Canrea Journal: Food Technology, Nutritions, and Culinary, 2024; 7 (1): 79-93 OPEN ACCESS

e-ISSN : 2621-9468

Type of the Paper (Article)

Effects of different cooking preparations on the nutritional composition and antioxidant properties of *Etlingera coccinea (Blume) S. Sakai & Nagam* (Tuhau)

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Abstract

Tuhau (*Etlingera coccinea*) is a traditional plant widely consumed in Southeast Asia due to its unique flavor and potential health benefits. However, the influence of various cooking preparations on its nutritional composition and antioxidant activities remains understudied. This research aimed to investigate the effect of different cooking methods on Tuhau, providing valuable insights for optimizing its preparation for enhanced health benefits. Tuhau rhizomes were purchased, sliced, and divided into six groups representing different cooking preparations: control, pickled, stir-fried, deep-fried, boiled, and blanched. Proximate analysis was conducted to determine the nutritional composition, including ash, protein, fat, moisture, crude fiber, and carbohydrate content. The antioxidant activities of the cooked Tuhau samples were evaluated using DPPH and ABTS radical scavenging assays, while the total phenolic content (TPC) was determined using the Folin-ciocalteu method. Uncooked Tuhau samples were used as a control for comparison. The findings indicate that different cooking methods significantly influence the nutritional composition and antioxidant activities of Tuhau. Cooking processes, such as boiling and blanching, increased the moisture content, while stir-frying and deep-frying led to higher fat content. Moreover, deep-fried Tuhau exhibited the highest crude fiber content and TPC, which could contribute to its enhanced antioxidant activities. However, the weak correlation between antioxidant assays and total phenolic content suggests that other compounds may also contribute to the observed antioxidant properties of Tuhau. This study demonstrates that cooking preparations impact the nutritional composition and antioxidant activities of Tuhau. The findings provide valuable insights for optimizing the cooking methods of Tuhau to enhance its health benefits. Further research is warranted toexplore other nutritional compositions and the use of Tuhau as a food ingredient in a variety of food products.

Article History
Received July, 5 2023
Accepted June,18 2024
Published June, 25 2024

Keywords
Tuhau, *Etlingera coccinea*, wild ginger, nutritional composition, antioxidant.

1. Introduction

Malaysia, a country with a population exceeding 30 million people representing diverse ethnic backgrounds, is home to various groups, particularly the indigenous communities predominantly residing in Borneo, comprising the regions of Sabah and Sarawak. Each ethnic group in Malaysia preserves a distinct culture and tradition, transmitted across generations. In recent years, there has been a growing interest in the food industry, specifically focused on

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ISSN 2621-9468 online, DOI 10.20956/canrea.v7i1.1067

the consumption of traditional foods (1). Within Southeast Asian countries, ginger plants (Zingiberaceae) are commonly incorporated into the local diet. Tuhau, scientifically known as *Etlingera coccinea*, is a wild ginger variety renowned as a traditional culinary delight in Sabah, Malaysia, particularly among the Kadazandusun ethnic group (1). In Sarawak and Java, it is referred to as "Tepus" by the local population (2,3). Some wild gingers, including Tuhau, are consumed as wild vegetables (4). The unique characteristic of Tuhau lies in its pungent aroma, which endears it to many, in addition to its harmonious combination of sour and spicy flavors. Tuhau can be prepared in various ways, catering to individual preferences. It can be pickled or transformed into floss (*serunding*). In Sarawak, Tuhau is traditionally boiled with other ingredients in bamboo to create a local delicacy known as "ayam pansuh," popular among the Dayak ethnic group (5). Beyond its culinary applications, Tuhau is also valued for its medicinal properties, being utilized as a traditional remedy for conditions such as stomachaches, gastric problems, and wound healing. These therapeutic effects could be attributed to the antioxidant activity of Tuhau, which aids in stabilizing the impact of free radicals within the gastrointestinal tract and inhibiting the overproduction of reactive oxygen species (ROS), thereby facilitating the wound healing process.

Despite its popularity and widespread consumption among the indigenous communities in Borneo, the nutritional composition and antioxidant properties of Tuhau following different cooking preparations have not been reported. Previous studies have demonstrated that different cooking methods can significantly impact the nutrient composition and antioxidant properties of food materials. For instance, boiling and stir-frying of bamboo shoots were reported to cause notable changes in nutrient components (6). Boiled bamboo shoots exhibited decreased protein content, soluble sugar, and ash content, as well as a loss in total free amino acids. Stir-fried bamboo shoots, on the other hand, experienced a significant increase in fat content due to the addition of edible cooking oil. Furthermore, boiling led to a reduction in L-ascorbic acid and total phenolic contents (TPC). In terms of antioxidant properties, stir-frying increased the antioxidant capacities of bamboo shoots, making it a more suitable cooking method for retaining high levels of antioxidants (6). Furthermore, cooking and microwaves appear to greatly lowers the biological activity of ginger rhizome (7). Conversely, frying or blanching preserves the bioactive constituents which are vital for the antioxidant potential of ginger and many other plant-based foods, by either retaining or even increasing their contents (7,8). By considering the findings from these studies, it is evident that the choice of cooking methods plays a crucial role in determining the nutritional outcomes of various plant species.

Despite the significance of cooking methods on nutritional composition and antioxidant properties, limited knowledge exists regarding the effects of different cooking methods on Tuhau. Therefore, this study aims to evaluate the effects of various cooking preparations on the nutritional composition and antioxidant activities of Tuhau, providing valuable insights for future references. The selected cooking preparations are based on the methods employed in existing Tuhau-based preparations, with the additional purpose of exploring the specific effects of each cooking method on the nutritional composition and antioxidant activities of Tuhau for future applications.

2. Materials and Methods

Tuhau samples were purchased from the local market in Keningau, Sabah, Malaysia (5°20'19.9"N 116°09'31.8"E). The edible part (rhizome) was used as sample throughout the

research. Samples were subjected to the following preparations prior to drying at 40°C before subsequent analysis (Figure 1). Uncooked Tuhau samples were used as comparison.

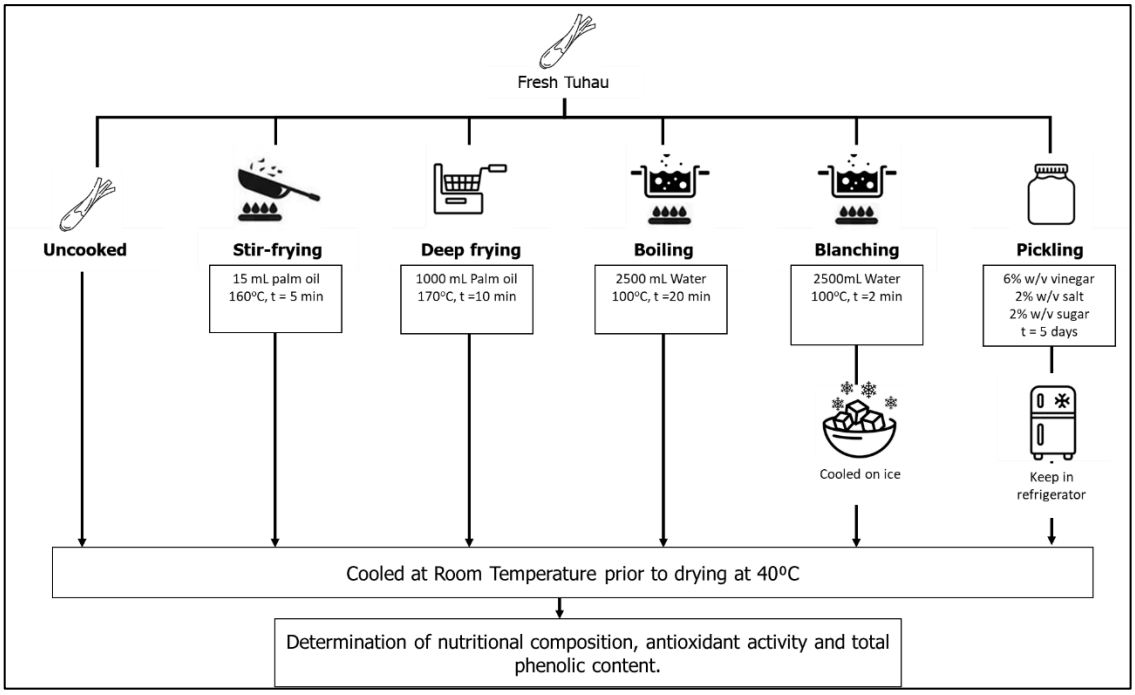

Figure 1. Schematic diagram depicting different cooking preparations of Tuhau.

2.1. Cooking Preparations

2.1.1. Pickling

The pickled Tuhau was prepared following previously described method (4,9) with slight modifications. A total of 550 g of Tuhau was thoroughly washed using tap water and sliced into small pieces approximately 0.5 cm thick. The sliced Tuhau was then placed into an airtight container. A brine solution was prepared by adding 6% w/v vinegar, 2% w/v salt, and 2% w/v sugar. The brine solution was added to the container, covering the sliced Tuhau, and the container was sealed. The pickling process was conducted at room temperature for 5 days, after which the container was transferred to a refrigerator prior to further analysis.

2.1.2. Stir-frying

The stir-fried Tuhau was prepared following the method outlined by (6,10), with slight modifications. A total of 550 g of Tuhau was sliced into small pieces as described above. In a frying pan, 15 ml of palm oil (Vesawit Cooking Oil) was heated until it reached a temperature of 160°C. The sliced Tuhau was then added to the frying pan and stirred continuously for 5 minutes. No taste enhancers were used during the cooking method. Following the cooking treatment, the sample was carefully removed from the frying pan and allowed to cool at room temperature.

2.1.3. Deep-frying

The deep-fried Tuhau was prepared following previously described method (11). A total of 550 g of Tuhau was sliced into small pieces approximately 0.5 cm thick. In a frying pan, 1 L of palm oil (Vesawit Cooking Oil) was heated to a temperature of 170°C. The sliced Tuhau was

then carefully placed into the pan and fried for a duration of 10 minutes until it reached a crispy texture.

2.1.4. Boiling

Boiled Tuhau was prepared following previously described method (11,12) with a slight modification. A 550 g of fresh sample were cut into small pieces of 0.5 cm of thickness and put into 2.5 L of 100℃ boiling water for 20 min in a covered stainless-steel pot on electric stove. The pot was covered to maintain the water level. The cooked samples were cooled at room temperature for 2 hr. The excess water was drained off. The samples were blotted to remove surface moisture.

2.1.5. Blanching

The preparation of blanched Tuhau was done following the method by (13) with a slight modification. 550 g of fresh Tuhau were blanched in 2.5 L of 100℃ boiling water for 2 min. The excess water was drained and the sample was rapidly cooled in ice after blanched to stop the cooking process. The Tuhau was bloated to remove surface moisture and cooled at room temperature.

2.2. Determination of Nutritional Composition

The samples were analyzed for crude protein, ash content, crude fat content, and carbohydrate following the method from the Association of Official Analytical Chemist official procedures, AOAC (14).

2.2.1. Moisture Content

The moisture content of the dried samples was determined as previously described (14). An empty clean petri dish with lid will be first dried in an oven at 105℃ for 30 min, and let cool at room temperature in a desiccator. The dished ware will be weighed using an analytical balance and labelled as (a). 2 g of sample powder will be transferred into a known weight crucible labelled as (b) and then dried in an oven at 105℃ for 24 hours. The crucible with lid containing the sample powder will be left to cool at room temperature in a desiccator after 24 hours and later weighed and labelled as (c). The percentage of moisture content of the sample will be calculated by the formula:

$$\% \text{ moisture content} = \frac{(b - c)}{(b - a)} \times 100\% \quad (1)$$

Where,
a = Mass of crucible (g);
b = Mass of crucible + sample (g);
c = Mass of crucible + sample after oven dried for 24 hours (g).

2.2.2. Ash Content

The ash content of uncooked and Tuhau following different cooking preparations (pickled, stir-fry, deep-fry, boiling, blanching) were determined (14). A clean empty crucible with lid was dried in an oven at 105℃ for 3 hours, then cooled in a desiccator. The empty crucible was weighed and labelled as W1. From the pickled-treated samples, 2 g of the sample

powder was weighed and labelled as W2. The crucible that contains 2 g of powder sample was pre-ashed on a hot metal plate until no white smoke in a fume chamber to prevent contamination. The pre-ashed sample was transferred to a muffle furnace at 550℃ for 24 hours until the sample colour turned whitish ash. After the ashing process, the crucible containing ashed sample was kept in a desiccator to cool down. The crucible containing ashed sample was weighed and labelled as W3. The percentage of ash content of the sample was calculated by the formula:

$$\text{Ash content } (\%) = \frac{(\text{W3} - \text{W1})}{(\text{W2} - \text{W1})} \times 100\% \quad (2)$$

Where,
W1 = Mass of empty crucible with lid;
W2 = Mass of crucible with lid + pre-ash sample
W3 = Mass of crucible with lid + sample after complete ashing

2.2.3. Crude Protein Content

The protein content was analyzed by Kjeldahl method following the method from (14). 0.5 g of each dried sample powder was weighed on a filter paper with an analytical balance. The weighed sample was transferred into a Kjeldahl flask. 15 ml of concentrated sulphuric acid (H_2SO_4) along with 1 Kjeldahl tablet was added into the flask. The Kjeldahl tablets act as catalyst. Then, the sample was dissolved with a digestive machine for 1 hour 30 min. Kjeldahl tube was inserted into a Kjeltec 2300 machine. Distillation and nitration process were carried out.

2.2.4. Crude Fat Content

The total fat content of the dried samples was extracted by hexane based on the standard Soxhlet extraction method as previously described with a slight modification (15). 2 g of dried sample powder was transferred into the thimble. 90 ml of hexane was poured into a 500 ml round bottom flask as extraction solvent. The thimble with the sample powder was heated with hexane to let the vapour to rise through the vertical tube and into the top condenser. The process was carried out for 1 hour 20 minutes within 40-60℃. After the solvent was removed, the hexane-oil mixtures were placed into a rotary vacuum evaporator at 45℃ for 2 hours. This method was done to remove the hexane traces. The extracted fat was cooled in a desiccator and weighed. The percentage of total fat contents was determined by using the formula:

$$\text{Total fat yield} = \frac{\text{Mass of extracted Tuhau fat (g)}}{\text{Mass of Tuhau powder (g)}} \times 100\% \quad (3)$$

2.2.5. Crude Fiber Content

The crude fiber content of dried sample powder was analyzed following the procedures by (14) An empty fiber bag was weighed and labelled as M1. 1 g of the sample was weighed and labelled as M2. The sample was put into the fibre bag. The fiber bag was marked using a pencil. The fiber bag was put into a Fibreterm machine carousel. As the process run, it covered the cleaning phase I, removal of acid, cleaning phase II and removal of alkali, where these

were carried out automatically in the carousel. During cleaning process phase, 0.13 moles of sulphuric acid (H_2SO_4) and 0.313 moles of sodium hydroxide (NaOH) were used. The process was run for 2 hours. After completion, the fiber bag was removed from the carousel and transferred in a crucible. The weight of the empty crucible was weighed and labelled as M4. The fiber bag was dried using an oven at 105℃ for overnight. The dried fiber bag in the crucible was cooled in a desiccator for 10 min and weighed and labelled as M6. The crucible was placed in a furnace at 550℃ for 4 hours until the ash was produced. The crucible containing the ash was cooled in a desiccator for 15 min, later labelled as M3. The percentage of crude fiber content of the sample will be calculated using the formula:

$$\text{Crude fiber content } (\%) = \frac{(\text{M3} - \text{M1}) - (\text{M4} - \text{M5})}{\text{M2}} \times 100\% \quad (4)$$

Where,
m1 = Weight of empty fiber bag (g);
m2 = Weight of dried sample powder (g);
m3 = Weight of fiber bag with sample after furnace treatment + crucible (g);
m4 = Weight of empty crucible (g);
m5 = Weight of empty fiber bag ash (g);
m6 = Weight of dried fiber bag after oven dried (g).

2.2.6. Total Carbohydrate Content

The carbohydrate content was determined by using the procedures as described by AOAC (2000) (14). Total carbohydrate of the samples was determined by subtraction of the total percentage values of moisture content, protein, ash, fat content, and crude fiber obtained from 100%.

2.3. Preparation of Extract

Extracts were prepared as previously described (11). Cooked and uncooked samples were dried by cabinet drying. The dried samples were grounded to pass a 1 mm sieve. 1 g of the sample powder was mixed with 10 ml of 80% methanol overnight and incubated in dark condition at room temperature. The mixture was centrifuged at 3000 rpm for 15 min. The supernatant was separated via filtration with Whatman No. 1 filter paper and evaporated at 40℃ using a rotary evaporator. The yield of the extraction was calculated.

2.4. Determination of Antioxidant Properties

2.4.1. DPPH Radical Scavenging Activity

The antioxidant activity of Tuhau samples was determined by DPPH (2,2'-diphenyl-1-picryl-hydrazyl) method as described by (16) with a slight modification. 0.5 mg of Tuhau sample was mixed with 1 mL methanol to prepare the sample extract. 250 µL of 0.004% DPPH solution that was produced from 4.2 mg of DPPH dissolved in 50 mL of methanol was included into the mixture. Methanol was used due to the solubility of DPPH in polar organic solvents. The mixture was stirred until well mixed and later incubated in dark for 30 min. The absorbance was measured at 540 nm using the UV-Vis spectrophotometer. Methanol was taken as blank while ascorbic acid was used as positive control. This analysis was conducted

under dark surroundings due to sensitivity of DPPH towards light. The antioxidant activity percentage was determined using the following equation:

$$\% \text{ antioxidant activity} = \frac{\text{Absorbance (control)} - \text{Absorbance (sample/Ascorbic acid)}}{\text{Absorbance (control)}} \text{ x } 100 \quad (5)$$

2.4.2. ABTS Radical Scavenging Activity

The method for ABTS radical scavenging activity followed the method as described by (17) with slight modifications. The preparation of the stock solution was done by mixing 10 mL of 7.4 mM ABTS solution with 10 mL of 2.6 mM potassium thiosulfate ($K_2S_2O_2$). The mixture was wrapped with aluminium foil in a volumetric flask and left in the dark at room temperature for 15 hours, and then kept at room temperature until further use. As for the working solution, 1 mL of stock solution was diluted with 60 mL of methanol to obtain an absorbance value of 1.1 ± 0.02 at λ = 734 nm. Sample analysis was initiated by the addition of 2.85 mL of the working solution to 0.15 mL of the sample extract. The solution was left in the dark at room temperature for 2 hours. Ascorbic acid was used as positive control. UV-Vis spectrophotometer was used to measure the absorbance (λ = 734 nm). The antioxidant activity was determined using the following equation:

$$\% \text{ antioxidant activity} = \frac{\text{Absorbance (control)} - \text{Absorbance (sample/Ascorbic acid)}}{\text{Absorbance (control)}} \text{ x } 100 \quad (6)$$

2.5. Determination of Total Phenolic Content

The total phenolic contents for the Tuhau extracts were determined by using the Folin-Ciocalteu reagent (18). The extracts were dissolved in ethanol (1 mL, 0.5 mg/mL). 40 µL of the sample extracts were obtained and added in test tubes. 3.16 mL of distilled water was added. The samples were mixed with 0.2 mL Folin-Ciocalteu reagent and 0.6 mL sodium carbonate. The absorbance at 765 nm was measured using spectrophotometers after incubated for 2 hours. The linear curve of standard gallic acid solution was obtained ($y = 0.0152x + 0.02$; $R^2 = 0.9992$), where the extract total phenolic content was expressed as mg GAE/g extract.

2.6. Statistical Analysis

Data obtained was analyzed with Statistical Package for the Social Science (SPSS) Window, version 27. All assays were done in triplicate (n=3). The results were expressed as mean value and standard deviation. One-way analysis of variance (ANOVA) and Tukey test were carried out to analyze the effect of different cooking preparations on the nutritional composition and antioxidant activities, with a significance of variance of less than 0.05 ($p < 0.05$). Pearson's correlation was carried out to find correlations between TPCs and antioxidant activities.

3. Results and Discussion

Figure 2 shows Tuhau samples following different cooking preparations (Uncooked, pickled, stir-fried, boiled, deep-fried and blanched). Table 1 presents the nutritional composition of Tuhau following different cooking preparations. Water, as a predominant component in food products, plays a crucial role in their perishability. The moisture content of pickled, stir-fried, and deep-fried Tuhau was found to be significantly reduced compared to the uncooked sample ($p<0.05$). Conversely, boiling and blanching processes significantly

increased the moisture content compared to the uncooked, pickled, stir-fried, and deep-fried samples ($p<0.05$). The moisture content of fruits is closely associated with their quality, reflecting their freshness at harvest or storage duration prior to analysis. Furthermore, moisture content is an important indicator of shelf-life stability (19). High moisture content can promote microbial activities during storage (20).Therefore, the findings of this study suggest that Tuhau subjected to pickling, stir-frying, and deep-frying processes may have an extended shelf life due to their lower moisture content.

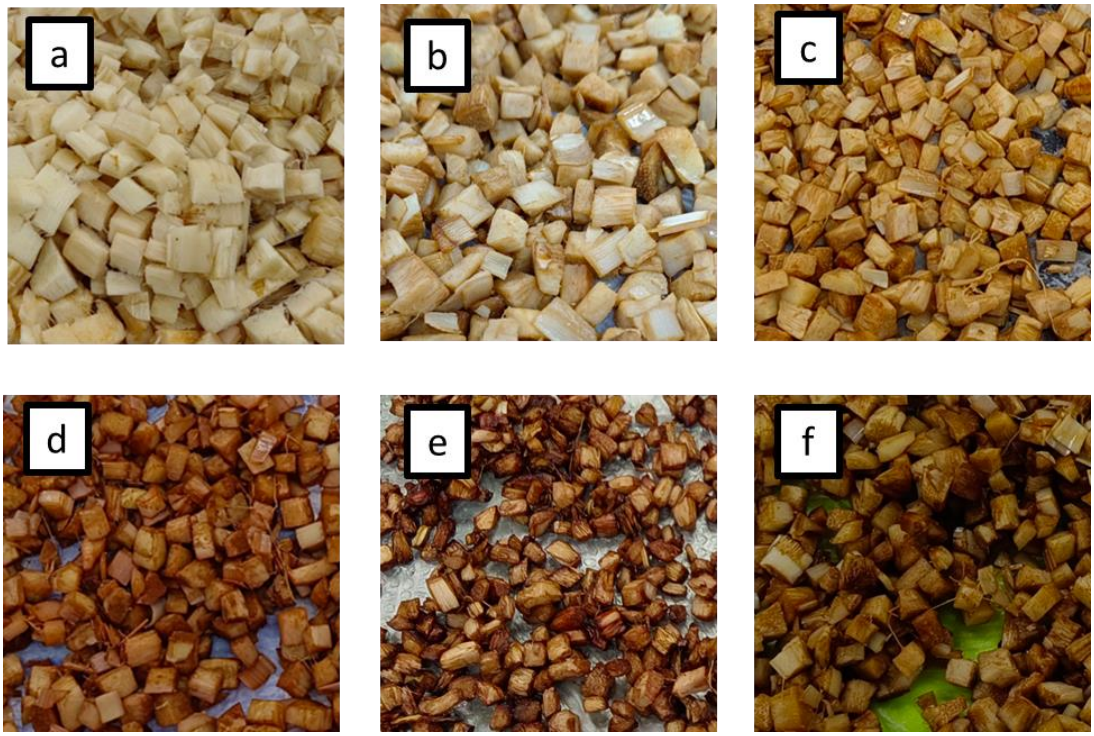

Figure 2. Tuhau samples following different cooking preparations. a) Uncooked; b) Pickled; c) Stir-fried; d) Boiled; e) Deep-fried; and f) Blanched.

Table 1. Nutritional composition of uncooked, pickled, stir-fried, boiled, deep-fried and blanched Tuhau (*Etlingera coccinea*).

Cooking Preparations	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Crude fibre (%)	Carbohydrate (%)
Uncooked	2.16 ± 0.06^{b}	22.35 ± 0.11^{c}	4.88 ± 6.87^{ab}	2.96 ± 0.75^{a}	21.66 ± 0.28^{ab}	45.28 ± 6.39^{b}
Pickled	0.78 ± 0.07^{a}	40.31 ± 0.52^{d}	4.33 ± 0.20^{a}	1.41 ± 0.87^{a}	8.70 ± 1.29^{a}	44.47 ± 0.21^{b}
Stir-fried	0.41 ± 0.03^{a}	14.12 ± 0.35^{b}	8.11 ± 0.61^{ab}	38.42 ± 3.88^{b}	30.93 ± 7.18^{bc}	8.00 ± 4.89^{a}
Boiled	2.87 ± 0.48^{c}	12.01 ± 0.06^{a}	12.48 ± 0.29^{b}	1.85 ± 1.13^{a}	32.22 ± 0.52^{bc}	39.29 ± 0.88^{b}
Deep-fried	0.61 ± 0.03^{a}	12.62 ± 0.03^{a}	7.84 ± 1.01^{ab}	31.07 ± 2.26^{b}	41.27 ± 11.54^{c}	14.96 ± 2.97^{a}
Blanched	2.91 ± 0.10^{c}	14.49 ± 0.52^{b}	0.48 ± 0.31^{a}	7.03 ± 8.33^{a}	27 ± 0.87^{bc}	48.09 ± 8.87^{b}

Data are expressed as mean ± standard deviation. Different letter(s) (a-d) in the same column indicate significant differences according to 1-way ANOVA ($p<0.05$)

All cooking preparations (stir-fry, boiling, deep-fry and blanching) except pickled Tuhau showed significant reduction in the ash content compared to uncooked Tuhau which serve as the control ($p<0.05$). The decrease in ash contents after blanching and boiling are likely a result of the diffusion of certain minerals into the cooking water or oil (21). There are no significant differences in terms of the ash content between boiling and deep-frying; where as there is no significant differences between stir-frying and blanching ($p>0.05$). The highest ash content was found to be in the picked sample which reported the values of 40.31%. The samples showed a significant increase in ash content after drying, thereby increasing the nutrient concentration (22). Moreover, the increased ash content after drying can also be explained by the low volatility of minerals, which are not destroyed by the heating process. The ash content represents the total amount of minerals present in a food (23). Blanching obtained the least protein content among the five samples (0.48±0.31%) even though the values are not statistically significant compared to deep fry, stir-fry, pickled and uncooked control sample ($p>0.05$). This result can be explained by high water content in the food matrix, which decreased the nutrient concentration (22). However, the results also showed that Tuhau following boiling process contains the highest protein content which is 12.48%, which is statistically significant compared to other samples ($p<0.05$).

Human dietary fiber comes from plant sources, such as fruits, vegetables, and seeds. Crude fiber is a measure of cellulose, hemicellulose, and lignin. Pickled, stir-fry, deep-dry, boiling and blanching do not show any significant differences in terms of the crude fiber content when compared to uncooked Tuhau ($p>0.05$). Deep-frying method exhibited the highest content of crude fiber in comparison to uncooked and pickled Tuhau ($p<0.05$), where as the values do not differ significantly when compared to stir-fry, boiling and blanching ($p>0.05$). Adequate intake of crude and dietary fiber is recommended for healthy food consumption. The importance of consuming fiber-rich food is well-known for its benefits as crude fiber aids in peristalsis movement of foods, helping in bowel movement, binding to fat deposits in the digestive tract, lowering blood cholesterol, and reducing the risk of colon cancer. For the carbohydrate content, stir-fry and deep-fry showed significant reduction compared to uncooked Tuhau ($p<0.05$). Other cooking preparations, namely pickled, boiling and blanching do not exhibit any significant differences with the uncooked sample ($p>0.05$). This implies that aside from uncooked Tuhau, the cooking methods such as pickled, boiling and blanching provides higher calorific values compared to the other two cooking methods (stir-fry and deep-fry), thus it is a more reliable and healthier alternatives for the source of energy. Besides, it can be said that uncooked, pickled, blanched and boiled Tuhau could be a good source of carbohydrate which constitutes a major class in naturally occurring organic compounds used to maintain life in plants and animals.

The increase of fat content was found to be significant for stir-fried and deep-fried samples compared with other cooking preparations ($p<0.05$). Fat increase can be due to the oil penetration into the sample after water is partially lost by evaporation. The increase in fat content of stir-fried and deep-fried Tuhau is also related to oil absorption during the cooking process. These results are in accordance previous findings who reported that the fat content in fried fish meat was significantly higher than the fresh and other cooked fish (24). The lowest fat content was exhibited by uncooked, pickled and blanched Tuhau samples.

The antioxidant activity of different cooking preparations of Tuhau is shown in Table 2. All the fresh and cooked Tuhau were able to reduce the stable, purple-coloured radical, DPPH, into the yellow-coloured DPPH-H. Interestingly, all cooking preparations exhibited

significantly higher antioxidant capacity when compared to uncooked Tuhau (control) ($p<0.05$). The highest DPPH free radical scavenging activity was shown by the ascorbic acid which acts as the positive control in this analysis. This is followed by the boiling and deep-frying methods. Pickled Tuhau showed the lowest antioxidant activity in scavenging the DPPH free radicals compared to other samples ($p<0.05$).

Table 2. DPPH and ABTS scavenging activities of uncooked, pickled, stir-fried, boiled, deep-fried and blanched Tuhau (*Etlingera coccinea*).

Cooking Preparations	DPPH scavenging activity (%)	ABTS scavenging activity (%)
Uncooked	27.62 ± 0.75^{a}	47.12 ± 0.34^{c}
Pickled	44.16 ± 0.74^{b}	42.20 ± 0.29^{b}
Stir-fried	56.29 ± 0.70^{d}	40.86 ± 0.15^{a}
Boiled	56.72 ± 0.41^{de}	80.01 ± 0.12^{e}
Deep-fried	58.68 ± 0.12^{e}	80.37 ± 0.12^{e}
Blanched	50.02 ± 0.02^{c}	61.92 ± 0.14^{d}
Ascorbic Acid	65.33 ± 0.01^{f}	89.49 ± 0.00^{f}

Data are expressed as mean ± standard deviation. Different letter(s) (a-d) in the same column indicate significant differences according to 1-way ANOVA ($p<0.05$).

The findings from DPPH assay corroborated the results shown by ABTS scavenging assays. This assay indicated that boiled and deep-fried Tuhau exhibited the highest activities in terms of scavenging the ABTS free radicals, with the values of 80.01% and 80.37%, which are significantly higher than the other methods used to prepare the Tuhau in this study ($p<0.05$). However, the results also showed that stir-fried and pickled Tuhau exhibited the lowest ABTS scavenging activities with the mean of 40.86% and 42.20%. Previous study reported an improvement in the antioxidant activity of tomatoes after heat treatment due to the increased release of phytochemicals, such as lycopene, from the matrix (25). Boiling of several vegetables would attribute to the suppression of oxidation by antioxidants due to thermal inactivation of oxidative enzymes (26). In addition, the boiling process may destruct the cell wall and subcellular compartments thus release of potent radical-scavenging antioxidants. It has been reported that boiling, microwave cooking and steaming induced significant increases in total antioxidant activity of pepper, green beans, broccoli and spinach (27). Therefore, our findings suggested that heat treatment might promotes the antioxidant capacity of Tuhau, thus corroborated the results of other previous studies.

Table 3 shows the total phenolic content of Tuhau following different cooking preparations. There is no significant difference in terms of the total phenolic content of pickled and blanched Tuhau when compared to uncooked control ($p>0.05$). This implies that these cooking preparations were able to preserve the beneficial compounds that might be responsible for the health benefits of the Tuhau. The tendency for the reduction of polyphenols and flavonoids could be due to disruption of the plant tissue and their release from the food matrix after heating (21). Significantly lower content of total phenolics exhibited by boiled Tuhau could likely a result of the diffusion of certain polyphenols into the cooking water during the cooking process (21). Lower values of total phenolics for boiling

methods could also be attributed to degradation of the bioactive compounds and absorption of water during boiling, resulting in dilution of the active compounds (28). The longer the cooking time, the greater losses of the total phenolic compound measured. This could be due to breakdown of phenolics or losses (leached out) during cooking as most of the bioactive compounds are relatively unstable to heat and easily solubilized. Literatures also have reported that after cooking (boiling, steaming and microwaving), the total phenolic compound of squash, peas and leek was significantly reduced. Interestingly, deep fried Tuhau contain the highest total phenolic content compared to other cooking preparations ($p<0.05$). However, the antioxidant activities were not significantly correlated with the total phenolic content of Tuhau following different cooking methods ($p>0.05$). This could be attributed to the existence of other compounds in Tuhau other than phenolics that might have better antioxidant capacities.

Table 3. Total phenolic content of uncooked, pickled, stir-fried, boiled, deep-fried and blanched Tuhau (*Etlingera coccinea*).

Cooking Preparations	Total Phenolic Content
Uncooked	6.22 ± 0.20^{c}
Pickled	6.71 ± 0.49^{c}
Stir-fried	4.20 ± 0.33^{b}
Boiled	1.10 ± 0.49^{a}
Deep-fried	8.58 ± 0.24^{d}
Blanched	6.18 ± 0.45^{c}

Data are expressed as mean ± standard deviation. Different letter(s) (a-d) in the same column indicate significant differences according to 1-way ANOVA ($p<0.05$).

Previous studies have found that cooking gave rise to an increase in phenolics in green beans, pepper and broccoli (28). The authors suggested that this is probably due to the increased level of free flavonols in the vegetables as affected by the heat treatment. It has been reported that there is an enhanced bioavailability of carotenoids after heat treatment in carrots and spinach, but boiling for 6 minutes have resulted in significantly lower β-carotene content than that of 4 minutes boiling (28). In general, processing of vegetables resulted in breakdown of the cellulose structure of the plant cell and thus improves the bioavailability of carotenoids. In a previous study, the antioxidant activity of barley was increased by roasting and microwave cooking treatments (29). Microwave heating retains the active components in cooked tissue (26). The antioxidant activity of vegetables cooked by microwaving was generally higher than that of vegetables cooked in boiling water, because microwaving, roasting, and baking do not stimulate the release of ascorbic acid or other antioxidants from cooked tissue (10). Also, various antioxidant substances leach into the water during boiling, which results in a decrease of the food's antioxidant capacities. Therefore, previous findings suggested that microwaving and roasting were better methods for retaining antioxidant activity than other cooking methods. In the context of current study, several limitations should be acknowledged such as the scope was limited to proximate analysis, antioxidant assays, and total phenolic content, focusing on only five cooking methods (deep frying, boiling, stir-frying, blanching, and pickling) alongside uncooked Tuhau.

Other common cooking methods, such as roasting, microwaving, steaming, and braising, were not investigated, restricting our understanding of their impacts on Tuhau's phytonutritional composition and potential health benefits.

4. Conclusions

This study showed that the nutritional composition of Tuhau can be affected by different cooking preparations. Certain cooking methods can be particularly beneficial when incorporating Tuhau into the diet. For instance, regular consumption of uncooked and pickled Tuhau may be advantageous due to the retention of mineral content, as indicated by higher ash content compared to other cooking methods. Additionally, pickling Tuhau can maintain or even enhance certain nutrients through the fermentation process. For those seeking to increase antioxidant intake, consuming cooked Tuhau (through methods such as deep frying and boiling) might be more beneficial than consuming it uncooked, as heat treatment was found to increase the release of phytochemicals. Additionally, the selection of appropriate edible frying oils, through the addition of antioxidants like vitamin E, can collectively contribute to maximizing the antioxidant potential and nutritional benefits of fried foods. Further studies need to be performed on other different cooking methods (roasting, microwaving, steaming and braising, among others) as well as different conditions like time, temperature, and cooking mediums, which will be aimed at reducing the unwanted deleterious effects of cooking like lipid peroxidation and oxidation of food. An optimum cooking method also will be able to increase the nutritional content of Tuhau as well as improving its health beneficial properties. Further research also could explore on other nutritional composition and the addition of Tuhau as a food ingredient into many food products in order to increase the availability of value-added products in the market.

Acknowledgements

The authors gratefully acknowledge all technical assistance from the staff of Faculty of Food Science and Nutrition, Universiti Malaysia Sabah during the completion of this work.

Author Contributions

N.H.A. and E.Z.J. conceived and designed the experiments; E.Z.J. performed the experiments; E.Z.J. and N.H.A. analyzed the data; E.Z.J. wrote the paper; N.H.A monitored the planning and execution of the study.

Funding

The materials and chemicals used in this research as well as the APC were funded by Universiti Malaysia Sabah via Skim Penyelidikan Lantikan Baru grant (Grant number SLB2223).

Institutional Review Board Statement

Not applicable.

Data Availability Statement

The data for this study may be obtained from the corresponding author upon reasonable request.

Conflicts of Interest

None declared.

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