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Characterization of chemical properties of fish-flavoured spicy tamarind cube

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Abstract

Fish-flavoured spicy tamarind cube is categorized as a type of bouillon cube. It is a processed food that has been developed and benefits the consumers due to low cost, being ready to use, reduced cooking time and giving intense flavour to the cooking dish. Food processing improves the stability, safety, taste and makes the food healthier. While there are various advantages to processing, the chemical food characteristics might be adversely affected. The study aimed to evaluate the amount of chemical composition, macromolecule, phytochemical content, peroxide value and antioxidant activity present in the fish-flavoured spicy tamarind cube. The analysis was performed using a different methodology. The content of mineral and ascorbic acid of the cube was evaluated by using scanning electron microscopy-energy dispersive X-ray (SEM-EDX) and titration methods respectively. Carbohydrate was estimated by difference using equation and protein by micro Kjeldahl method. For both phytochemical compounds, total phenolic and flavonoid are measured spectrophotometrically in this study. In addition, peroxide value was determined by titration method and antioxidant activity was assayed using 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical. The result showed the cube contained 2.12% sodium, 1.22% copper and 0.43% potassium while the ascorbic acid value was 66.00 mg/100 g. The macromolecule content recorded was 40.15 g/100 g for carbohydrates and 7.54 g/100 g for protein. The cube had 10.77 mg GAE/g and 21.72 mg QE/g for total phenolic and flavonoid respectively. The peroxide value of the cube was 9.52 meq/kg and classified in a moderate oxidation state. Furthermore, the half-maximal inhibitory concentration (IC_{50}) for antioxidant activity analysed was 89.04 µg/mL which means the cube shows intermediate antioxidant activity. Based on the result, the cube is safe to consume and can provide health benefits to consumers.

1. Introduction

Food is contributing to health effects. Therefore, it is essential to eat good quality food as it will affect our bodies. Bouillon cubes are one of the processed foods that have been developed and give benefit to the consumers. This is due to the low cost, ready-to-use, reduced cooking time and intense flavour of the cooking dish (Masseri *et al.,* 2021). Fish-flavoured-spicy-tamarind cube is a type of bouillon cube, meaning a small block of dried flavouring that needs to dissolve in hot water before being it in dishes according to Food Act and Regulations. The sourness of the cube traditionally comes from sour tamarind and spiciness from the use of fresh chili peppers. Chili peppers are used as the main ingredient and facilitated to add natural flavor and color. They are considered a functional food and a source of bioactive compounds because of the biological activity displayed by numerous of their phytochemicals, such as ascorbic acid, flavonoids, and phenolic compounds may give health advantages (Hui *et al.,* 2010). The cube involves a simple production process involving several processing techniques such as cutting, cooking, drying/evaporating, grinding, homogenizing and cubing. Thermal processing can be harmful to bioactive substances (Montoya-Ballesteros *et al.,* 2014). The nutrients and bioactive substances found in food can be harmed by processing requiring prolonged temperature exposure or processing at high temperatures for short periods of time (Montoya-Ballesteros *et al.,* 2014). The aim of drying is to remove the water content from food which is necessary for the growth of microorganisms thus resulting in longer shelf life (Ahmed *et al.,* 2013).

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Drying time should be properly adjusted according to the air temperature to keep the good quality and nutritional composition of food products (Masseri *et al.,* 2021). Nowadays, people prefer a healthy eating lifestyle. Therefore, convenient yet nutritious food will be their choice. Chemical properties and amount of nutrients play an important role in helping the body get enough nourishment from the food. This study aimed to evaluate the amount of chemical composition, macromolecule, phytochemical content, peroxide value and antioxidant activity present in the fish-flavoured spicy tamarind cube.

2. Materials and methods

2.1 Raw materials and chemicals

Spicy tamarind paste purchased from Hawa Foods Enterprise company located at Ampang, Selangor and *Rastrelliger branchysoma* (mackerel) fish powder was prepared. Methanol, gold and palladium film, metaphosphoric acid, phenolphthalein, 2,6-dichlorophenol-indophenol (DCPIP), ascorbic acid, Folin–Ciocalteu reagent, sodium carbonate, gallic acid, sodium nitrite, aluminium chloride, quercetin, acetic acid, chloroform, potassium iodide, sodium thiosulphate, 2,2-diphenyl-1- picrylhydrazyl (DPPH) are the chemicals used provided by UTHM Pagoh.

2.2 Sample preparation

Spicy tamarind paste was defrosted during the preparation process before being used. The moisture content of the paste before the drying process was taken using a rapid moisture analyzer (MX-50, A&D, Japan). Next, the paste was spread on baking paper at the top of the tray forming a thin layer. After well spread in a thin layer, it was placed in the food dehydrator (Hendi, UK) for 48 hrs at 60°C. After 48 hrs, the paste was taken out to measure the moisture content. The moisture must be below 15% to proceed with the following process. Dried spicy tamarind paste was ground using the dry blender (Panasonic, MX-SM1031, Japan) for 2 mins to become powder. Mackerel fish powder was added to the spicy tamarind powder in a ratio of fish powder to paste 1:200. The powder was homogenized together before the cubing process. A cube moulder was used and assisted with a machine for compression purposes. The machine pressed the moulder ten times on top and ten times below to make the powder fully compact. Fish-flavoured spicy tamarind cube was removed from the moulder and kept inside the freezer for further analysis.

2.3 Determination of ascorbic acid

Ascorbic acid content was measured using a 2,6-dichlorophenol-indophenol (DCPIP) titration method in accordance with the technique of Kamal *et al.* (2019). For each 2 g of sample was mixed with 5 mL of 20% metaphosphoric acid solution and filtered through Whatman No. 1 filter paper. An aliquot (1 mL) of the filtrate was mixed with 10 mL of deionized water in a small beaker. Then, 2 mL of the solution was transferred into a beaker and 2 drops of phenolphthalein solution were added to it before it was shaken and titrated against DCPIP to produce a pink hue. Ascorbic acid content was determined using Equation (1).

$$\text{Ascorbic acid mg/100 g} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up}}{\text{Volume of filtrate taken} \times \text{weight of sample}} \times 100 \quad (1)$$

The dye factor is the quantity of DCPIP necessary to neutralize a known volume of standard ascorbic acid [Dye factor = 0.5/Titre, where 0.5 indicates that a 5 mL of the standard ascorbic acid solution contains 0.5 mg ascorbic acid].

2.4 Determination of macromolecule content

2.4.1 Carbohydrate

Carbohydrates were estimated by difference using Equation (2). It was obtained by deducting the total of the moisture, fat, protein and ash contents percentages from 100%.

$$\text{Carbohydrate (\%)} = 100\% - (\%\text{ moisture} + \%\text{ protein} + \%\text{ fat} + \%\text{ ash}) \quad (2)$$

2.4.2 Protein

The crude protein content was measured using the micro Kjeldahl technique (Satter *et al.,* 2016). The percentage of nitrogen (N) was determined using the Equation (3).

$$\text{Nitrogen (\%)} = \frac{((S - B) \times N \times 0.014 \times D \times 100)}{\text{Weight of sample} \times V} \quad (3)$$

Where D denotes the dilution factor, T denotes the titration value = (S – B), W denotes the weight of the sample and 0.014 denotes the constant value. Crude protein was derived using Equation (4) by multiplying the corresponding total nitrogen content by a standard factor of 6.25.

$$\text{Crude protein (\%)} = \%\text{ of N} \times 6.25 \quad (4)$$

2.5 Determination of total phenolic content

Total phenolic content was obtained spectrophotometrically using the modified Folin–Ciocalteu colorimetric method described by Maurya *et al.* (2018). After extracting 1g of sample with 10 mL methanol overnight in a shaker, 125 µL of the methanolic extract was mixed with 375 µL of distilled water in a test tube followed by the addition of 2.5 mL of 10% Folin–Ciocalteu reagent and let to stand for 6 mins. Following that, 2 mL of 7.5% sodium carbonate solution

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was added. Each sample was incubated at room temperature in darkness for 90 mins and the absorbance was measured at 760 nm using an Ultraviolet-Visible (UV/Vis) spectrophotometer. Results presented as gallic acid equivalents in mg/g dry mass.

2.6 Determination of total flavonoid content

The flavonoid content was measured spectrophotometrically using a method based on the production of a flavonoid-aluminium complex (Loizzo *et al.,* 2013). An aliquot (1 mL) of the extract was put into a 10 mL volumetric flask. Distilled water was added to make a volume of 5 mL together with 0.3 mL of 5% sodium nitrite added to the flask. After 5 mins, 0.6 mL of 10% $AlCl_3$ was added to the mixture followed by the addition of 1 M NaOH at 6 mins and the addition of 2.1 mL distilled water. Absorbance at 510 nm read immediately. Quercetin was chosen as a standard and the amounts of total flavonoid content will be stated as quercetin equivalents in mg per g extract (Sassi *et al.,* 2022).

2.7 Determination of peroxide value

The peroxide value of the oil in the sample was determined using the method described by Godswill *et al.* (2018). The samples were weighed and poured into 250 mL glass stoppered Erlenmeyer flasks. The weights have been recorded. Next, 30 mL acetic acid-chloroform solution was added by using graduated cylinders. The flasks were swirled until all of the samples were completely mixed in. Then, 0.5 mL of saturated potassium iodide solution was added using 1 mL Mohr pipettes. The flasks were capped and the contents were shaken precisely 1 min before being placed in a dark room for 1 min. Next, 30 mL of distilled water was added through graduated cylinders. The flasks stoppered and rapidly shaken to release the iodine from the chloroform layer. Sodium thiosulphate (0.1 N) was used to fill burettes. Each flask was added 1 mL of the starch indicator and titrated with the thiosulphate until the blue-grey colour vanished. Additionally, a blank titration was performed using all components except the oil samples. The peroxide values are calculated from Equation (5).

$$\text{Peroxide value} = \frac{(S - B) \times N \times 1000}{\text{Weight of sample}} \quad (5)$$

Where S is the volume of thiosulphate used in the titration of the sample, B is the volume of thiosulphate used in the titration of the blank and N is the normality of sodium thiosulphate.

2.8 Antioxidant activity

The antioxidant activity of the cube was assayed by utilising the 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical. The free radical scavenging ability is studied using stable DPPH radicals with slight modification (Roy *et al.,* 2013). The prepared sample (400 µL) is filled up to 2.0 mL with 0.1 mM of DPPH methanol solution. Prepared control without the testing compound identically. For around 30 mins, the reaction was finished in the dark. Absorption of the sample at a 517 nm wavelength was determined. DPPH reduction is calculated using Equation (6) when considering the absorption of the control investigation and the observed activity is compared to the gallic acid calibration curve. The outcomes are reported in terms of gallic acid antioxidant activity equivalent /100 mL of the solution.

$$\text{DPPH radical scavenging activity (\%)} = \left(\frac{A_{control} - A_{sample}}{A_{control}}\right) \times 100 \quad (6)$$

where A_{sample} and $A_{control}$ are the absorbance of sample and control

3. Results and discussion

3.1 Chemical composition

The chemical composition analysis that was conducted included mineral content and ascorbic acid. The results obtained are presented in Table 1.

3.2 Mineral content

The composition of mineral content determined by EDX analysis of fish-flavoured spicy tamarind cube as shown in Table 1 contains a noticeable percentage amount of Na (2.12±0.21%), Cu (1.22±0.13%) and K (0.43±0.10%). Mineral content present in the cube was predicted derived from the mackerel fish as well as chili. Sea and ocean types of fish were categorized to be rich in Na and K. In addition, Cu may be included in the cube as a result of marine pollution caused by human activities and also from the chili itself. Nevertheless, their content depends on feeding habits, maturity stages and size (Bastías *et al.,* 2017). The mineral element present was similar to the findings by Olatunji and Afolayan (2018) where from the analysis conducted, Na recorded the highest percentage of mineral present followed by Cu and the lowest K. In contrast, a study by Salau and Hassan (2014) revealed the highest amount of mineral content in spicy tamarind dishes was K followed by Na and Cu. Different amounts of K between the two studies may cause of processing of the food. The study by Oz *et al.* (2017) reveals the amount of K content reduced the highest during microwave cooking. Another study found that Na and K of lean beef decreased in concentration with cooking methods (Purchas *et al.,* 2014). National Coordinating Committee on Food and Nutrition, Ministry of Health Malaysia (2017) suggested the recommended nutrient intake (RNI) for Na, Cu and K

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are 1500 mg/day, 900 µg/day and 4.7 g/day respectively. From the findings, it can be determined that the level of sodium and copper content in the cube satisfies the RNI whereas the potassium content in the cube was insufficient.

Table 1. Chemical composition of fish-flavoured spicy tamarind cube

Parameter Name	Value
Sodium (Na)	2.12±0.21%
Copper (Cu)	1.22±0.13%
Potassium (K)	0.43±0.10%
Ascorbic acid	66.00±0.15 mg/100 g

Values are presented as mean±SD of three replicates.

Figure 1 shows the morphology of a fish-flavoured spicy tamarind cubes using SEM. It was observed the powder showed an irregular surface structure and pore development after undergoing the drying process at 65°C at 48 hrs. Pore development depended strongly on drying temperature. It has been found that extended exposure to high drying temperatures causes significant degradation of food quality features such as colour, nutritional content, flavour and texture (Maskan, 2000). The study reported by Fazaeli *et al.* (2012) showed that cell damage is least reported at 40°C and is mostly caused by extended drying time. The higher air velocity will be resulting more separated and ruptured structures.

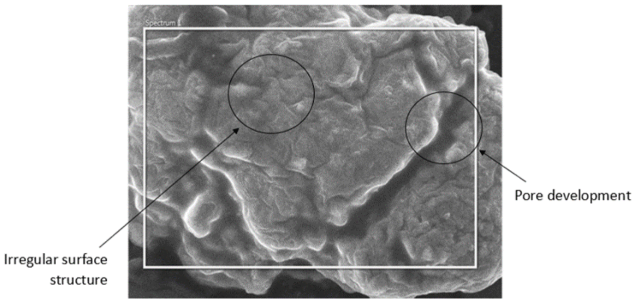

Figure 1. Scanning electron microscopy (SEM) photo microscopic images of fish-flavoured spicy tamarind cube at 1000× magnification.

3.3 Ascorbic acid

RNI of ascorbic acid recommended for Malaysian adults (>19 years old) is 70 mg/day (National Coordinating Committee on Food and Nutrition, Ministry of Health Malaysia, 2017). The ascorbic acid determined in the fish-flavoured spicy tamarind cube is 66.00±0.15 mg/100 g. The result obtained was in agreement with the finding by Kumar and Tata (2009). Study shows that a gradual increase of ascorbic acid content in various genotype of chili peppers from green to red ripening decreased after the chili undergoes a drying process (Kumar and Tata, 2009). The finding study by Martinez *et al.* (2005) stated that drying only retained 12% amount of ascorbic acid resulting in only 19.19 mg/100 g which is lower than the obtained result. According to a report by Daood *et al.* (2006), ascorbic acid that undergoes drying at 50 to 100°C will undergo a reduction of up to 50%. Vitamin C levels in dried samples may be low owing to degradation upon thermal processing (Olatunji and Afolayan, 2018). Increased drying temperature has a significant impact on vitamin content. Thus, exposure to light, oxygen, and heat is a proxy for the nutritional loss caused by thermal processes. Consequently, since the cube vitamin C content fell short of achieving the RNI, an extra source of vitamin C was required by the consumer to achieve the recommendation.

3.4 Macromolecule content

The macromolecule content of the fish-flavoured spicy tamarind cube that has been analysed was carbohydrate and protein. The result is tabulated in Table 2. The macromolecule content was expressed per 100 g of sample.

Table 2. Macromolecule content of fish-flavoured spicy tamarind cube

Type of macromolecule	Value (g/100 g)
Carbohydrates	40.15±0.73
Protein	7.54±0.03

Values are presented as mean±SD of three replicates.

3.4.1 Carbohydrate

The value of carbohydrate obtained in the cube was 40.15 g/100 g as reported in Table 2. A well-balanced diet and a healthy body are both dependent on carbohydrates, which serve as the primary source of energy for everyday activities (Alex, 2020). Carbohydrates, particularly starches are the least costly, readily accessible, the most easily accessed, and the most quickly digested kind of nourishment that may be obtained. Carbohydrate consumption has been shown to increase satiety (Anderson and Woodend, 2003). Furthermore, the composition of starches is a predictor of satiety because it alters the metabolic reaction that occurs after the consumption of the starch substance. It is possible that carbohydrate from the starch and sugar utilized in the cube's constituents will add to its overall carbohydrate content. Chili and mackerel fish also contribute to the amount of carbohydrates. Previous study shows the carbohydrate value for capsicum ranges from 3.0 to 78.1 g/100 g (Motukuri and Jaswanthi, 2020). The processing method may affect the value of carbohydrate obtained since it decreases when the fish is boiled, smoked or fried (Okpanachi *et al.,* 2018).

3.4.2 Protein

Fish protein is well-known for being of excellent quality, holding a high concentration of important amino

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acids, being readily digestible and being a significant source of energy. Fish and fish products are among the most readily accessible sources of protein for human beings. The addition of mackerel as a fish in this bouillon cube is one of the elements that contribute to the quantity of protein. The protein content of fish-flavoured spicy tamarind cube was 7.54±0.03 g/100 g. Consequently, the protein content of mackerel was observed to be anywhere between 18.3% to 22.4% indicating that they are a very high-protein food source (Alkuraieef *et al.,* 2021). The effect of cooking for 50 mins was discovered to result in a substantial drop of 3.4% in the protein content (Clemente *et al.,* 1998). Alakali *et al.* (2015) investigated the influence of temperature on *M. oleifera* leaves. It was discovered that the protein content trend was decreasing when the drying temperature was increasing. Increased drying temperature corresponds to a rise in protein denaturalization which resulted in a significant reduction in protein content.

3.5 Phytochemical compound

The phytochemical compounds that were being evaluated were the total phenolic content and total flavonoid content. The result is shown in Table 3.

Table 3. Phytochemical content of fish-flavoured spicy tamarind cube

Type of phytochemical	Value
Total phenolic content	10.77± 0.07 mg GAE/g
Total flavonoid content	21.72±8.33 mg QE/g

Values are presented as mean±SD of three replicates.

3.5.1 Total phenolic content

The absorbance values obtained were determined by using the Folin-Ciocalteu method using gallic acid as the standard. The absorbance values obtained at various gallic acid concentrations were utilised to generate gallic acid curve. The total phenolic content (TPC) of the extracts was determined using the regression equation of the calibration curve (R^2 = 0.9252) and expressed as mg gallic acid equivalents (GAE) per gram of sample. TPC of the fish-flavoured spicy tamarind cube was 10.77±0.07 mg GAE/g. The total phenolic content of dried pepper ranged from 84 to 110 mg GAE/g depending on the drying conditions (Alakali *et al.,* 2015). Compared to the TPC of dried pepper study by Reis *et al.* (2013) and Campos-Hernández *et al*. (2018) at 1415.44 mg GAE/kg and 14.76 mg GAE/g respectively, the cube presents lower amount of phenolic compound. Drying methods may accelerate enzymatic degradation and dictate the breakdown or combination of phenols with other plant components, resulting in a reduction in the total amount of phenolic compounds in the final product (Miean and Mohamed, 2001). The hot air-drying method also caused a high loss in TPC (Maurya *et al*., 2018). A study on grapes by Agudelo *et al.* (2017) proves that increased degradation of flavonoid content is favoured by the applied temperature of the drying process. Additionally, raising the temperature above 60°C significantly decreased the phenolic content (Miean and Mohamed, 2001).

3.5.2 Total flavonoid content

The total flavonoid content (TFC) of the extract was measured from the regression equation of the quercetin calibration curve (R^2 = 0.99) and expressed as mg quercetin equivalent (QE) per gram of sample. The absorbance values gathered at various quercetin concentrations were utilized to develop the quercetin curve. The Flavonoid content of the fish-flavoured spicy tamarind cube was recorded as 21.72±8.33 mg QE/g. The estimated daily intake of quercetin in the human diet is around 5-40 mg/day (Brglez Mojzer *et al.,* 2016). From the result, this cube is able to give a sufficient amount of quercetin level for humans to consume. Miean and Mohamed (2001) reported TFC of red pepper and bell pepper 829 and 892 mg/kg respectively. Zahoor and Khan (2021) recorded the TFC of bell pepper under different drying conditions ranging from 24 to 33 mg QE/g while Denev *et al.* (2019) reported amount the TFC of 63 Balkan pepper was 3.2 to 64.3 mg/g. Minimal processing such as peeling and cutting can cause major losses of flavonoid content since part of the product was removed. The study by Gennaro *et al.* (2002) reported onion cutting can result in a 39% reduction in flavonoids. Frying and cooking on the other hand may lower the amount of quercetin in food by 25% to 33% (Lee *et al.,* 2008). Thermal processes differ primarily in the amount of exposure time and the temperature at which they are processed. Generally speaking, it is acknowledged that the use of a method involving heating might result in a reduction in flavonoid content as a result of thermal degradation (Ren *et al.,* 2020).

3.6 Peroxide value and antioxidant activity

A test on Peroxide Value (PV) was performed to determine the amount of peroxide produced due to the lipid oxidation of used cooking oils. The peroxide concentration sometimes referred to as peroxide value is a parameter that indicates the early stages of oxidation or rancidity in unsaturated fats and oils (O'Brien, 2008; Godswill *et al.,* 2018). According to the Codex Alimentarius Standard, refined oils may have a maximum peroxide value of up to 10 milliequivalents of active oxygen/kg. The peroxide value of the fish-flavoured spicy tamarind cube tabulated in Table 4 was close to the maximum level of permitted standard which is 9.52±0.03 meq/kg and classified as a moderate oxidation state (Moigradean *et al.,* 2021). When heated, frying oils normally undergo substantial deterioration and various chemical changes. Oils are hydrolyzed during frying resulting in the development of free fatty acids (FFA), mono- and diglycerides and the accumulation of these compounds in the frying oil. Oils may also oxidize resulting in the formation of hydroperoxide, hydroxides, aldehydes, and ketones. It is possible that these compounds may fracture into smaller pieces or that they will stay in the triglyceride molecule and cross-link with one another resulting in dimers and higher polymeric triglycerides. Increasing concentrations of these volatile chemicals in the oil samples might be linked to increases in FFA content as well as PV in the oil samples (Innawong *et al.,* 2004).

Table 4. Peroxide value and antioxidant activity of fish-flavoured spicy tamarind cube

Parameter Name	Value
Peroxide value	9.52±0.03 meq/kg
Antioxidant activity (IC_{50})	89.04±0.25 µg/mL

Values are presented as mean±SD of three replicates.

Next, the percentage of inhibition was determined to assess the antioxidant activity of the extracts and their ability to inhibit free radicals. The five different concentrations demonstrate the percentage of inhibition. The bar chart in Figure 2 shows scavenging activity was increased with the increase of concentration.

The radical scavenging activity of the fish-flavoured spicy tamarind cube in Figure 2 shows no significant difference as $p > 0.05$. At 25 µg/mL, the extract exhibits the best antioxidant activity while at 5 µg/mL the extract exhibits the lowest antioxidant activity which is 22.15% and 11.95% respectively. Percentage inhibition ($p > 0.05$) of pepper variety reported by Morakinyo *et al.* (2021) was decreased after drying compared to fresh. A study on *Capsicum chinense* Jacqui by Reis *et al.* (2013) revealed the antioxidant activity was 57.19% when undergoing drying at 65°C. Differences in result might be due to the drying process being performed at low temperatures but requiring extensive drying durations which could result in a reduction in antioxidant capability (Garau *et al.,* 2007). The half-maximal inhibitory concentration (IC_{50}) value was calculated. The value will determine the concentration of the sample required to inhibit 50% of the radical (Jadid *et al.,* 2017). The lower the IC_{50} value, the higher the antioxidant activity of samples. IC_{50} of antioxidant activity recorded in fish-flavoured spicy tamarind cubes was recorded as in Table 4 which is 89.04±0.25 µg/mL. According to Phongpaichit *et al.* (2007), extracts which possess IC_{50} values ranging from 50 to 100 µg/mL are classified to exhibit intermediate antioxidant activity. Extracts with IC_{50} value ranging between 10 to 50 µg/mL, on the other hand, is considered to have strong antioxidant activity. Thus, this cube can be concluded to exhibit intermediate antioxidant activity.

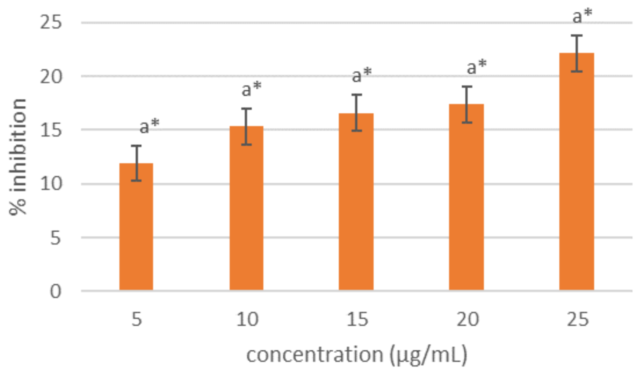

Figure 2. The radical scavenging activity represented by percentage of inhibition in fish-flavoured spicy tamarind cube. Bars with the same notations are not statistically significantly different ($p<0.05$).

4. Conclusion

To conclude, the chemical properties of the cube studied were present in lower limit values indicating they are present in safe amounts. Mineral available in fish-flavoured spicy tamarind cubes were sodium, copper and potassium. The amount of ascorbic acid and macromolecule was recorded in this study. Next, the cube was analyzed to have a lower total phenolic compound than the total flavonoid compound in phytochemical content analysis. The peroxide value of the cube was classified in a moderate oxidation state but still in the acceptable range of fresh oil. Furthermore, the cube was studied for antioxidant activity resulting in intermediate antioxidant activity. Fish-flavoured spicy tamarind cube was produced because they are convenient, beneficial for humans and safe to ingest. Despite this, processing methods and temperatures may change some physical and chemical characteristics that influence the stability of the bioactive compounds. Drying time also influences the morphology and amount of compounds present in the cube. Thus, further research is suggested to increase the drying temperature at a short drying time or lower the drying temperature if a long drying time is required to improve the morphology and chemical properties of the cube.

Conflict of interest

The authors declare no conflict of interest.

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