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Comparative Study Between Deep-Fat Frying and Air Frying of Sweet Potato Perkedel

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Abstract: Fried meals have become incredibly popular all around the world among people of all ages due to its rapid and simple preparation and relatively low production cost. However, due to the high amount of oil used, consuming deep-fat fried foods has been associated with an increased risk of cardiovascular disease and diabetes. Recently, due to its ease of use and significantly lower oil consumption than traditional deep-fat frying, the air frying method has grown in favour, especially for household use. However, using little or no oil could have an impact on a number of physical properties of the fried products, such as texture, colour, and moisture content. Additionally, the sensory qualities might also not be comparable to those of conventional deep-fat fried foods. Therefore, the objective of this study was to evaluate the impact and efficacy of the air frying process on the physical and sensory quality attributes of fried sweet potato perkedel at varying temperatures and times and compared it with conventional frying. Moisture content, color, hardness, and sensory evaluation of the fried sweet potato perkedel were analyzed under varied temperatures (120 ◦C, 160 ◦C, and 200 ◦C) and time periods (10 min, and 15 min). Statistical analysis (ANOVA) was then applied to determine the presence of significance different between samples. Results indicated that moisture content, and L*-value for both deep-fat and air-fried perkedel were adversely related to the frying temperature and time, but the hardness, a* and b*-value of both deep-fat and air-fried perkedel were increased as the frying temperature and time increased. Additionally, it was determined that there was a statistically significant difference ($P < 0.05$) between the samples of deep-fat and air-fried perkedel for all sensory qualities examined, indicating a significant alteration in the perceived product quality. In comparison, air-fried perkedel was higher in moisture content (59.41%), and hardness (34.64 N) with a lower value of a* (29.37) than deep-fat fried perkedel; where moisture content (40.37%), firmness (26.56 N) and a* value (37.71), with temperature and time extended up to 200 ◦ C and 15 min. Such information could be beneficial to the community so they are more aware of advocating the use of air frying, especially for fried food, as a preventative strategy for various health risks like cardiovascular

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disease. The public and food industry manufacturers may also consider air-fried foods as an alternative to deep-fried foods.

Keywords: Deep-Fat Frying, Air Frying, Perkedel, Sweet Potato

1. Introduction

In recent years, fried meals have become incredibly popular all around the world. There are a number of factors that contribute to the popularity of fried food consumption, including its rapid and simple preparation and relatively low production cost. It is also suitable for consumption by all ages. Fried food's distinct colour, flavour, texture, and scent are all a result of the frying process. According to Zaghi et al. [1], physical and chemical reactions like oxidation, hydrolysis, and polymerization that occur during frying provide food the desired food attributes including brown colour, crispy texture, and pleasant taste. Fried meals can be manufactured commercially utilising a variety of frying processes since the frying process is a fundamental unit operation that is widely employed in food factories, restaurants, households, and other settings, mostly due to convenience, speed, and economic considerations. Numerous frying techniques, such as deep-fat, vacuum, hot air, and pressure frying, are available to food producers. Typically, food is prepared by dipping it in fats or oils; this method is known as deep-fat frying. Deep-frying is one of the oldest culinary methods, and consumers value it for its flavour.

In more detail, the immersion of a product into hot oils and/or fats caused the water to exit and the oil to enter, which led to changes in the texture and colour of food products. However, due to the high amount of oil used, consuming deep-fat fried foods has been associated with an increased risk of cardiovascular disease and diabetes, both of which are serious conditions that can be fatal, according to Cahill et al. [2]. In addition, people who consume fried food are more likely to become obese because the food is high in fat and empty calories [1]. Malaysia has the highest rate of adult obesity in Southeast Asia, according to a report released on March 5, 2021 by the University of Malaya. As a result, according to study by Fikry et al. [3], researchers are still seeking innovative ways to fry food products while maintaining their quality features and making them technically and financially practical for the food business.

Perkedel (Bergedel) is one of the fried foods that uses deep-fat frying for its production, which is not favored by health-conscious people because of the high fat content produced by dipping in oil. However, excluding the use of oil, perkedel is one of the main fried vegetables in Southeast Asia, especially in Indonesia and Malaysia, which is considered a very nutritious product, mostly due to its vegetarian-based content, such as vitamins, dietary fiber and bioactive components [5].

Due to its ease of use and significantly lower oil consumption than traditional deep-fat frying, the air frying method has recently grown in favour, especially for household use. Instead of using heated oil to cook, air frying circulates hot air, which dehydrates food and aims to give the flavour and texture of traditionally manufactured fried dishes while absorbing far less fat into the final product [4]. Many foods, including fish skin, fried potatoes, surimi, and donuts, can be prepared well utilising air frying techniques.

To date, there is a scientific article that compares hot air frying to traditional frying as of this writing. At the same temperature (180 °C), Andres et al. [6] examined the kinetics of mass transfer and volume changes in hot air frying and deep oil frying and came to the conclusion that both are influenced by medium type. Because air has a lower heat transfer coefficient than oil, heat transfer was slower when air was the fluid phase. In addition, Teruel et al. [4] also claims that there is a significant knowledge gap in their research paper because their study makes little to no mention of the product's quality and sensory characteristics. In order to assess the impact of frying sweet potato perkedel fritters in air frying, this study examined the physical quality and sensory features of the air and deep-fat fried perkedel fritters that fried at various temperatures (120 ◦C, 160 ◦C, and 200 ◦C) and times (10 min, and 15 min).

2. Materials and Methods

2.1 Air and deep-fat fried sweet potato perkedel preparation

Sweet potato perkedel, which was prepared by referring to the method of Prastica et al. [19] with modifications, with the ingredients were purchased from a local market in Pagoh, Johor. Table 1 shows the ingredients for 45 g sweet potato perkedel. The initial moisture content of the perkedel was 77.49 ± 0.58 (% w.b.). To obtain air fried perkedel, the air fryer (Philips, Model AF-501J, Netherlands) was set at the desired temperature for 10 min. The frying process was conducted at three different temperatures (120 ◦C, 160 ◦C, and 200 ◦C) for two different times (10 min, and 15 min) for both air and deep-fat frying processes. These conditions were chosen based on our preliminary study. Next, the temperature and time were adjusted at the desired frying conditions then; three perkedel pieces were placed in a thin layer of the aluminium foil inside the container of the fryer without using oil. Meanwhile, for deep-fat fried perkedel, three perkedel pieces were fried in the hot oil (300 ml) by using a deep non-stick frying pan, with the temperature of the oil was monitored with a digital thermometer (MCP, Model Med-24, China) constantly during frying. Then, the deep-fat and air-fried perkedel samples were collected from the fryer. All fried perkedel samples were allowed to cool at room temperature; until performing texture, color and moisture content analysis.

Table 1: Ingredients for 45 g sweet potato perkedel (bergedel) [19]

Ingredients	Amount (g)
Orange Fleshed Sweet Potato (*Ipomoea batatas L.*)	31.50
Chickpeas	10.00
Salt	0.25
Pepper	0.50
Onion	1.50
Garlic	1.00
Scallion	0.25

2.2 Physical analyses of air and deep-fat fried sweet potato perkedel

The texture, colour, and moisture content of sweet potato perkedel fritters made using both frying procedures were examined.

2.2.1 Texture analysis

Texture analysis was done by following the method of Vengu et al. [18]. The hardness (firmness) of sweet potato perkedel fritters was evaluated using a texture analyzer (TA-XT Plus Texture Analyzer, Stable Micro System, United Kingdom) using a 30 kg load cell. Whole perkedel fritter sample was placed on the stage. A cylindrical probe (P/10) with a flat base with a diameter of 10 mm was used. The settings were as follows: pre-test speed: 1.50 mm/s; test speed: 1.50 mm/s; post-test speed: 10.00 mm/s; target mode distance: 8.00 mm; trigger force: 10.00 g; trigger type: auto.

2.2.2 Colour analysis

Colour analysis was done by following the method of Yu et al. [7]. Colour of the samples that were produced from air frying and deep-fat frying were measured by using colorimeter. First and foremost, the samples were placed in a petri dish, and covered (Pathare et al., 2013). After that, the surface of sweet potato perkedels were measured individually in triplicates and recorded as L*, a* and b*, where L* stands for (luminosity/lightness), a* (positive value for reddish and negative values for greenish) and b* (positive value for yellowish and negative values for bluish). Finally, the results were expressed as mean±standard deviation values.

2.2.3 Moisture content

The moisture content of sweet potato perkedels made using deep-fat and air frying under different frying conditions; were measured by using a moisture analyzer. The analyses were performed in three replications. A digital balance of moisture analyzer was used to weigh up to 2 grammes of each sample, which was placed on a folded piece of aluminium foil to hold it. After that, the sample was heated for 27 minutes at 200 °C. Both the percentage of moisture and the amount of moisture lost were automatically calculated. Initial moisture content is defined as the moisture content of the raw coated sweet potato perkedel, whereas final moisture content is defined as the moisture content of the fried sweet potato perkedel sample with crust.

2.3 Sensory evaluation of air and deep-fat fried sweet potato perkedel

Sensory evaluation was done by following the method of Ali et al. [8]. The samples were assessed for colour, flavour, texture, taste and overall acceptability by thirty (30) untrained sensory panelists using a 9-point hedonic rating scale, where “1” denotes dislike extremely and “9” denotes like extremely. The deep-fat and air fried sweet potato perkedels were freshly prepared and were presented to the panelists 15 min after the frying process while the fritters were still warm and crispy. Each panelist was presented with six samples of deep-fat and air fried sweet potato perkedel. The panelists also were given a form with an all-attribute column and an overall acceptance column on which they were able recorded their sensory evaluations. The data was properly tabulated for statistical analysis. The sensory analysis was conducted among Food Technology students of Tun Hussein Onn Pagoh University, Johor, Malaysia.

2.4 Statistical analysis

The results of the analysis were displayed as the mean and standard deviation of the three sets of data. One-way analysis of variance (ANOVA) was used to determine whether there are variations in the data collected. A value is considered significant if it is $p<0.05$. The ANOVA was carried out using Microsoft Excel.

3. Results and Discussion

3.1 Texture of air and deep-fat fried sweet potato perkedel under different frying condition

Firmness is the strongest force required to compress food between teeth. The kinetics of textural changes in the 12 various types of perkedel samples were investigated using a compression test. Analyze the formation of the product's crust and the changes towards its interior were made possible by the evaluation of the texture parameter (firmness/hardness) at 8 mm. According to previous studies by Moyano et al. [9], heating sweet potato perkedel results in significant physical, chemical, and structural changes. These changes can be divided into two stages: tissue softening during the first few minutes of frying, followed by crust formation and subsequent hardening. Crust was defined as the emergence of a porous, dried, overheated region. This zone develops as a result of a vaporisation front near the heat exchange surface that gradually travels toward the product centre during the course of the frying process. Miranda and Aguilera [10] demonstrated that when potato goods are exposed to temperatures exceeding 100 °C, such as those experienced during frying, the surface-located starch granules and cells get dried and create an exterior crust, which gives the product its crispy texture. Table 2 displays the firmness/hardness work (N) required for the probe to pierce a sample's surface. With time, both processes increased the hardness values for the exterior and interior regions ($P > 0.05$). Regarding the effects of frying techniques, it was generally found that there were differences between the two frying techniques for the crust region at various frying times and temperatures; visually, it was noticeable that the air-fried perkedel had a surface crust that was thinner, more uniform, and free of imperfections than the deep-fat fried perkedel. Meanwhile, the air fried samples showed higher hardness values ($P < 0.05$) than the deep-fat fried samples in this investigation. In general, the hardness of raw perkedel was 12.80 N, and it increased to 21.13 N (120 °C, 10 min) after air-frying. The hardness of air-fried perkedel further increased with the rise of air-frying time and temperature, which reached the highest value 34.64 N at 200 °C for 15 min. These variations in firmness/hardness texture may be caused by a lesser degree of gelatinization in air-fried samples, which is related to the more frequent occurrence of lower temperatures inside the product. To sum up, both fried goods clearly have different texture qualities in the crust and interior, as evidenced by the texture data in Table 2.

Table 2: Compression test result of sweet potato perkedel under different frying conditions

Analysis			120 ° C	160 ° C	200 ° C
Texture (Firmness/ Hardness (N))	10 min	Raw	12.80 ± 0.01^b	12.80 ± 0.01^b	12.80 ± 0.01^b
		Deep-fat	2.59 ± 0.06^c	9.42 ± 0.03^c	10.74 ± 0.06^c
		Air	21.13 ± 0.20^a	22.60 ± 0.07^a	31.68 ± 0.09^a
	15 min	Raw	12.80 ± 0.01^c	12.80 ± 0.01^c	12.80 ± 0.01^c
		Deep-fat	23.48 ± 0.62^b	24.16 ± 0.24^b	26.56 ± 0.38^b
		Air	27.91 ± 0.08^a	28.66 ± 0.15^a	34.64 ± 0.05^a

Mean ± SD. The values showing different superscripts within a column are significantly different at $p<0.05$

3.2 Color of air and deep-fat fried sweet potato perkedel under different frying conditions

Color is one of the most important qualities of fried food that determines consumers' desire to purchase since they prefer fried products with light colours. The conditions of the frying process should therefore be properly controlled. Heat and mass transfer caused perkedel's colour to alter, which resulted in moisture loss and an increase in the oil component. Using a colorimeter, the values of brightness (L*), redness (a*), and yellowness (b*) were calculated to define the surface colour of the perkedel sample. The variation of L*, a*, and b* during the deep-fat and air-frying processes were displayed in Table 3. The L* value, which is defined for the brightness of fried foods, is an important parameter in the frying sector [11]. During the deep-fat and air-frying processes of perkedel, it decreased gradually and significantly ($p \leq 0.05$) from 63.35 to 32.92, and 49.63, respectively, as temperature and time increased due to moisture loss and weakened light reflection, which caused the surface of the fried perkedel to brown and darken. Additionally, it was stated that the Maillard reaction would result in a brown colour and crust [12]. In the meantime, it was anticipated that sugar would caramelise over a lengthy period of time and at a high temperature. According to Table 3, the a* value for air fried perkedel was a slightly increased with the increase of frying temperature and time. When the air-frying condition was 200 °C and 15 min, the a* value turned 29.37 from 23.48, indicating the increased of redness. According to a report, the amount of acrylamide formation is directly correlated with a* improvement. It was supported by a prior study by Mogol and GőKmen [13], who reported that a high a* value was directly correlated with the generation of the carcinogenic compound acrylamide. In research from Yu et al. [7], consumers did not prefer the positive value of a* since it showed a significant non-enzymatic browning. With increasing frying heat, the b* value of air-fried perkedel also significantly increased. A higher b* value meant the product will be more yellow, which is acceptable and preferred in fried dishes. The b* value of raw perkedel was 39.65, and after air-frying it for 15 minutes at 200 °C, it increased sharply to 52.06. Furthermore, Table 3 makes it evident that for air-fried perkedel, b* initially decrease, reach a minimum value, and then gradually grow. Additionally, Table 3 also demonstrated that deep-fat frying caused a significant rise in both a* and b*. In comparison to air frying, the development of the a* and b* values in deep fat frying were obviously higher. It can be explained by different heat transfer kinetics. According to Pathare et al., nonenzymatic browning reactions are strongly temperature dependent. Therefore, although air frying takes considerably longer to process, it may be possible to produce the distinctive colour of deep fat fried items.

Table 3: Color analysis for sweet potato perkedel under different frying conditions

Analysis			120 ° C	160 ° C	200 ° C
L* value	10 min	Raw	63.35 ± 0.08[a]	63.35 ± 0.08[a]	63.35 ± 0.08[a]
		Deep-fat	53.50 ± 0.50[c]	51.40 ± 0.12[c]	35.73 ± 0.04[c]
		Air	58.43 ± 0.22[b]	56.60 ± 0.16[b]	54.91 ± 0.65[b]
	15 min	Raw	63.35 ± 0.08[a]	63.35 ± 0.08[a]	63.35 ± 0.08[a]
		Deep-fat	52.02 ± 0.10[c]	45.36 ± 0.10[c]	32.92 ± 0.03[c]
		Air	57.72 ± 0.51[b]	56.25 ± 0.23[b]	49.63 ± 0.06[b]
a* value	10 min	Raw	23.48 ± 0.01[c]	23.48 ± 0.01[c]	23.48 ± 0.01[c]
		Deep-fat	24.14 ± 0.07[a]	31.58 ± 0.10[a]	32.50 ± 0.57[a]
		Air	23.69 ± 0.13[b]	25.03 ± 0.12[b]	27.13 ± 0.14[b]

	Raw	23.48 ± 0.01^{c}	23.48 ± 0.01^{c}	23.48 ± 0.01^{c}
	15 min			
	Deep-fat	26.21 ± 0.03^{a}	34.86 ± 0.25^{a}	37.71 ± 0.09^{a}
	Air	25.21 ± 0.07^{b}	26.96 ± 0.61^{b}	29.37 ± 0.11^{b}
b* value	Raw	39.65 ± 0.02^{b}	39.65 ± 0.02^{c}	39.65 ± 0.02^{c}
	10 min			
	Deep-fat	55.76 ± 0.30^{a}	60.65 ± 0.08^{a}	61.17 ± 0.49^{a}
	Air	32.74 ± 0.09^{c}	48.72 ± 0.17^{b}	51.97 ± 0.80^{b}
	Raw	39.65 ± 0.02^{b}	39.65 ± 0.02^{c}	39.65 ± 0.02^{c}
	15 min			
	Deep-fat	57.84 ± 0.05^{a}	58.49 ± 0.16^{a}	62.41 ± 0.12^{a}
	Air	34.95 ± 0.08^{c}	49.65 ± 0.21^{b}	52.06 ± 0.52^{b}

Mean ± SD. The values showing different superscripts within a column are significantly different at $p<0.05$

3.3 Moisture content of air and deep-fat fried sweet potato perkedel under different frying conditions

A key quality indicator for fried foods is moisture content (MC), which can draw customers in with a crisp exterior and the right amount of moisture inside. Referring to Table 4, it could be observed that the MC value was negatively correlated with frying temperature and time ($P < 0.05$) for both deep-fat as well as air frying; which decreased with the rise of temperature and extension of time. These results were aligned with Andres et al. [6] who evaluated the kinetics of moisture loss between these two frying techniques. According to earlier investigations by Bingol et al. [14], the mechanism of water loss during frying has been characterised as a dehydration process. It is clear from Table 4 that the moisture content decreases more rapidly in deep-fat frying than air frying ($P < 0.05$). This is because the heat transfer rate in liquid oil phase was much faster than that in air phase, thus influencing the moisture transfer [4]. Furthermore, previous study from Isik et al. [15], also found that the surface temperature of air-fried foods increased instantly as soon as the hot air began to blow, which could enable them to reach the boiling point quickly and form a dried layer. In the meantime, this dried layer could aid in limiting further interior moisture loss during air frying process. Meanwhile, it has also been reported that the Maillard reaction, will benefit from the lower content of MC, which will enhance the formation of acrylamide. From previous study Gertz et al., temperatures greater than 120 °C are seen as the main cause of acrylamide formation in starch food due to non-enzymatic browning, known as the Maillard reaction. In conclusion, the data above show that deep-fat fried food is more immediately exposed to the formation of acrylamide than air fried food since deep-fat fried food displayed the same downward trend but had a lower absolute value of MC, with the extension of temperature and time.

Table 4: Moisture content (%) analysis for sweet potato perkedel under different frying conditions

Analysis		120 ° C	160 ° C	200 ° C
Moisture content (%)	Raw	77.49 ± 0.58^{a}	77.49 ± 0.58^{a}	77.49 ± 0.58^{a}
	10 min			
	Deep-fat	60.08 ± 0.02^{c}	53.64 ± 0.02^{c}	48.42 ± 0.40^{c}
	Air	71.75 ± 0.22^{b}	69.27 ± 0.45^{b}	63.09 ± 0.18^{b}
	Raw	77.49 ± 0.58^{a}	77.49 ± 0.58^{a}	77.49 ± 0.58^{a}
	15 min			
	Deep-fat	54.56 ± 0.08^{c}	47.77 ± 0.57^{c}	40.37 ± 0.42^{c}
	Air	67.16 ± 0.09^{b}	63.15 ± 0.40^{b}	59.41 ± 0.07^{b}

Mean ± SD. The values showing different superscripts within a column are significantly different at $p<0.05$

3.4 Sensory analysis

A panel evaluated colour, flavour, texture, taste and overall acceptability of the products obtained by both the processes. It was determined that there were statistically significant differences for all of the attributes ($P < 0.05$) employed, which suggests a significant change in the perceived qualities of the product. In terms of colour, there was a substantial difference between the air-fried and deep-fat-fried samples in the degree of brownness and evenness of cooking, which was also consistent with instrumental colour measurement. The structure of the products produced when samples were fried in oil or air differs significantly. Visual inspection revealed that samples that had been deep-fried had a thick, dry, and crispy surface crust structure. According to Teruel et al. [4], this was due to the swiftly rising surface temperature of the product, which results in a strong localised evaporation of water that hindered the gelatinization of starch in this area. The water evaporates much more slowly in the case of air-fried foods, resulting in a surface crust that is thinner, homogenous, and devoid of imperfections, which gives rise to a detectable difference in taste. In general, the sensory analysis results indicate that sensory characteristics of the products obtained from the two frying processes were significantly different. To conclude, from the overall acceptance of sensory scores, it shows that samples deep-fat fried perkedel when the deep-fat frying condition was 160 °C and 15 minutes; and 200 °C and 10 minutes, were preferred by the 30 panelists. However, considering the large amount of oil used and the drawbacks of deep-fat frying, oil undergoes a number of chemical processes when heated at high temperatures, including oxidation; numerous oxidative chemicals are generated during this process, including hydroperoxide and aldehydes, which might be ingested by the fried foods [16]; people should take this into account while choosing their food. The findings also shown that the panelists could accept the air-fried perkedel despite certain distinctions between them and deep-fat fried foods in terms of qualities including colour, flavour, texture, taste, and overall acceptability. The table below shows the average attributes score value for 12 types of samples by 30 untrained panelists.

Table 5: The average attributes score for twelve (12) types of samples by 30 untrained panelists

	397	178	611	562	400	364	753	473	851	265	242	315

Colour	5.7	7.0	5.4	7.0	5.5	7.4	5.6	6.7	5.6	7.1	5.8	6.8
Flavour	5.9	7.2	5.4	7.1	5.8	6.8	7.0	7.6	5.5	7.2	7.2	6.6
Texture	5.7	6.8	5.3	6.7	5.4	6.7	6.5	7.2	6.1	7.2	6.6	7.1
Taste	5.4	6.8	5.2	6.8	5.5	6.8	6.5	7.1	5.3	7.2	6.7	6.8
Overall Acceptability	5.4	6.7	5.1	6.9	5.2	6.8	6.3	7.1	5.4	7.1	6.3	6.8

Note, 397: Air frying (10 min, 120 ° C), 178: Deep-fat frying (10 min, 120 ° C), 611: Air frying (15 min, 120 ° C), 562: Deep-fat frying (15 min, 120 ° C), 400: Air frying (10 min, 160 ° C), 364: Deep-fat frying (10 min, 160 ° C), 753: Air frying (15 min, 160 ° C), 473: Deep-fat frying (15 min, 160 ° C), 851: Air frying (10 min, 200 ° C), 265: Deep-fat frying (10 min, 200 ° C), 242: Air frying (15 min, 200 ° C) and 315: Deep-fat frying (15 min, 200 ° C)

4. Conclusion

In conclusion, air frying can be a healthy substitute for traditional frying. By comparing the lower moisture content, higher hardness, and lower a*-value of air-fried food to deep-fat fried food, this study shows that air-fried food can compete with deep-fried food despite requiring longer processing periods for colour. The community can benefit from this information by becoming more aware of the benefits of air frying, especially for fried meals, as a method for reducing health risks including cardiovascular disease and cancer; as acrylamide exposure raises the risk for multiple types of cancer.

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