also affect the consumers' acceptance of the product. Moreover, the effects of types of packaging materials (LDPE, MDPE, and HDPE) and storage temperatures (room temperature: 25 ℃, cold temperature: 4 ℃, and frozen temperature: −18 ℃) on the quality of crispy chicken burger patties particularly texture and color were also investigated to ensure the quality of the products.

2. Materials and methods

2.1. Raw materials

The chicken burger patties were obtained from the small-medium enterprise (SME) company, Juara Rasa Maju Sdn. Bhd. The raw materials include wheat flour (Cap Sauh, FFM Berhad, Malaysia), corn flour (Cap Bintang, Thye Huat Chan Sdn. Bhd., Malaysia), crispy flour (Adabi Consumer Industries Sdn. Bhd. (ACISB), Malaysia), spicy flour (Bestari, Bestari Food, Malaysia), rice flour (Cap 1 Gajah, Titi Serong Sdn. Bhd., Malaysia), sunflower and canola oil (Naturel, Lam Soon Edible Oils Sdn. Bhd., Malaysia) and grade A eggs were bought from the local market at Seri Kembangan, Selangor.

2.2. Batter preparation

Batter formulas that differed in flour-based sources (wheat and rice) and ratios (2:2:1:1, 2:1:2:1 - wheat flour/rice flour: corn flour: crispy flour: spicy flour) were prepared. The first batter formulation consisted of wheat flour (WF), corn flour (CF), crispy flour (CR), spicy flour (SF), and 4 eggs, while the second batter formulation consisted of rice flour (RF), CF, CR, SF, and 4 eggs. Table 1 shows four different batter formulations namely wheat flour-based batter 1 (WFBB1), rice flour-based batter 1 (RFBB1), wheat flour-based batter 2 (WFBB2), and rice-flour-based batter 2 (RFBB2).

Table 1. Ingredients used in the batter formulation of the crispy chicken burger patties.

	Formulation (%)			
Ingredients	WFBB1	RFBB1	WFBB2	RFBB2
Wheat flour	50	-	50	-
Rice flour	-	50	-	50
Crispy flour	50	50	25	25
Corn flour	25	25	50	50
Spicy flour	25	25	25	25

The different flours were weighed using a weighing balance (Dura Tools, Dura Tools Sdn. Bhd, Malaysia). Then, they were sieved through a 200-mesh sifter (IKEA, IKEA Malaysia, Malaysia) to obtain a homogenous flour mixture. Half of the flour mixture was added to a stand kitchen mixer (MK-GB3WSK, Panasonic Malaysia Sdn. Bhd., Malaysia). After that, eggs were added to the mixer and the mixer was continuously stirred at low speed for 20 seconds to produce a batter. After that, the frozen chicken burger patties were allowed to defrost at room temperature for about 10 seconds before use. It is worth noting that defrosting the chicken burger patties for more than 10 seconds would make them too soft and hard to coat. Then, frozen chicken burger patties were dipped into the batter for about 20 seconds and allowed to drip for 10 seconds manually using a hand. After that, the chicken burger patties were coated with another half of the flour mixture. The battered burger patties were deep-fried immediately using an electric deep-fryer (American Micronic, American Micronic Instruments, India). The same procedures were repeated for different sample formulas and ratios.

Before deep-frying, the fresh sunflower canola oil was preheated and maintained at 180 ± 2 °C for half an hour. Battered chicken burger patties were deep-fried in the deep-fryer for 5 minutes at the temperature of 180 °C until they became light golden brown. Fried crispy chicken burger patties were then drained on paper towels and cooled to room temperature (25 °C). Sunflower canola oil was chosen for frying because it is inexpensive, has a high smoke point (230 °C), and is not extracted from a product that is a food allergen such as soybean oil.

2.3. Determination of proximate compositions

The moisture, ash, protein, and fat contents were determined in terms of percentage according to the standard methods of the Association of Analytical Chemists (AOAC) [14].

2.3.1. Determination of moisture content

The moisture content for different formulations of crispy chicken burger patties was determined using an oven drying method based on the AOAC Method 950.46 [14]. Approximately 5.0 g of sample was weighed in a crucible and dried for 3 h at 105 °C in an oven (Memmert, Memmert GmbH + Co.KG, Germany). Then, the sample was cooled in a desiccator and weighed again. The sample was then returned to the oven for further drying. Drying, cooling, and weighing were done repeatedly at hourly intervals until a constant weight was obtained. The moisture content was calculated as the percentage of the sample weight loss due to the oven drying to the sample weight as the following:

$$\text{Moisture content (\%)} = (W - A)/W \times 100 \quad (1)$$

where W is the weight of the samples in grams and A is the dry weight of the sample in grams.

2.3.2. Determination of ash content

The ash content was obtained after the incineration of moisture-free dry samples in a muffle furnace (Carbolite, Carbolite Gero, UK) at 550 °C for 6 h according to the AOAC Method 923.03 (AOAC, 2016). Approximately 3.0 g of the sample was measured in a previously weighed porcelain crucible. The sample was burnt to ashes in a muffle furnace. When the sample had completely become ash (white), the sample was cooled in a desiccator and weighed. The procedures were repeated until a constant weight is achieved. The weight of ash obtained was determined by difference and calculated as a percentage of the weight of the sample analyzed:

$$\text{Ash content } (\%) = ((B + C) - C) \times 100/W \quad (2)$$

where B is the weight of crucible and ash in grams, C is the weight of crucible in grams, and W is the weight of the samples in grams.

2.3.3. Determination of fat content

Fat content was determined by the Soxhlet extraction method described by AOAC Method 991.36 (AOAC, 2016). An amount of 3 g of the samples was accurately weighed into an extraction thimble containing cotton wool which was then transferred into the Soxhlet extractor (Gerhardt Soxtherm, Gerhardt GmbH & Co. KG, Germany). The fat was extracted in an 8-hour reflux flask with 40 mL of petroleum ether (Systerm, Lab Engineering Sciences Sdn. Bhd., Malaysia) as the solvent. A rotary evaporator was used to evaporate the fat. To eliminate any leftover solvent, the flask (containing the oil extract) was dried in an oven at 125 °C for 30 min. The flask was then cooled in a desiccator and weighed. This process was allowed to go on repeatedly for 4 h before the defatted sample was removed, the solvent was recovered, and the oil extract was left in the flask. The fat content of crispy chicken burger patties was reported as the percentage of the residue in the vessel to the crispy chicken burger patties sample weight as the following:

$$\text{Fat content } (\%) = (W \times 100)/D \quad (3)$$

where W is the weight of the sample in grams and D is the weight of oil in grams.

2.3.4. Determination of protein content

The approved AOAC (2006) Kjeldahl 992.15 [14] method was used for protein determination. An amount of 0.5g of the sample was accurately weighed and placed in a Kjeldahl digestion flask, folded in a nitrogen-free filter paper. A catalyst tablet (Carl Roth, Carl Roth GmbH & Co. KG, Germany) and sulphuric acid (H_2SO_4) (Systerm, Lab Engineering Sciences Sdn. Bhd., Malaysia) were carefully added to digest the sample in a fume chamber. A 40% NaOH (Systerm, Lab Engineering Sciences Sdn. Bhd., Malaysia) solution was used for back titration against a 0.1 N NaOH solution. A 6.25 was used as the standard conversion factor for nitrogen into the protein content of the sample. A reagent blank was also digested, distilled, and titrated. The nitrogen content and hence the protein content was calculated using the following formula:

$$\text{Protein content (\%)} = (V_a - V_b) \times 1.4 \times M \times 6.25 \quad (4)$$

where V_a is the volume of standard acid required for the test portion, V_b is the volume of standard acid to titrate blank, M is the molarity of standardized acid, and 6.25 is the protein factor.

2.3.5. Determination of carbohydrate content

The total percentage of carbohydrate content was estimated by subtracting the sum of fat content, protein content, ash content, and moisture content from 100 as follows:

$$\text{Carbohydrate (\%)} = 100 - (\text{Moisture (\%)} + \text{Ash (\%)} + \text{Fat (\%)} + \text{Protein (\%)}) \quad (5)$$

2.4. Sensory evaluation

Sensory evaluation was conducted in the laboratory of the Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia. The hedonic test was done according to Lawless and Heymann [15]. The sensory attributes that were evaluated were overall acceptability, appearance, taste, crispiness, juiciness, and color. A total of 30 untrained panelists which consisted of students from the Department of Process and Food Engineering were served with quarter parts of the burgers just after frying. The panelists were instructed to taste and evaluate the samples using an evaluation sheet of hedonic scores. The evaluation was performed in triplicate for each sample. The scores were based on a 9-point hedonic scale ranging from 1 (Dislike Extremely) to 9 (Like Extremely). Unsalted crackers and water were given to panelists to refresh their palates before tasting subsequent samples.

2.5. Storage qualities of crispy burger patties

The fried crispy burger patties were cooled down to room temperature (25 °C) and immediately packed in three different types of packaging materials including LDPE MDPE, and HDPE using an impulse sealer. Then, the packed crispy burger patties were stored at three storage temperatures, which were room temperature (25 °C), cold temperature (4 °C), and frozen temperature (−18 °C). The storage qualities of the samples were analyzed in terms of texture and color at 0, 3, 6, 9, and 12 day of intervals.

Color analysis of crispy burger patties was performed using a color spectrophotometer (UltraScan Pro Spectrophotometer, Hunter Lab, USA) at a visual angle of 10° equipped with a D65 illuminant. The CIE Lab-scale was used, where L*, a*, and b* indicated black (0) to white (100), red (+) to green (−), and yellow (+) to blue (−), respectively. Calibration was performed using a white plate.

The hardness and crispness of crispy chicken burger patties were determined using a texture analyzer (TA.XT2, Stable Micro System Ltd., UK). After frying, the samples were allowed to cool to room temperature. Cubic samples (1 × 1 × 1 cm) were cut from the crispy burger patties and tested for two-cycle compressions. The samples were compressed to 70% of their original height with a cylindrical probe of 10 cm in diameter at a compression load of 25 kg and a cross-head speed of 20 cm/min [16]. The hardness of the samples was assessed from the force-time plot as the highest peak force measured during the first compression, whereas the crispiness of the samples was reported as the first significant peak or the first fracture point in the first compression [17].

2.6. Statistical analysis

Analysis of variance (ANOVA) was performed using Minitab software (Minitab 20.3, Minitab LLC, USA). Tukey's test was used to compare the means between the samples and the statistical significance was established at $p < 0.05$. All experiments in Sections 2.3 and 2.5 were repeated at least three times under the same conditions (same temperature, storage days, and equipment) using three different crispy burger patty samples for each formulation, produced using the same ingredients and raw materials as well as went through processing on the same day.

3. Results and discussion

3.1. Proximate analysis

Table 2 presents the moisture, ash, fat, protein, and carbohydrate compositions of the crispy chicken burger patties. The use of different flour-based at different ratios of formulations did not affect the ash and carbohydrate contents but affected the moisture, fat, and protein composition of the crispy chicken burger patties. The moisture content of the crispy chicken burger patties with WFBB formulations was slightly higher ($p < 0.05$) than the RFBB formulations. These findings were supported by Adedeji and Ngadi [18] who reported that batter formulated with wheat flour retained more moisture compared to rice flour due to higher fiber content that contains non-starchy polysaccharides which possess water-binding capacity [19].

Table 2. Proximate compositions of crispy chicken burger patties made with different formulations.

Proximate compositions (%)					
Sample	Moisture	Ash	Fat	Protein	Carbohydrate
WFBB1	39.57 ± 0.44^a	2.10 ± 0.02^a	12.85 ± 0.49^a	10.96 ± 0.10^b	34.52 ± 0.30^a
RFBB1	37.49 ± 0.55^b	2.12 ± 0.02^a	10.45 ± 0.77^b	12.34 ± 1.03^a	37.61 ± 2.33^a
WFBB2	39.23 ± 0.11^a	2.16 ± 0.01^a	12.78 ± 0.38^a	10.84 ± 0.69^b	35.00 ± 0.19^a
RFBB2	37.37 ± 0.17^b	2.14 ± 0.01^a	10.10 ± 0.17^b	12.24 ± 0.06^a	38.16 ± 0.05^a

*Values in the same column showing the same small letters are not significantly different ($p > 0.05$).

Meanwhile, the fat content exhibited a similar trend to that of moisture content. A similar trend of the results was reported by Jackson et al. [6] where the fat content for fried chicken nuggets with wheat batter treatments was higher than that of fried chicken nuggets with rice batter treatments. Shih and Daigle [20] reported that rice flour-based batters absorbed less oil during frying compared to wheat flour-based batters which proved why WFBB contained more fat compared to RFBB.

For the protein composition, it was found that WFBB contained less protein than RFBB. Jackson et al. [6] in their work revealed that wheat flour contained a slightly lower amount of protein (20.00%) compared to rice flour (20.13%). This supported the findings in this study whereby WFBB contained a slightly lower amount of protein than RFBB. On the other hand, the use of different flour-based formulations did not affect the carbohydrate compositions probably due to the usage of the same amount of wheat and rice starch in the flours. The ash content for the crispy chicken burger patties was also not affected by the different ingredients and formulations probably due to the low mineral content in all the flour used whereby the mineral turned into ashes when burnt [21].

3.2. Sensory analysis

The evaluation of sensory attributes for crispy chicken burger patties made using different formulations and ratios of batter coatings are presented in Table 3. The results show the preference for crispy chicken burger patties in terms of overall acceptability, appearance, taste, crispness, and color was the highest for RFBB1 compared to others. The ranking for all the attributes was followed by WFBB1, RFBB2, and WFBB2 formulations. It is important to point out that all the attributes obtained scores ranging from 5.80 to 8.90 which represent a classification of "Neither Like nor Dislike" to "Like Very Much" according to the 9-point hedonic scale. Since the values for all the attributes were higher than 5, this indicated that all the formulations were acceptable whereby all the panelists accepted and/or liked all the crispy chicken burger patties made from different formulas and ratios of batter coatings.

Table 3. Sensory evaluation results of crispy chicken burger patties produced using different formulas and ratios.

	WFBB1	RFBB1	WFBB2	RFBB2
Overall Acceptability	8.40 ± 0.50^{ab}	8.53 ± 0.51^{a}	7.83 ± 0.79^{c}	7.77 ± 0.73^{b}
Appearance	8.80 ± 0.41^{a}	8.90 ± 0.31^{a}	7.67 ± 0.71^{b}	7.83 ± 0.75^{b}
Taste	8.40 ± 0.50^{a}	8.60 ± 0.50^{a}	6.73 ± 1.14^{b}	6.77 ± 0.57^{b}
Crispness	7.97 ± 0.50^{b}	8.83 ± 0.50^{a}	7.90 ± 0.59^{b}	8.73 ± 0.61^{a}
Juiciness	8.10 ± 0.31^{a}	7.17 ± 0.38^{b}	7.83 ± 0.38^{a}	6.77 ± 0.50^{c}
Colour	8.77 ± 0.43^{a}	8.80 ± 0.41^{a}	8.73 ± 0.45^{a}	8.73 ± 0.45^{a}

*Values in the same row showing the same small letters are not significantly different ($p > 0.05$).

For the overall acceptability attribute, the mean values for WFBB1 and RFBB1 were higher than for WFBB2 and RFBB2. This finding shows that the panelists preferred crispy chicken burger patties made from both wheat flour-based batter and rice flour-based batter with a ratio of 2:2:1:1 compared to both flour-based batters with the ratio of 2:1:2:1. The panelists preferred the crispy chicken burger patties with rice/wheat flour combined with a higher amount of crispy flour compared to that combined with a higher amount of corn flour. This was most likely attributable to the combination of the rice/wheat flour with a higher amount of crispy flour resulting in a crispier final product.

Figure 1 shows the effects of different formulations of the batters on the appearance of the crispy chicken burger patties after frying. For the appearance attributes, the mean values were insignificantly different between formulations of the same ratio. For example, WFBB1 and RFBB1 mean values were insignificant to each other, as were WFBB2 and RFBB2. On the other hand, the mean values for the ratio of 2:2:1:1 were slightly higher than 2:1:2:1 might be due to WFBB1 and RFBB1 containing a higher amount of crispy flour, producing a crispier texture on the surface which contributed to a more preferable appearance compared to WFBB2 and RFBB2. Nonetheless, the crispy texture of the crispy chicken burger patties after frying was hardly distinguished from Figure 1. All the samples were in the ideal color which was light golden brown, due to the browning reaction during frying as shown in Figure 1, consistent with the mean values for the color attribute that were insignificantly different between all the formulations as tabulated in Table 3.

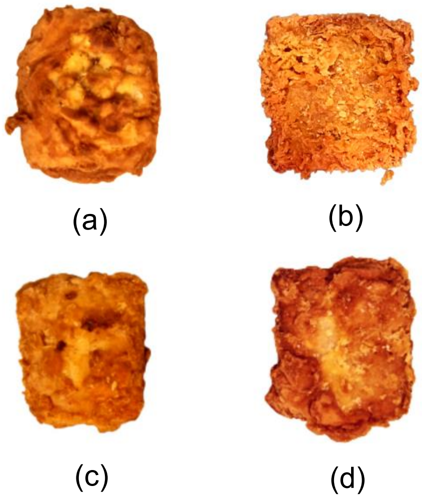

Figure 1. The appearance of crispy chicken burger patties after frying made with different formulas and ratios of (a) WFBB1, (b) RFBB1, (c) WFBB2, and (d) RFBB2.

For the taste attributes, the mean values for WFBB1 and RFBB1 (8.40 and 8.60, respectively) were higher than the mean values of WFBB2 and RFBB2 (6.73 and 6.77, respectively). The use of the ratio formulation of 2:2:1:1 was preferable to that of 2:1:2:1 due to the higher content of crispy flour which resulted in a crispier texture, thus improving the taste of the crispy chicken burger patties. For the crispness attribute, there was a significant difference between samples made from wheat flour-based batter and rice flour-based batter but there was no significant difference between the same flour-based at different ratios. The RFBB1 and RFBB2 had almost the same crispness level within the value range of 8.73-8.83 while WFBB1 and WFBB2 also had almost the same crispness level within the value range of 7.97-7.90 which was lower than that of samples made from rice flour-based batter. This was because of the differences in the properties of flour used. According to Tortoe et al. [22], rice flour-based batter resisted oil absorption and moisture better than wheat flour-based batter, thus the differences in crispness could arise from air spaces that may form within the crisp structure, sogginess, and moisture uptake after frying.

Meanwhile, for the juiciness attribute, the mean values for crispy chicken burger patties with WFBB formulations (8.10 and 7.83 for WFBB1 and WFBB2, respectively) were higher than the RFBB formulations (7.17 and 6.77 for RFBB1 and RFBB2, respectively). The juiciness attribute can be related to the moisture trapped inside the samples after frying as discussed previously.

It can be deduced that the most preferred samples were the samples that contain a higher amount of crispy flour due to the crispier texture, producing a better appearance and better taste of the samples. Nonetheless, rice flour formulation was preferred over wheat flour in terms of crispness while wheat flour formulation was preferred over rice flour in terms of juiciness.

3.3. *Storage qualities of crispy burger patties*

The storage qualities of crispy chicken burger patties made with RFBB1 formulation, packed using three types of packaging materials which were LDPE, MDPE, and HDPE, and stored at three temperatures which were room temperature (25 °C), cold temperature (4 °C), and frozen temperature (−18 °C) for 12 days were investigated in terms of color changes and texture. Color is an important quality attribute of fried battered food. The ideal color for fried battered food is light golden brown which is due to the browning reaction during frying. Table 4 presents the L* and b* values while Figure 2 shows the percentage changes of L* and b* values of crispy chicken burger patties during storage. Note that there was no measurement of L* and b* values for crispy chicken burger patties stored at 25 °C on days 6, 9, and 12 because the qualities of crispy chicken burger patties deteriorated over time and have reached shelf-life limits whereby mold started to grow when kept for longer than 3 days at room temperature. Meanwhile, the a* value was not discussed since this value (positive a* = redness; negative a* = greenness) is not related to deep-fried food color.

Table 4. L* and b* values for crispy chicken burger patties packed in 3 types of packaging materials (LDPE, MDPE, and HDPE) stored at frozen (−18 °C), cold (4 °C), and room (25 °C) temperatures during 12 days of storage.

Days	0	3	6	9	12
Lightness (L*)					
LDPE Packaging					
−18 °C	48.58 ± 0.09^{c}	45.66 ± 0.11^{d}	39.69 ± 0.04^{c}	39.26 ± 0.31^{d}	37.85 ± 0.02^{d}
4 °C	48.27 ± 0.23^{c}	46.06 ± 0.09^{d}	47.74 ± 0.39^{a}	44.17 ± 0.41^{b}	38.67 ± 0.07^{c}
25 °C	52.51 ± 0.03^{a}	50.37 ± 0.21^{a}	-	-	-
MDPE Packaging					
−18 °C	44.73 ± 0.45^{e}	42.85 ± 0.36^{e}	40.12 ± 0.28^{e}	37.43 ± 0.07^{e}	35.27 ± 0.05^{f}
4 °C	50.45 ± 0.04^{b}	49.39 ± 0.04^{b}	47.63 ± 0.26^{b}	46.23 ± 0.03^{a}	40.13 ± 0.10^{b}
25 °C	52.03 ± 0.17^{a}	50.61 ± 0.11^{a}	-	-	-
HDPE Packaging					
−18 °C	43.55 ± 0.12^{f}	41.33 ± 0.13^{f}	38.47 ± 0.08^{d}	37.47 ± 0.07^{e}	36.70 ± 0.04^{e}
4 °C	47.37 ± 0.16^{d}	45.93 ± 0.05^{d}	45.87 ± 0.02^{b}	42.84 ± 0.02^{c}	40.43 ± 0.02^{a}
25 °C	48.76 ± 0.13^{c}	46.67 ± 0.04^{c}	-	-	-
Yellowness (b*)					
LDPE Packaging					
−18 °C	6.66 ± 0.11^{a}	8.22 ± 0.13a	12.95 ± 0.43^{a}	14.24 ± 0.11^{b}	17.91 ± 0.21^{a}
4 °C	6.60 ± 0.04^{a}	8.20 ± 0.23^{a}	12.04 ± 0.38^{b}	12.90 ± 0.07^{c}	15.80 ± 0.18^{c}
25 °C	4.95 ± 0.13^{c}	5.90 ± 0.25^{d}	-	-	-
MDPE Packaging					
−18 °C	5.88 ± 0.10^{b}	7.64 ± 0.24^{ab}	10.55 ± 0.64^{c}	10.72 ± 0.30^{e}	12.36 ± 0.09^{e}
4 °C	3.68 ± 0.30^{d}	4.78 ± 0.23^{e}	7.66 ± 0.19^{e}	10.81 ± 0.09^{e}	11.24 ± 0.14^{f}
25 °C	3.58 ± 0.22^{d}	2.74 ± 0.19^{f}	-	-	-
HDPE Packaging					
−18 °C	5.54 ± 0.42^{bc}	7.45 ± 0.26^{bc}	9.22 ± 0.29^{d}	14.84 ± 0.07^{a}	17.29 ± 0.20^{b}
4 °C	5.29 ± 0.27^{bc}	7.26 ± 0.26^{bc}	7.44 ± 0.24^{e}	11.31 ± 0.11^{d}	14.81 ± 0.24^{d}
25 °C	5.93 ± 0.30^{b}	6.93 ± 0.21^{c}	-	-	-

* Values in the same row showing the same small letters are not significantly different ($p > 0.05$).

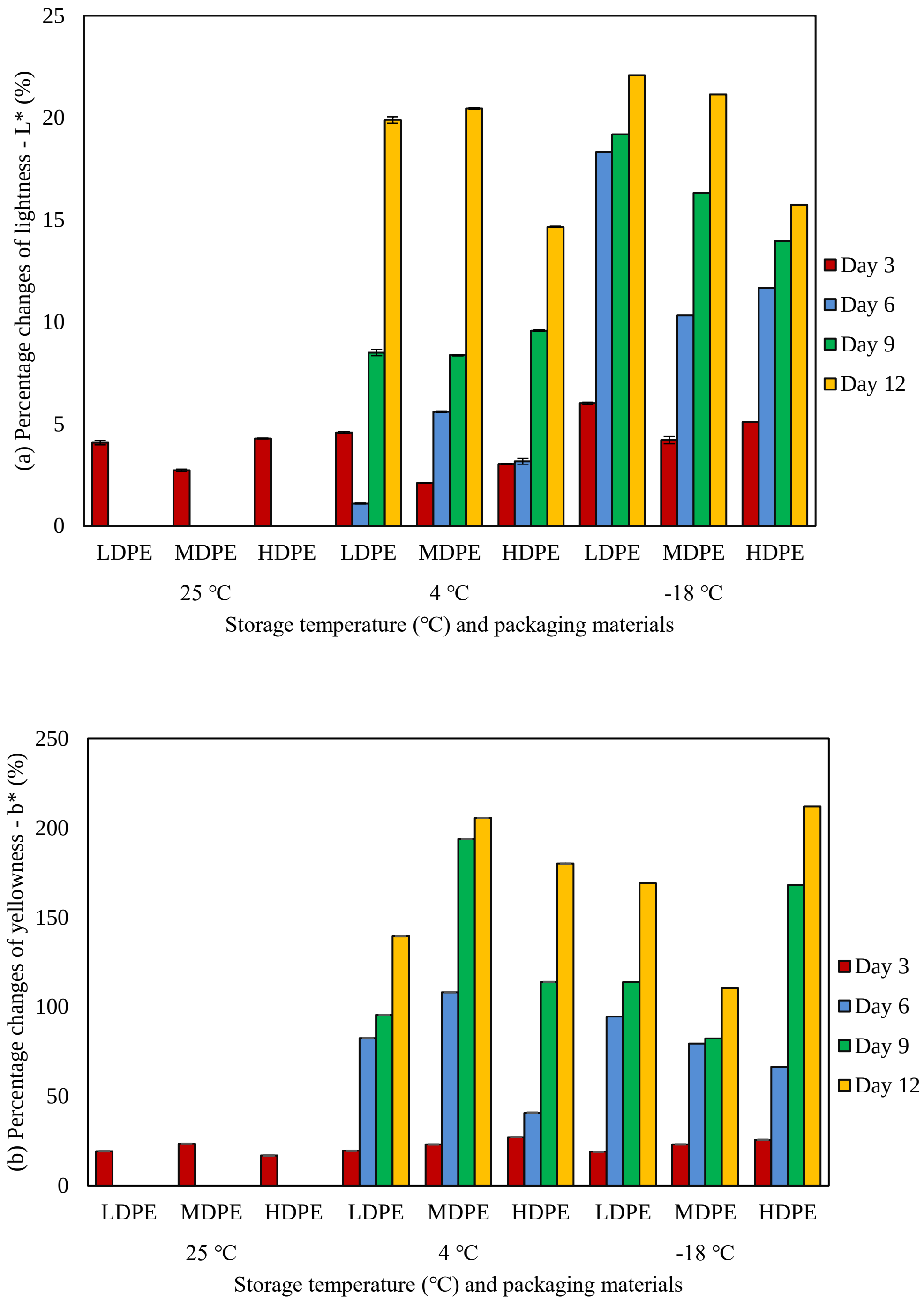

Figure 2. Percentage changes (%) of (a) L* and (b) b* values of crispy chicken burger patties packed in 3 types of packaging materials (LDPE, MDPE, and HDPE) and stored at frozen (−18 °C), cold (4 °C), and room (25 °C) temperatures during 12 days of storage.

Table 4 shows that in general, the L* values of crispy chicken burger patties packed in LDPE, MDPE, and HDPE packaging materials and stored at −18, 4, and 25 °C temperatures decreased gradually with storage time. The samples stored at frozen temperature (−18 °C) exhibited a higher percentage decrement of L* values (LDPE = 22.09%, MDPE = 21.15%, and HDPE = 15.73%) than other temperatures at the end of 12 days of storage indicating that the samples exhibited darker colors than others. This was due to the formation of metmyoglobin which imparted brownish discoloration to the product. Banerjee et al. [23] found a decrease in L* values for chicken nuggets stored at frozen storage temperature due to the formation of metmyoglobin. Metmyoglobin formed when iron in the samples oxidized and turned brown. On the other hand, the samples stored at cold temperature storage (4 °C) had a slightly lower percentage decrement of L* values than samples stored at the frozen temperature (LDPE = 19.88%, MDPE = 20.46%, and HDPE = 14.65%) which were also due to oxidative spoilage [24].

Meanwhile, there was also a decrement in L* values of crispy chicken burger patties stored at room temperature from day 0 until day 3. The percentage decrements were 4.08, 2.73, and 4.29% for crispy chicken burger patties packed in LDPE, MDPE, and HDPE packaging, respectively. After 3 days, the crispy chicken burger patties packed in all packaging materials became spoilt due to the room storage temperature which was higher than cold and frozen temperatures. The temperature affected the quality of the crispy chicken burger patties whereby the samples deteriorated faster at a higher temperature due to the fact that pathogenic microorganisms grow rapidly at a higher temperature [25].

In terms of packaging materials, crispy chicken burger patties packed in HDPE packaging and stored at 4 °C exhibited the lowest percentage decrement of L* values (14.65%) after 12 days of storage attributed to the packaging material that exhibited better gas barrier properties that prevented oxidation of the crispy chicken burger patties compared to other packaging materials. In fact, crispy chicken burger patties packed in HDPE packaging and stored at 18 ℃ also exhibited the lowest percentage decrement of L* compared to that packed in MDPE and LDPE. The oxygen permeability value for HDPE is the lowest which is in the range of 26.3 to 98.5 $cm^3·mm/m^2·d·atm$ compared to MDPE (98.5 to 210 $cm^3·mm/m^2·d·atm$) and LDPE (98 to 453 $cm^3·mm/m^2·d·atm$) [26]. The lowest percentage decrement in L* value is desirable because the product will undergo a frying process again before being consumed in which the browning reaction will occur and cause the product to become darker.

Meanwhile, Table 4 shows that the b* values of the samples increased gradually with storage time and decreased with the increase in storage temperature. This was also due to the formation of metmyoglobin which caused the brown discoloration of the samples as discussed before. Similarly, Adrah et al. [27] and Grillo et al. [28] noticed the same trend of color change for the chicken nuggets during storage time. They justified the color changes in chicken nuggets by myoglobin which is an oxygen-binding protein conversion to metmyoglobin during storage time. The percentage increments of b* values of crispy chicken burger patties were generally the highest when kept at frozen storage temperature (−18 °C) which were 168.92% for LDPE, 110.20% for MDPE, and 212.09% for HDPE. There was a trend of decreasing percentage increment of b* values with the increase in storage temperature. The percentage increment of b* values samples stored at cold temperature storage (4 °C) was 139.39% for LDPE, 205.43% for MDPE, and 179.96% for HDPE. The higher percentage increment in b* values indicated more yellowish samples after 12 days of storage. The yellowish color is desirable for deep-fried products because it can enhance the visual appearance of crispy chicken burger patties and match consumer perception of fried food. The yellow pigmentation of the samples was caused by the non-enzymatic browning reactions which involve the oxidation of proteins, lipids, and carbohydrates during storage [29,30].

In general, in terms of packaging materials, HDPE presents a high percentage increment in b* values. Thus, in terms of color changes, it is recommended to store the crispy chicken burger patties in HDPE packaging material due to the fact that HDPE packaging is more impermeable to gas and water vapor [26]. However, it is worth noting that the decision on the packaging materials should also be made in terms of the texture of the crispy chicken burger patties instead of color alone.

On the other hand, Table 5 presents the hardness and crispness while Figure 3 shows the percentage changes of hardness and crispness of crispy chicken burger patties during storage. From Table 5, it can be seen that the hardness of the crispy chicken burger patties kept at all temperatures decreased with the increase in time. This was in agreement with the finding of Ibadullah et al. [24] where the hardness of the fried fish crackers decreased significantly ($p < 0.05$) with the increase in storage time due to moisture loss of fried fish crackers packed in polyethylene terephthalate-polyethylene-aluminum-linear low-density polyethylene (PET-PE-ALU-LLDPE) and oriented polypropylene-polyethylene-metalized polyethylene terephthalate-linear low-density polyethylene (OPP-PE-MPET-LLDPE).

Table 5. Hardness and crispness for crispy chicken burger patties packed in 3 types of packaging materials (LDPE, MDPE, and HDPE) stored at frozen (−18 °C), cold (4 °C), and room (25 °C) temperatures during 12 days of storage.

Day	0	3	6	9	12
Hardness (N)					
LDPE Packaging					
−18 °C	30.08 ± 0.01^{a}	26.07 ± 0.12^{a}	20.89 ± 0.04^{d}	18.19 ± 0.17^{e}	16.77 ± 0.15^{h}
4 °C	44.33 ± 0.07^{a}	38.93 ± 0.06^{a}	38.62 ± 0.02^{a}	20.79 ± 0.71^{f}	20.51 ± 0.16^{f}
25 °C	42.36 ± 0.04^{a}	39.27 ± 0.08^{a}	-	-	-
MDPE Packaging					
−18 °C	24.18 ± 0.09^{b}	22.00 ± 0.01^{c}	20.63 ± 0.01^{d}	15.24 ± 0.21^{g}	12.68 ± 0.22^{i}
4 °C	30.32 ± 0.12^{b}	26.30 ± 0.08^{c}	24.19 ± 0.17^{d}	22.34 ± 0.31^{e}	17.92 ± 0.06^{g}
25 °C	34.41 ± 0.11^{c}	30.09 ± 0.11^{c}	-	-	-
HDPE Packaging					
−18 °C	28.22 ± 0.02^{a}	24.32 ± 0.29^{b}	20.82 ± 0.02^{d}	16.59 ± 0.04^{g}	14.15 ± 0.13^{h}
4 °C	40.10 ± 0.11^{a}	32.20 ± 0.01^{b}	26.41 ± 0.35^{c}	21.81 ± 0.02^{e}	21.80 ± 0.09^{e}
25 °C	32.25 ± 0.03^{b}	29.39 ± 0.02^{b}	-	-	-
Crispness (N)					
LDPE Packaging					
−18 °C	11.28 ± 0.21^{b}	15.23 ± 0.21^{b}	18.51 ± 0.18^{d}	22.19 ± 0.17^{g}	24.15 ± 0.13^{h}
4 °C	16.72 ± 0.03^{d}	13.77 ± 0.15^{f}	15.19 ± 0.17^{h}	17.82 ± 0.02^{d}	19.00 ± 0.01^{c}
25 °C	20.08 ± 0.05^{a}	17.27 ± 0.13^{a}	-	-	-
MDPE Packaging					
−18 °C	15.45 ± 0.15^{b}	19.10 ± 0.17^{a}	20.33 ± 0.31^{d}	36.42 ± 0.36^{e}	36.9 ± 0.06^{f}
4 °C	15.18 ± 0.03^{h}	11.53 ± 0.13^{i}	12.24 ± 0.21^{g}	17.89 ± 0.04^{d}	23.07 ± 0.12^{a}
25 °C	20.23 ± 0.03^{c}	17.90 ± 0.11^{c}	-	-	-
HDPE Packaging					
−18 °C	15.13 ± 0.12^{b}	19.10 ± 0.10^{b}	19.81 ± 0.01^{d}	24.41 ± 0.35^{f}	30.13 ± 0.12^{i}
4 °C	11.22 ± 0.04^{f}	9.68 ± 0.22^{f}	13.59 ± 0.04^{f}	17.63 ± 0.01^{d}	21.32 ± 0.29^{a}
25 °C	19.32 ± 0.01^{b}	16.39 ± 0.02^{b}	-	-	-

* Values in the same row showing the same small letters are not significantly different ($p > 0.05$).

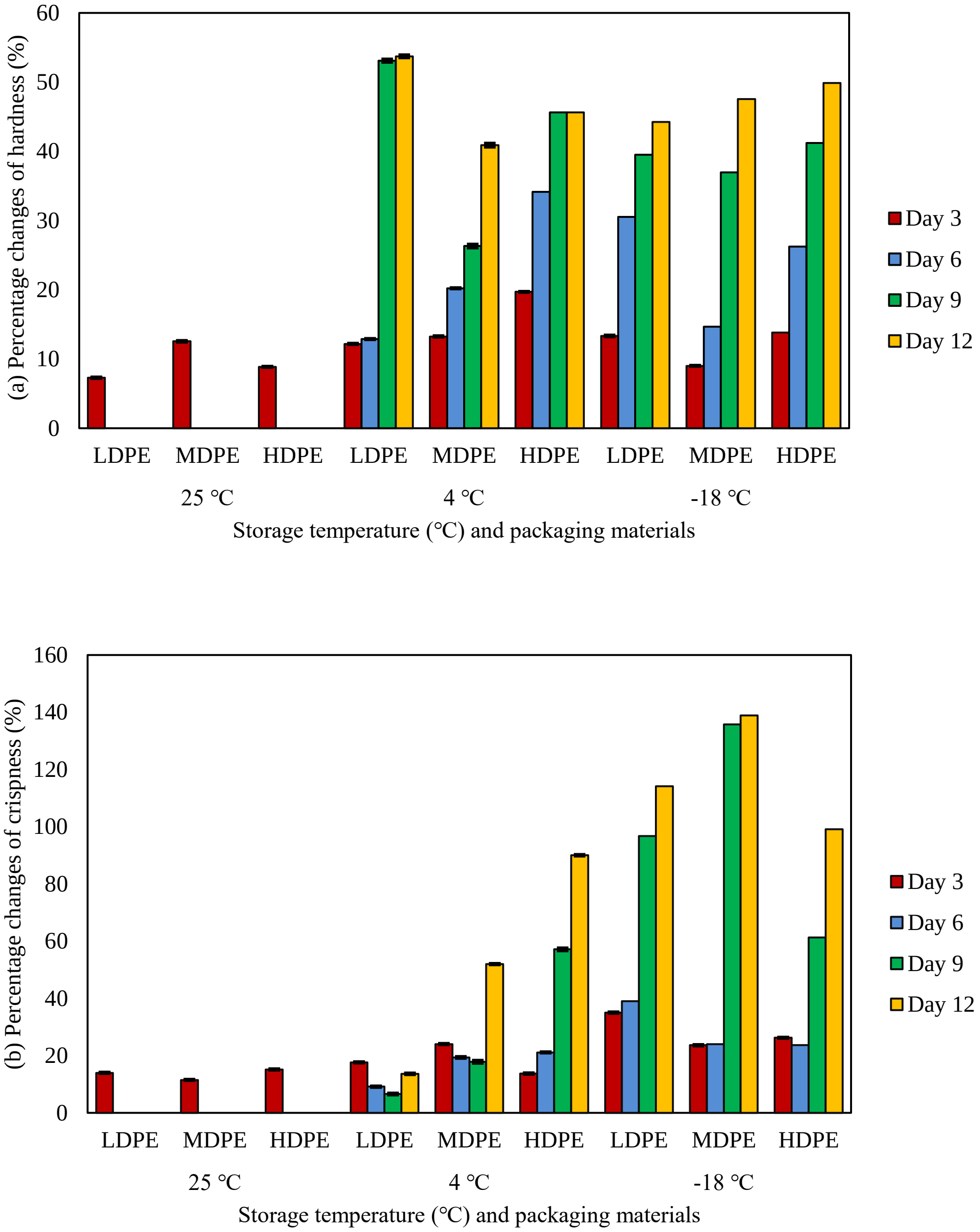

Figure 3. Percentage changes (%) of (a) hardness and (b) crispness for crispy chicken burger patties packed in 3 types of packaging materials (LDPE, MDPE, and HDPE) stored at frozen (-18 °C), cold (4 °C), and room (25 °C) temperatures during 12 days of storage.

The hardness of the crispy chicken burger patties kept at frozen temperature decreased from 30.08 to 16.77 N in LDPE packaging (44.25%), from 24.18 to 12.68 N in MDPE packaging (47.56%), and from 28.22 to 14.15 N in HDPE packaging (49.86%) as storage time increased from day 0 to day 12. During cold storage, the percentage changes of hardness throughout 12 storage days were 53.73, 40.90, and 45.64% for crispy chicken burger patties in LDPE, MDPE, and HDPE packaging materials, respectively. While, during storage at room temperature, the percentage changes after 3 storage days were 7.29, 12.55, and 8.87% for crispy chicken burger patties packed in LDPE, MDPE, and HDPE packaging, respectively.

Meanwhile, the crispness of the final fried crust is an important index in battered, fried food. Some of the texture changes occurred when moisture was removed from the crust during frying. The breaking force (N) is an indicator of the extent of crispness. In general, the crispness of crispy chicken burger patties in LDPE, MDPE, and HDPE packaging materials stored at frozen and cold temperatures increased ($p<0.05$) gradually with the increase in storage time and decrease in storage temperature. This was due to the loss of moisture through the packaging material during storage [31]. The decrease in moisture caused by migration or other reactions resulted in a harder texture on the surface which increased crispness. For storage at room temperature, the crispy chicken burger patties only last for 3 days.

The percentage increment of crispness from day 0 to day 12 for the crispy chicken burger patties packed in MDPE packaging and kept at frozen temperature was 138.83% followed by LDPE and HDPE packaging which was 114.10% and 99.14%, respectively. The percentage changes in the crispness of crispy chicken burger patties stored at room temperature were the highest for HDPE (15.17%) followed by LDPE (13.99%) and MDPE (11.52%) while that stored at cold temperature were HDPE (90.02%) followed by MDPE (51.98%), and LDPE (13.64%). The hardness and crispness of the products should be maintained, and the percentage changes should be minimized throughout storage time because it is desired to maintain the properties of crispy chicken burger patties throughout storage.

Based on the results above, moisture loss was the cause of the decrease in hardness and increase in crispness value. When the moisture loss is low, the reduction in hardness is low. As a result, the texture of crispy chicken burger patties is not too hard and dried. Meanwhile, when the moisture loss is high, it contributes to the crispness of the products. The desirable final texture of crispy chicken burger patties is to have a crispy but not too hard texture. Thus, it is important to determine the best packaging material and storage temperature to achieve this condition. These desired properties were achieved when using LDPE as packaging material and stored at frozen (−18 °C) and cold temperatures (4 °C). This is because LDPE exhibited a medium barrier property between MDPE and HDPE (WVP: LDPE- 0.39 to 0.59 $g{\cdot}mm/m^2{\cdot}d$, MDPE- 0.4 to 0.6 $g{\cdot}mm/m^2{\cdot}d$, and HDPE- 0.1 to 0.24 $g{\cdot}mm/m^2{\cdot}d$) [26] that resulted in the satisfactory texture of crispy burger patties. The moisture loss for samples in LDPE was not too high and too low due to the moderate water vapor permeability to cause the increase in hardness and decrease in crispness, respectively.

4. Conclusions

Batters for crispy chicken burger patties were successfully formulated. According to the proximate composition results, rice flour-based batter had lower moisture and fat contents but higher protein content than wheat flour-based batter. Nonetheless, the carbohydrate and ash contents were insignificantly different for all batter formulations. The sensory evaluation results revealed that crispy chicken burger patties formulated with rice flour-based batter of ratio 2:2:1:1 (RFFB1) were most preferable compared to other formulations in terms of overall acceptability, appearance, taste, crispness, and color, hence have the potential for commercialization. Based on the sensory evaluation, all the crispy chicken burger patties formulations were acceptable to the panelists. The storage studies of crispy chicken burger patties at the optimum formulation (rice flour-based batter of ratio 2:2:1:1) packed using different packaging materials (LDPE, MDPE, and HDPE) and stored at different storage temperatures (room temperature of 25 °C, the cold temperature of 4 °C, and frozen temperature of

18 °C) revealed that there was a decrease in lightness and an increase in yellowness with the increase in storage temperature. In general, the hardness of crispy chicken burger patties decreased while the crispness increased during storage due to moisture loss. In terms of texture, the crispy chicken burger patties were best packed in either cold or frozen temperature storage using LDPE packaging material.

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Conflict of interest

All authors declare no conflicts of interest in this paper

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