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Effect of broccoli (*Brassica oleracea*) florets and stems as a fat replacer on the physicochemical and sensorial properties of chicken patties

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ABSTRACT

This study aimed to evaluate the effects of replacing chicken skin with various levels of broccoli (0, 25, 50, 75, and 100%) on the physicochemical and sensory properties of chicken patties. Fresh broccoli florets and stems were blanched and minced before being added to the patties' formulation, and all samples were analysed for their physicochemical and sensorial properties. The highest significant (P<0.05) changes of moisture, protein, and fibre content were noted as the broccoli incorporation increased, especially in patties with 100% broccoli, at 62.85%, 19.78%, and 9.35%, respectively. The patty with the lowest (P<0.05) fat content was produced by fat replacement at 100% broccoli, with a fat content of 9.35 % compared to the control at 12.47%. The textural properties of all samples showed no significant difference (P>0.05) in terms of hardness, cohesiveness, chewiness, and work of shearing. Nevertheless, the sensory analysis determined that patties with 75% and 100% broccoli were negatively affected, especially in colour, flavour, and overall acceptance. However, 25% and 50% broccoli were comparable to the control. In conclusion, broccoli may be used as a fat replacer for up to 25 to 50% in producing healthier chicken patties without jeopardizing their physicochemical and sensory properties.

INTRODUCTION

Patties refer to flattened processed meat products crafted from ground or minced meat combined with fat, salt, spices, and additional additives. Recently, processed meat products made from poultry meat have been preferred over red meat for several reasons, including a healthier alternative with

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lower saturated fat and calorie content, a leaner protein source, and religious beliefs. With an average of 50 kilograms of poultry meat consumed per person in 2022, Malaysia is among the countries with the highest global consumption of poultry meat (Statista Research Department, 2022). Poultry meat, specifically chicken meat, is more favourable for processing compared to other types of meat due to its neutral flavour, light colour, and excellent texture and consistency (Wigmann *et al.,* 2018). Thus, these admirable qualities of chicken meat make it a wise choice for the production of processed meat products such as patties.

Fat is one of the main components in processed meat products that contribute to their texture, flavour, juiciness, tenderness, and palatability. However, due to the presence of saturated fatty acids (SFA), trans fat, and cholesterol in fat, numerous studies have linked its effects to several health problems. Therefore, the practice of substituting animal fats with healthier fat replacers has drawn increased attention to addressing this health issue. As defined by the American Dietetic Association, fat replacers are ingredients that can perform all or some of the functions of fat while offering lower calories than fat. Carbohydrates, starches, protein, and fibre from plant-based ingredients are some of the ingredients that can be used to replace fat in processed meat products. Extensive literature data has shown promising results for fat replacement in processed meat products with the mentioned ingredients (Li *et al.,* 2022; Pindi *et al.,* 2023). Furthermore, the incorporation of vegetable products in meat products can improve their functional properties, provide natural antioxidants and dietary fibre, lower the production cost, and enhance or at least retain the sensory and nutritional qualities of the final products (Kaur et al., 2022; Dahriya et al., 2023).

Chicken skin is a rich source of fat (31.69% on dry matter basis) and protein (13.65 % on dry matter basis), with moisture ranging from 53-55% in fresh skin (Faridah *et al*., 2021). Broccoli had approx. 87.25% moisture, 6.5-6.7 pH, and 29.91% crude protein and 1.18% fat on dry matter basis (Abdulla et al., 2017). Broccoli, (*Brassica oleracea* var. *italica*), belongs to the Brassicaceae family. Physically dark green with compact flower bud clusters and firm stalks, it is often consumed as a vegetable. Broccoli is a popular fresh vegetable and is considered one of the vegetables with the highest nutritional value in the market due to its composition of some phytochemical compounds, such as glucosinolates and isothiocyanates (Ordiales *et al.,* 2017). Besides, broccoli also has antioxidant and anti-carcinogenic compounds that provide health benefits. Based on studies, cruciferous vegetables of the genus Brassica, including cauliflower, broccoli, cabbage, and Brussels sprouts, are rich sources of antioxidants including carotenoids, tocopherols, ascorbic acid, flavonoids, vitamins, and fibre but contain little fat and energy (Kaur *et al*., 2022). Moreover, broccoli or broccoli extracts, being a rich source of various phenolic compounds, can be incorporated into meat products as a source of natural antioxidants to prolong quality and stability (Mahn & Rubio, 2017).

Additionally, a study of incorporating broccoli puree in beef meatballs at levels of 10%, 15%, and 20% has shown improvements in quality, nutritional values, and health benefits—increased moisture content, decreased fat, and total calorie contents. A few studies have also been done to investigate the effects of broccoli incorporation in meat products in different forms, i.e., powder (Banerjee at al., 2012; Farag, 2014), raw (Talens *et al.,* 2022), and juice (Mirhaj *et al.,* 2022). Despite this, the effects of broccoli, specifically as a fat replacer in processed meat products, have not been investigated yet. Thus, the objective of this study was to evaluate the effects of adding various levels of broccoli (0, 25, 50, 75, and 100%) as the fat replacer on the physicochemical and sensory properties of chicken patties.

MATERIALS AND METHODS

Preparation of chicken patties

Fresh broccoli, chicken breast meat, chicken skin, salt, and crushed ice were purchased from Pasar Borong Selangor, Seri Kembangan, Selangor, Malaysia. Broccoli heads and stems were processed immediately after purchase by washing, cutting into single florets, and blanching at 57°C for 13 min to make them softer and prevent enzymatic degradation (Mahn and Rubio, 2017). Next, the cut florets and stems were ground into paste form by using a hand blender (Panasonic MX-GS1, Malaysia). The chicken breast meat and chicken skin were minced separately using a mincer machine (Hobart 4822, USA). Chicken patties were formulated according to the methods described by Ismail et al. (2022) with slight modifications as shown in Table 1. Firstly, the meat was ground for 5 min in a bowl cutter (ZB-20L, China) to increase the surface area of the proteins and meat particles for improved functionality. Next, the ground meat was mixed with other ingredients for 1.5 min. Generally, crushed ice was added little by little throughout the mixing to keep the mixture cold and prevent the heat denaturation of proteins due to the friction of mixing. The homogenous mixture was then transferred into a patty mould and pressed to obtain patties with 80 g. The patties were placed in a stack with plastic liners in between. The patties were packed, frozen, and stored at -18°C until further analysis.

Cooking procedure

The chicken patties were cooked using a griddling method

Table 1. The formulation of fat-replaced chicken patties

Ingredients (%)	Control	25BROC	50BROC	75BROC	100BROC
Chicken breast meat	73	73	73	73	73
Chicken skin	20	15	10	5	0
Broccoli	0	5	10	15	20
Salt	1.5	1.5	1.5	1.5	1.5
Sodium tripolyphosphate (STPP)	0.5	0.5	0.5	0.5	0.5
Crushed ice	5	5	5	5	5

[*] Control, 100% fat; 25BROC, 75% fat + 25% broccoli; 50BROC, 50% fat + 50% broccoli; 75BROC, 25% fat + 75% broccoli; 100BROC, 100% broccoli.

that was adapted from Ismail et al. (2022). The raw chicken patties were thawed before being cooked using a countertop electric griddle (MSM Hot Plate Model HP-6000, Malaysia), whereby the surface of the griddle was preheated to a temperature of 150 °C then smeared with a thin layer of palm oil. The duration of griddling was set to 4 min on each side until the patties reached a core temperature of 75°C.

Proximate analysis

The proximate compositions of the chicken patties, such as moisture (Oven drying method) (Method No. 930.15), ash (Muffle furnace method) (Method No. 930.05), protein (Kjeldahl method) (Method No. 930.05), and fat (Soxhlet method) (Method No. 930.05) were determined by using the AOAC (2012) method.

pH measurement

Ten grams of chicken patties were mixed and homogenized with 10 mL of distilled water. Then, the pH value was measured using a pH meter (Jenway Model 3505 pH meter, UK) (Rusman *et al.*, 2023).

Cooking yield

The weights of the chicken patty were measured at room temperature before and after cooking. The cooking yield was reported in percentage, as indicated in the formulation below (Jandyal *et al.*, 2022):

Cooking yield (%) = (Weight of cooked patties / Weight of uncooked patties) x 100

Reduction in diameter and thickness

The reduction in diameter and thickness of the raw and cooked patties was recorded using Vernier callipers and calculated using the following formulations (Ismail *et al.*, 2021).

Reduction in diameter (%) = [(Diameter of raw patties – Diameter of cooked patties) / Diameter of raw patties] x 100

Reduction in thickness (%) = [(Thickness of raw patties – Thickness of cooked patties) / Thickness of raw patties] x 100

Colour profile measurement

The colour measurement of the chicken patty was evaluated using a chromameter (CR-40, Minolta Camera Co., Japan) by obtaining rates of lightness (L*), redness (a*), and yellowness (b*) of samples. The analysis was carried out in triplicate, taking three measurements of each sample (Faridah *et al.*, 2023).

Texture profile analysis (TPA)

TPA was determined by using a computer-assisted Stable Micro Systems texture analyser (Model TA-XT2i, Stable Micro System, Surrey, UK). The samples were examined using a probe of the 75-mm square compression platen type. The hardness, cohesiveness, springiness, and chewiness of chicken patties were measured. The texture analyser settings for TPA were: load cell at 25 kg, pre-test speed at 1.00 mm/sec, test speed at 1.00 mm/sec, post-test speed at 5.00 mm/sec, and strain at 70% (Ismail *et al.*, 2021).

Warner-Bratzler analysis

Chicken patty samples were obtained from the middle part of each patty. Each patty was cut into 5.0 cm (L) × 2.5 cm (W) × 2.0 cm (D) and sheared with a Warner-Bratzler blade set attached to a texture analyser (Model TA-XT2i, Stable Micro System, Surrey, UK). The test speed was set at 2 mm/s. Data was collected and analysed to determine the work of shearing (N.s) required to shear through each sample (Ismail *et al.,* 2021).

Sensory evaluation

The sensory evaluation was carried out by using a nine-point hedonic scale to evaluate the colour, texture, flavour, appearance, juiciness, and overall acceptability. The hedonic scales are as follows: 9: like extremely, 8: like very much, 7: like moderately, 6: like slightly, 5: neither dislike nor like, 4: dislike slightly, 3: dislike moderately, 2: dislike very much, and 1: dislike extremely. The evaluation was determined by serving patties to 50 untrained but experienced panellists (Ismail *et al.,* 2022).

Statistical analysis

All the physicochemical analyses were done in triplicate and the complete data on the physicochemical and sensory properties of chicken patties were analysed statistically by using one-way ANOVA and Tukey's test for pairwise comparision using Minitab Statistical Software Version 19 (Minitab Inc., State College, PA, USA). The statistical confidence level was expressed at 95%.

RESULTS AND DISCUSSION

Proximate composition

The proximate compositions of cooked chicken patties formulated with different percentages of broccoli are shown in Table 2. The moisture content of the patties showed an increasing trend from control to fat-replaced patties as the broccoli increased. The broccoli itself contains a high amount of moisture and fibre (Table 2) which could contribute to the higher moisture content in the patties. The crude fibre content also showed an increasing pattern, especially for 50%, 75% and 100% (P<0.05). Fresh broccoli was rich in fibre (11.47%) which could be a factor in the higher fibre content in the patties. This study outcome is in agreement with the study by Yadav et al. (2018), who reported that the crude fibre content of sausages increased significantly after the incorporation of fibre sources into meat such as wheat bran and dried carrot pomace. Meanwhile, the fibre might hold the water in the patties, and once cooked, it could contribute to increasing the ability to retain water in the meat matrix, thus increasing the moisture content (Al-Kuraieef *et al.,* 2019).

Table 2. The proximate composition of cooked chicken patties formulated with different percentages of broccoli paste as the fat replacer

[1]Sample	Control	25BROC	50BROC	75BROC	100BROC
Moisture (%)	57.64 ± 2.20^{b}	58.23 ± 2.59^{ab}	60.96 ± 1.60^{a}	62.65 ± 1.70^{a}	62.85 ± 3.81^{a}
Crude Protein (%)	21.19 ± 0.83^{a}	21.87 ± 0.58^{a}	20.61 ± 0.32^{b}	19.86 ± 0.98^{b}	19.78 ± 0.88^{b}
Crude Fat (%)	12.47 ± 1.14^{a}	11.89 ± 1.37^{ab}	10.84 ± 1.89^{ab}	10.94 ± 1.79^{ab}	9.35 ± 0.95^{b}
Ash (%)	4.01 ± 0.16a^{a}	3.70 ± 0.33^{ab}	3.28 ± 0.44^{b}	2.91 ± 1.74^{bc}	2.78 ± 0.15^{c}
Crude Fibre (%)	5.32 ± 0.38^{b}	6.19 ± 0.49^{ab}	6.26 ± 0.17^{a}	6.31 ± 0.08^{a}	6.35 ± 0.30^{a}

[1]Control, 100% fat; 25BROC, 75% fat + 25% broccoli; 50BROC, 50% fat + 50% broccoli; 75BROC, 25% fat + 75% broccoli; 100BROC, 100% broccoli. $^{a-b}$Mean ± SD with different letters is significantly different (P<0.05) within the same row

The ash content of the chicken patties is expected to increase as the level of broccoli increases due to the presence of essential minerals such as potassium, phosphorous, calcium, sodium, magnesium, and others (Zaini *et al.,* 2019). However, the broccoli paste added in the study has high amount of moisture and it replaced the chicken skin, therebty leading to decrease in the ash content upon increasing levels of broccoli in the formulations. Such as, Farag (2014) studied the effects of broccoli powder on antioxidant activity and quality attributes of ostrich meat nuggets and reported that the ash contents of the samples were significantly increased (P<0.05) as the amounts of broccoli powder in the samples' formulation increased.

The crude protein content in chicken patties showed a decreasing trend with the increasing levels of broccoli paste. The lower protein content in the treated products might be due to the considerable low amount of protein in the broccoli paste. Similarly, in the study by Choi et al. (2016), they reported that the protein content of chicken patties was slightly decreased when the wheat sprout level was increased from 0% to 2%.

By reducing the amount of chicken skin in the formulations, the fat content can be successfully reduced. This can be observed in Table 2, which shows a decreasing pattern of crude fat content in the chicken patties as the percentage of broccoli increases. However, only at 100% fat replacement with broccoli did there appear to be a significant reduction (P<0.05) compared to the control sample. Since broccoli contains a very small amount of fat (1.18%) , the crude fat present in this sample is largely contributed by the fat associated with chicken meat alone. Kumar et al. (2013) also reported a decrease in fat content with the incorporation of broccoli powder in emu meat nuggets.

pH, cooking yield, reduction in diameter and thickness

Table 3 shows the cooking yield, pH value, and reduction in diameter and thickness of the patties formulated with different percentages of broccoli. No significant differences (P>0.05) in pH values were observed for all the cooked patties (5.95–5.99), indicating that the incorporation of broccoli did not significantly affected the pH of patties. The acidity and alkalinity of raw materials incorporated in the meat product formulation may influence the ultimate pH value and functional characteristics of the product (Serdaroğlu *et al.,* 2018). In addition, the pH measurement is important to determine the microbial growth of bacteria, as they grow optimally at approximately pH 7. A high pH in the final meat product has a higher potential for spoilage and a shorter shelf life (Carvalho *et al.,* 2019).

Table 3. pH, cooking yield, and reduction in diameter and thickness of chicken patties formulated with different percentages of broccoli paste as the fat replacer

[1]Sample	Control	25BROC	50BROC	75BROC	100BROC
pH	5.95 ± 0.05	5.95 ± 0.03	5.96 ± 0.04	5.99 ± 0.03	5.99 ± 0.05
Cooking yield (%)	74.16 ± 1.92^{b}	77.56 ± 0.69^{ab}	78.69 ± 0.91^{a}	76.88 ± 0.66^{ab}	76.56 ± 1.78^{ab}
Reduction in diameter (%)	9.47 ± 1.01	9.09 ± 4.19	9.19 ± 4.17	8.69 ± 1.49	12.47 ± 2.51
Reduction in thickness (%)	25.27 ± 11.19	15.27 ± 6.05	19.16 ± 6.29	16.20 ± 7.64	17.26 ± 6.76

[1]Control, 100% fat; 25BROC, 75% fat + 25% broccoli; 50BROC, 50% fat + 50% broccoli; 75BROC, 25% fat + 75% broccoli; 100BROC, 100% broccoli.

[a-b]Mean ± SD with different letters is significantly different (P<0.05) within the same row.

In burger patties processing, the grinding of meat results in a tender product due to the breakdown of myofibrils and connective tissue, which promotes weight loss during the cooking process (Serdaroğlu *et al.,* 2018). But in this study, replacing the chicken skin with broccoli improved the cooking yield, especially at 50% (P<0.05). The fibre from the broccoli may promote the stability of the patties' cooking yields. This was aligned with the report by Verma and Banarjee (2010), who suggested that fibre can retain water and decrease cooking losses in meat products.

There were no significant differences (P>0.05) in the reduction in diameter and thickness. It could be concluded that broccoli inclusion provided an equivalent diameter reduction to control samples, regardless of the level added. The higher thickness changes in the control sample in contrast to the fat-replaced samples could be attributed to the stabilizing properties of broccoli, which restricted the distortion of the fat-replaced patties during cooking (Serdaroğlu *et al.,* 2018). The reduction in diameter and thickness of patties during cooking is caused partly by muscle protein denaturation and partly by the evaporation of water and/or drainage of melted fat and juices (Alakali *et al.,* 2010).

Colour properties, textural profile analysis, an work of shear

Table 4 shows the colour properties of uncooked and cooked chicken patties, textural profile analysis, and work of shear of chicken patties formulated with different percentages of broccoli. The difference in lightness (L*), redness (a*), and yellowness (b*) of uncooked and cooked fat-replaced chicken patties with various broccoli levels was significant (P<0.05). The L* and a* values of both uncooked and cooked chicken patties decreased with an increase in the broccoli percentage. Sisik et al. (2012) explained that the increase proportion of broccoli in the formulation of chicken patties causes the dilution of myoglobin and can reduce the intensity of lightness and redness. Another explanation may be that the chlorophyll contained in broccoli can mask the redness of chicken meat, thereby reducing the redness values (Bakhsh *et al.,* 2023).

The decrease in a* value for cooked patties is due to the cooking process, which caused myoglobin denaturation and hence increased the soluble myoglobin content (Sen *et al.,* 2014). The yellowness value of cooked chicken patties shows a slight increase compared to uncooked patties. This may be due to the Maillard reaction that takes place when heat is applied. During the Maillard reaction, the formation of melanoidins occurs, which are brown pigments that can contribute to the yellow colour of the meat (Lund and Ray, 2017).

The incorporation of plant fibre into meat products may alter the product's texture properties, depending on the fibre and meat types. However, the findings from Table 4 revealed that other than springiness, there were no remarkable (P>0.05) differences in the textural parameters of hardness, cohesiveness, and chewiness. Springiness can be defined as the ability of a product to return to its original shape after being compressed (Ming-Min and Ismail-Fitry, 2023). Table 4 shows a decreasing trend of springiness as the broccoli incorporation increased; however, only the sample

Table 4. Colour properties, textural profile analysis, and work of shear of chicken patties formulated with different percentages of broccoli paste as the fat replacer

Treatment variables		**Control**	**25BROC**	**50BROC**	**75BROC**	**100BROC**
Colour properties of uncooked patties	Lightness (L*)	61.52 ± 1.55^{a}	57.19 ± 1.24^{b}	56.03 ± 0.83^{b}	49.22 ± 1.85^{c}	48.08 ± 1. 46^{c}
	Redness (a*)	8.24 ± 0.70^{a}	3.63 ± 0.67^{b}	0.61 ± 0.15^{c}	0.48 ± 0.25^{c}	0.42 ± 0.13^{c}
	Yellowness (b*)	13.68 ± 0.41^{b}	14.92 ± 0.66^{ab}	15.44 ± 1.37^{ab}	15.80 ± 0. 41^{a}	16.31 ± 0.43^{a}
Colour properties of cooked patties	Lightness (L*)	54.12 ± 1.09^{ab}	57.04 ± 3.24^{a}	53.91 ± 2.67^{ab}	50.30 ± 3.60^{ab}	46.78 ± 2.36^{b}
	Redness (a*)	14.38 ± 2.09^{a}	8.06 ± 2.39^{b}	7.33 ± 1.07^{b}	8.39 ± 2.29^{b}	3.99 ± 0.61^{b}
	Yellowness (b*)	31.20 ± 2.85^{a}	26.49 ± 1.04^{b}	26.63 ± 0.50^{b}	24.61 ± 0.97^{bc}	22.21 ± 1.08^{c}
Texture profile properties	Hardness (g)	24652.16 ±1885.44^{a}	20994.59 ±1604.50^{a}	21774.10 ±2845.03^{a}	23393.81 ±358.53^{a}	23483.09 ±1428. 08^{a}
	Cohesiveness (mm/mm)	0.52 ±0.03^{a}	0.52 ±0.03^{a}	0.52 ±0.03^{a}	0.50 ±0.02^{a}	0.56 ±0.01^{a}
	Springiness (mm/mm)	0.85 ±0.01^{a}	0.85 ±0.01^{a}	0.83 ±0.01^{ab}	0.84 ±0.01^{ab}	0.82 ±0.01^{b}
	Chewiness (g/m^{3})	10945.59 ± 719.58^{a}	9518.82 ±1151.51^{a}	9522.14 ±1557.13^{a}	10011.01 ±531.13^{a}	10838.64 ±1103.28^{a}
Work of shear (kg.sec)		30.32 ± 2.56^{a}	30.09 ± 5.79^{a}	25.06 ± 1.30^{a}	24.75 ± 2.46^{a}	28.3 ± 4.18^{a}

Control, 100% fat; 25BROC, 75% fat + 25% broccoli; 50BROC, 50% fat + 50% broccoli; 75BROC, 25% fat + 75% broccoli; 100BROC, 100% broccoli.
$^{a\text{-}b}$*Mean ± SD with different letters is significantly different (P<0.05) within the same row.*

with 100% fat replacement noted a significant (P<0.05) reduction compared to other samples. This means that a total replacement of animal fat, specifically chicken skin in this study, caused the chicken patties to be less springy, which might not be favourable to the overall textural attributes of the final product. Other studies have also reported a significant drop in the springiness of meat products with the addition of fibre sources: citrus and apple fibre (Barbut, 2023), citrus fibre (Song *et al.,* 2016), and sugarcane dietary fibre (Zhuang *et al.,* 2016).

The addition of vegetable fibre to meat products increases instrumental firmness (Cox and Abu-Ghannam, 2013), which is well correlated with the work of shearing. Theoretically, the work of shearing value is expected to increase with the addition of broccoli and the reduction of fat content since the fat contained in the meat products can promote lubrication of the blade, thus decreasing the required work to shear the sample. Nonetheless, an insignificant observation was recorded (P>0.05), with the sample control having a slightly higher (P>0.05) work of shearing compared to the other treated samples. This may be explained by the high amount of connective tissues from the chicken skin in the control sample, which are primarily collagen and transform into gelatin when heated, contributing to a firmer texture (Faridah *et al.,* 2023).

Sensory properties

Sensory evaluation is among the most crucial analyses to predict consumer acceptance of a new food product. The present sensory analysis data show that the control samples have dominant scores for certain attributes, particularly texture, taste, appearance, juiciness, and overall acceptability. The decrease in colour scores, especially at 75% and 100% fat replacement, may be due to the high green intensity of the chicken patties contributed by the broccoli. High intensity of green in chicken patties is generally regarded as undesirable because the colour green is not usually associated with fresh or desirable chicken meat products (Bergamaschi *et al.,* 2023). Colour property can be considered one of the most important sensory properties because it can further affect sensory expectations, especially for overall appearance and acceptance. This can be supported by the sensory data tabulated in Table 5, which shows that the overall appearance and acceptability of the 75% fat replacement sample scored the lowest as well. In a sensory evaluation by Jauhar et al. (2021), it was found that the chilled-stored chicken meat sample treated with green tea extract also had lower colour scores due to the yellow colour that was contributed by the green tea, which adversely affects the natural colour of the chicken flesh. The decrease in flavour scores may be due to the dilution of meaty flavour by the addition of broccoli in the formulation. In addition, reducing the amount of fat also affects the flavour scores, as the chicken skin and fat are responsible for contributing to the flavour of the chicken patties (Jauhar *et al.,* 2021). Similar results have been obtained by Choi et al. (2016) on the flavour acceptance of replaced-fat chicken patties with wheat sprouts at various levels.

Table 5. Sensory properties of chicken patties formulated with different percentages of broccoli paste as the fat replacer

[1]Sample	Control	25BROC	50BROC	75BROC	100BROC
Appearance and colour	7.28 ±1.32^{a}	7.38 ±1.17^{a}	7.20 ±1.195^{ab}	6.52 ±1.44^{b}	7.08 ±1.15^{ab}
Texture	7.40 ±1.45^{a}	6.92 ±1.22^{ab}	7.14 ±1.35^{ab}	6.42 ±1.51^{b}	6.60 ±1.50^{ab}
Flavour	7.46 ±1.51^{a}	6.90 ±1.65^{ab}	6.26 ±1.75^{bc}	5.42 ±1.96^{c}	5.44 ±1.92^{c}
Juiciness	6.14 ±1.47	6.70 ±1.38	6.74 ±1.22	6.72 ±1.81	6.87 ± 1.14
Overall Acceptance	7.56 ± 1.29^{a}	7.16 ±1.18^{a}	6.82 ±1.35^{ab}	5.72 ±1.80^{c}	6.28 ±1.51^{bc}

[1]Control, 100% fat; 25BROC, 75% fat + 25% broccoli; 50BROC, 50% fat + 50% broccoli; 75BROC, 25% fat + 75% broccoli; 100BROC, 100% broccoli.

[a-b]Mean ± SD with different letters is significantly different (P<0.05) within the same row..

Overall, the addition of broccoli up to 50% fat replacement had no discernible detrimental effects on the colour, texture, flavour, appearance, juiciness, and overall acceptance of the chicken patties. Replacing fat with broccoli at levels 75% and 100% shows the opposite. Therefore, 25–50% broccoli is likely the most appropriate amount to replace the chicken skin in the chicken patty formulations.

Conclusion

In conclusion, the results deduced the potential of replacing chicken skin with broccoli at different levels, especially at levels 25% and 50%. Results concluded that the moisture, protein, and fibre content of chicken patties improved as the level of incorporation of broccoli increased, with minimal effects on other parameters such as pH level, cooking yield, reduction in diameter and thickness, textural profiles, and work of shearing values. The incorporation of broccoli also did not negatively affect the colour profile, and the sensory evaluation documented a good rating from panellists especially for chicken patties with 25% and 50%. The outcome of this work can provide insightful information and be a reference for further research on replacing animal fats in processed meat products with high-fibre plant-based ingredients.

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