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Research Article

Physicochemical, Sensorial and Antioxidant Properties of Sardine Fish Patties Incorporated with Different Natural Additives

Chong Chi-Cheng[1], Muhamad Faris Ab Aziz[2] and Mohammad Rashedi Ismail-Fitry[1,3]*

1. Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
2. Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia 43400 UPM Serdang, Selangor, Malaysia
3. Halal Products Research Institute, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

Corresponding author: ismailfitry@upm.edu.my

ABSTRACT

Sardine fish patty is a processed seafood product that easily spoiled because of oxidation. Oregano, cloves, cinnamon, turmeric, and green tea contain antioxidant properties that could preserve the fish patty. This study aimed to incorporate these ingredients into sardine fish patties and investigate their effects on the physicochemical properties, sensory evaluation, and lipid oxidation of the patties. The fresh sardine patties were treated with 0.5% of oregano (PWO), cloves (PWC), cinnamon (PWCI), turmeric (PWT) or green tea (PWGT) before being cooked, cooled and chill-stored for 12 days. No significant effects of the treatments were observed on moisture content, cooking yield, and shrinkage of the patties. The incorporation of turmeric significantly ($P<0.05$) affected all colour parameters on the patties (PWT). Although PWGT showed slightly increased values in some texture profiling parameters, the PWGT also showed positive acceptability regarding sensory evaluation for most of the eating quality parameters. A significant ($P<0.05$) reduction in TBARS values in the patties incorporated with green tea (PWGT), while increased scavenging activity values of the PWGT and cloves (PWC) were observed. Thus, the study implied that green tea demonstrated a good effect on sardine fish patty, as compared to spices, which could be a potential natural preservative to preserve the fish product during storage.

Key words: Antioxidant activity, fish meat emulsion, fish product, lipid oxidation, seafood processing

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INTRODUCTION

The seafood industry is marked as an important sector in Malaysia due to its contribution towards the national economy (Department of Statistics, Malaysia, 2017). Fish, which put up a proportion of 85% of the total seafood production, has been recognized as the predominant seafood type among capture fisheries (Chowdhury & Yahya, 2012). Fish processing technology used to convert raw fish into fish products is getting diversified and upgraded nowadays. Examples of marketed fish-based products are fish cake, fish sausage, fish balls and fish patty. Owing to living in a fast-paced society, the demand for getting ready-to-cook food is gradually increasing (Yerlikaya *et al*., 2005). Fish patty is a type of ready-to-cook fish product which is uncommonly seen but potentially to be commercialized in Malaysia. Sardine is one of the small pelagic fishes under the family of Clupeidae, shows a high nutritional profile, which has a lipid composition of high unsaturated than neutral lipids and is one of the great sources of omega-3 polyunsaturated fatty acids (PUFAs) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Bandarra *et al*., 1997; Cardoso *et al*., 2018). The adequate intake of those types of omega-3 PUFAs from fish exerts beneficial impacts on human health, such as protecting from cardiovascular disease, diabetes, cancers, and optimal nervous and retinal developments and functions (Carwile *et al*., 2016; Sofoulaki *et al*., 2018). Thus, due to the positive health effects of omega-3 PUFA, there is an increased interest to produce meat and fish products rich in omega-3 PUFA (Wood *et al*., 2004).

However, the high percentage of omega-3 PUFAs causes sardine to be more susceptible towards lipid oxidation due to the existence of the high number of reactive double bonds (Jacobsen & Let, 2006). Lipid oxidation is one of the factors that can cause degradation and deterioration in the quality and nutritional values of meat and meat products, especially fish. Several studies reported that the oxidation of PUFA in fish is positively linked to the development of off-odour molecules, even the formation of toxic and mutagenic compounds that could implicate the development of chronic diseases in humans (Falowo *et al*., 2014; Huang & Ahn, 2019; Sottero *et al*., 2019). Therefore, the incorporation of antioxidants is necessary to reduce or delay rancidity and inhibit lipid oxidation, while maintaining the quality of the fish and fish products.

Recently, the uses of natural antioxidants are being explored to produce healthier meat and meat products, as alternatives to synthetic antioxidants that could potentially lead to harmful effects on consumers (Ribeiro *et al*., 2019; Awad *et al*., 2022). The natural antioxidant additives including the plant extracts, such as from herbs, spices, tea, fruits, vegetables, and seeds, contain high and potent natural bioactive compounds that can improve oxidative stability and microbial safety in meat and meat products (Awad *et al*., 2021; Awad *et al*., 2022). Different spices such as cloves, cinnamon, oregano, and turmeric, were demonstrated to improve nutritional quality, sensory properties, and oxidative and storage stabilities of meat products from beef, duck, and chicken (Jamwal *et al*., 2015; Zhang *et al*., 2017; Zahid *et al*., 2019; Augustyńska-Prejsnar *et al*., 2021; Ahmed *et al*., 2022; Leite *et al*., 2022). In addition to that, studies of using green tea as a natural antioxidant were also reported on meat-based products (Cho & Chung, 2010; Jayawardana *et al*., 2019; Jauhar *et al*., 2021; Passos *et al*., 2022). Although green tea is high in antioxidant capacity, its incorporation into fish products might affect the sensory properties compared to spices, which normally are more acceptable. Thus, the present study aimed to evaluate the oxidative stability, physicochemical and sensorial properties of sardine fish patties incorporated with five natural additives (cloves, cinnamon, oregano, turmeric, and green tea) during 12 days of storage, under chilling conditions.

MATERIALS AND METHODS

Raw materials

Fresh sardines were purchased from the wet market Pasar Borong Selangor, Seri Kembangan, Selangor, Malaysia, while the other raw materials (oregano, cinnamon, cloves, green tea, turmeric, salt, eggs & corn starch) were obtained from Lotus's, IOI Putrajaya, Malaysia.

Sardine fish patty preparation

Twenty-kilogram sardine fish (average length: 21.46 ± 0.71 cm) were washed under running water, deboned, and minced using a fish deboner machine (ICW-300, China) after complete removal of the head, tail, and internal organs. The formulations and procedure of preparing fish patties were slightly modified from previous work by López-Caballero *et al*. (2005). Six formulations (Table 1) with the incorporation of different natural additives in powder form were used to produce sardine fish patties. Minced sardine fish was weighed and divided into a ratio of 2:3. Minced fish with a ratio of 2 was first mixed with salt (NaCl), natural additive (for treatment samples) and crushed ice at a speed of 3 rpm for 3 min. Egg white and corn starch were added, and homogenization continued for another 5 min. The resulting batter was mixed again with the minced sardine fish reserved earlier (ratio of 3) for 7 min. The dough was processed into 1 cm thick fish patties (70 g) with a hamburger press (11426, Omcan Inc.) (Kahar *et al*., 2021). Processed patties were kept frozen and held at -18 °C overnight. Fish patties were stacked, packed, and sealed in polyethylene bags and kept at -18 °C storage for approximately one week before further analysis. The experimental design of the processing and analyses of the sardine fish patties is presented in Figure 1. The preparation and analyses of each set of sardine fish patties were carried out in triplicate.

Table 1. Formulations of sardine fish patties with the addition of different spices and green tea

Raw materials	Control		Treated Samples					
	Percentage	Control (g)	Percentage	PWO (g)	PWC (g)	PWCI (g)	PWT (g)	PWGT (g)
Minced sardine fish	86.5	550	86.5	550	550	550	550	550
Salt (NaCl)	1.5	9.54	1.0	6.36	6.36	6.36	6.36	6.36
Crushed ice	5.0	31.79	5.0	31.79	31.79	31.79	31.79	31.79
Egg white	2.0	12.72	2.0	12.72	12.72	12.72	12.72	12.72
Corn starch	5.0	31.79	5.0	31.79	31.79	31.79	31.79	31.79
Natural additives	0.0	0.00	0.5	3.18	3.18	3.18	3.18	3.18

*PWO = Patties with Oregano; PWC = Cloves; PWCI = Cinnamon; PWT = Turmeric; PWGT = Green Tea

Cooking yield and shrinkage

Frozen patties were defrosted at room temperature and cooked in a preheated electric oven at 160 °C for 30 min. The cooking yield of raw and cooked patties was determined using the following equation:

$$\text{Cooking yield (\%)} = \frac{\text{Weight of cooked patties}}{\text{Diameter of raw patties}} \times 100$$

The percentage of shrinkage of fish patties was calculated using the following equation:

$$\text{Shrinkage (\%)} = \frac{\text{Diameter of cooked patties}}{\text{Diameter of raw patties}} \times 100$$

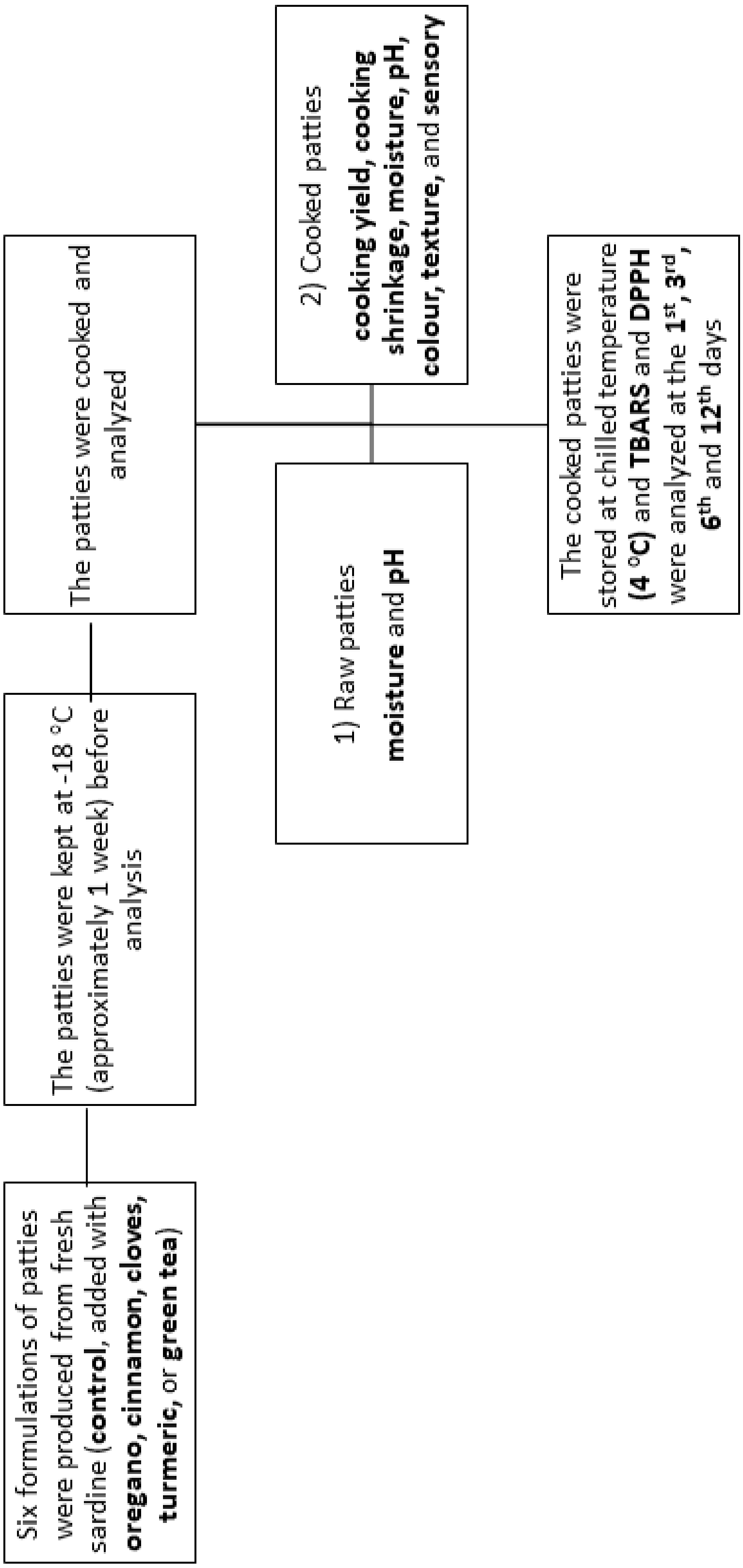

Fig. 1. Flowchart of the experimental design of the sardine fish patties with the addition of different spices and green tea.

Determination of moisture content

The moisture content of raw and cooked sardine fish patties was measured according to the AOAC (2005) method, using the following equation:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where W_1 = weight (g) of the sample before drying and W_2 = weight (g) of the sample after drying.

Determination of pH value

The pH value of raw and cooked sardine fish patties was determined using a pH meter (PB-10, Sartorius, Germany). The sample solution was prepared from a patty sample (5 g) with 50 mL of distilled water.

Determination of colour

Colour analysis for the cooked patties in aspects of lightness (*L**), redness (*a**), and yellowness (*b**) were carried out with minor modifications using a Chroma Meter (CR-410, Konica Minolta Incorporation, Japan) (Ramle *et al*., 2021).

Texture profile analysis (TPA)

The method by López-Caballero *et al*. (2005) was referred to and slightly modified. Fish patties were cut into 3 cm^2 and compressed using a cylindrical plunger with a diameter of 75 mm connected to a 5 kN load cell (TA-XT2i, Stable Micro Systems, London). The pre-test speed was set at 1.00 mm/s, the test speed at 0.83 mm/s and the post-test speed at 5.00 mm/s. The samples were compressed to 30% of the height.

Sensory evaluation

Sensory analysis of sardine fish patties was carried out by 30 untrained panellists where the patties samples were coded, and assessors were instructed to evaluate based on 9 points hedonic scale (Stanley *et al*., 2017). The criteria evaluated include appearance, aroma, colour, fishy smell, flavour, texture, and overall acceptability.

TBARS assay

Lipid oxidation on cooked patties was assessed based on the reaction between TBA (thiobarbituric acid) and MDA (malondialdehyde) at which a coloured pigment will produce. A method by Ismail *et al*. (2022) with some modifications was referred to. Absorbance was measured at 530 nm in a 10 mm cell and 1-butanol was used as a blank. The TBA values were calculated based on the following equation:

$$\text{TBA value} = \frac{50 \times (A - B)}{m}$$

Where 50 = factor valid if 25 mL volumetric flask and 10 mm cell width, A = absorbance of test solution, B = blank and m = mass in mg.

DPPH assay

The principle lies under DPPH is the reaction between stable free radicals with the free radicals found in cooked patties samples (Molyneux, 2004). A method by Tepe *et al*. (2005) was applied and methanol was used as a blank with absorbance taken at 517 nm. The percentage of radical scavenging was calculated using the following equation:

$$\text{Radical scavenging} = \frac{B - A}{B} \times 100$$

Where A = absorbance of the test solution and B = blank.

Statistical analysis

Statistical analysis was performed using Minitab software, version 19 (Penn State, USA). Analysis of variances (ANOVA) and Tukey's test was used to test significant differences at a confidence level of 95%.

RESULTS

Cooking yield, cooking shrinkage, moisture content and pH

No significant differences (P>0.05) were observed for cooking yield and cooking shrinkage between the control and treated patties (Table 2). However, in terms of values, the cooking yields of the PWO, PWCI, PWT, and PWGT were slightly higher compared to the control, while more shrinkages were observed in PWO, PWC, PWCI, PWT, and PWGT. There was no significant difference in the moisture content between the cooked control and treated patties, indicating that the additives had no effect in retaining water in the sardine fish patties (Table 2). The moisture content of cooked patties, however, decreased as compared to raw patties. In terms of pH, a significant difference (P<0.05) was detected in raw patties, where PWC demonstrated a decrease in pH as compared to the control (Table 2). When compared to PWT and PWGT, the PWCI demonstrated a significant (P<0.05) reduction in pH among cooked patties. Meanwhile, after the cooking procedure, each patty sample showed a rise in pH value.

Colour properties

The colour of cooked sardine fish patties was determined using L^*, a^*, and b^* parameters (Table 3). When compared to the control, there was a significant (P<0.05) increase in lightness (L^*) for the PWC and PWT. Meanwhile, the redness (a^*) values of PWO, PWGT, and PWT were considerably (P<0.05) lower when compared to the control. The PWT, on the other hand, revealed a significant (P<0.05) increase in yellowness (b^*). These findings suggested that turmeric had a significant impact on the colour of sardine fish patties.

Texture profile analysis (TPA)

The textural properties of the control and treated sardine fish patties did not differ significantly (Table 4). However, the values of the hardness, gumminess, and chewiness of PWGT were observed to be higher compared to other patties.

Sensory evaluation

There was no statistically significant difference (P>0.05) in the sensory evaluation characteristics of all patties' appearance, aroma, colour, fishy smell, and texture. However, significant (P<0.05) reductions in flavour and overall acceptability of PWC were observed when compared to other patties (Table 5). Furthermore, PWC received the lowest score in almost all sensory attributes. Overall, PWT had a high score for reduced fishy smell, aroma, flavour, and texture while having the greatest overall acceptability.

TBARS assay

TBARS analysis was used to assess the oxidation of lipids in cooked control and treated sardine fish patties. The greater the TBARS value, the more lipids are oxidised. On day 1 of storage, there was a significant reduction (P<0.05) in TBARS value in PWGT compared to the control, but no significant differences in TBARS values during the remaining storage period (Table 6), indicating that green tea is effective in suppressing lipid oxidation in fish patties. Meanwhile, the TBARS values of PWO and PWGT increased significantly (P<0.05) throughout the storage day. However, most of the values also showed an increasing trend until day 12 of the storage.

DPPH assay

The antioxidant activity of the additives was determined by measuring the scavenging activity of free radicals in cooked and treated sardine fish patties. Scavenging activity on PWC and PWGT increased significantly (P<0.05) as compared to other treatments throughout all storage times (Table 7). Meanwhile, there was a significant increase (P<0.05) in scavenging activity for PWC between days 3 and 6, indicating that six days of storage may be optimal. After day 6, all samples' scavenging activity began to decline.

DISCUSSION

Cooking yield, cooking shrinkage, moisture content and pH

Cooking yield is one of the quality parameters which determine the product behaviour during cooking (Asyrul-Izhar *et al*., 2021). The present study showed that the addition of different spices and green tea had no effects on the cooking yield and cooking shrinkage of the sardine fish patties. This could be due to the low concentration of the added treatments and the effect for both parameters could not be observed for the concentration of 0.5% of the treatments. Das *et al*. (2012) reported that the addition of *Moringa oleifera* crude extract (0.1%) did not affect the cooking yield of the goat meat patties. However, increasing the concentration of the destoned olive cake powder treatment up to 4% increased cooking yield, while reducing the cooking shrinkage of the beef patties (Hawashin *et al*., 2016), suggesting the concentration-dependent effect of the treatments on cooking yield and shrinkage of meat products. According to Alakali *et al*. (2010), the occurrence of shrinkage during the cooking process was due to the muscle protein denaturation in the patties, and water and fat retention from the patties. With the addition of increased concentration of the treatments, the presence of fibre, solid or non-meat contents would create a stronger network and increase the ability of the patties to interact with water and fat, thus affecting the cooking yield and shrinkage of the food products (Hawashin *et al*., 2016; Sayas-Barberá *et al*., 2020; Ali *et al*., 2022). Despite no significant effects of the additives, the treated patties showed a slight increase in the cooking yield even with a low concentration of the treatments, suggesting the potential improvement for fat and fluid interaction in the patties incorporated with those treatments.

Moisture content analysis is crucial in food processing as improper levels of moisture may cause food spoilage and wastage. The current study demonstrated the moisture content was not affected by the treatment, thus suggesting that a lower concentration of the treatment (0.5%) would not be enough to exert the effect. The study by Hawashin *et al*. (2016) showed that increasing the destoned olive cake concentration decreased the moisture content of the raw beef patties, while the increase in destoned olive cake concentration slightly increased the moisture content of cooked beef patties, suggesting the association between the concentration of the treatment and temperature effect on moisture content, which affects the binding of the meat matrix by the presence of total solids or non-meat contents on the patties following the treatment (Aleson-Carbonell *et al*., 2005; Hawashin *et al*., 2016). Meanwhile, the reduction of the moisture in cooked patties, as compared to raw patties was due to water loss during the patties' cooking process. A similar finding was found by Alakali *et al*. (2010) and was further enhanced by Sheridan and Shilton (2002) as they stated dripping and evaporation process will cause moisture loss in cooked patties. Gelatinization occurs when starch is heated in the presence of water. The gelatinization transition is attributed to the formation of hydrogen bonds between water and starch molecules at temperatures ranging from 60 to 80 °C (Donmez *et al*., 2021). Since the corn starch used for all the patties was consistent in weight, no changes in terms of moisture content are expected. Furthermore, other elements that could influence gelatinization, such as water content, temperature, and the presence of salt, were kept constant, which led to the consistency of moisture content in all patties.

Table 2. Cooking yield, cooking shrinkage, moisture content of raw and cooked, and pH values of raw and cooked sardine fish patties incorporated with different spices and green tea

Analyses	Samples					
	Control	PWO	PWC	PWCI	PWT	PWGT
Cooking yield (%)	69.67 ± 2.27^{a}	72.91 ± 0.80^{a}	67.27 ± 3.61^{a}	72.35 ± 2.01^{a}	71.88 ± 4.33^{a}	72.22 ± 5.70^{a}
Cooking shrinkage (%)	6.30 ± 3.15^{a}	8.56 ± 1.19^{a}	9.44 ± 10.25^{a}	11.00 ± 3.96^{a}	8.04 ± 1.12^{a}	11.16 ± 3.61^{a}
Moisture (Raw) (%)	72.81 ± 1.59^{ab}	72.48 ± 0.53^{ab}	74.80 ± 0.88^{a}	74.02 ± 0.49^{ab}	72.86 ± 1.62^{ab}	71.43 ± 0.52^{b}
Moisture (Cooked) (%)	57.18 ± 2.36^{a}	59.41 ± 0.91^{a}	60.51 ± 0.70^{a}	61.70 ± 2.24^{a}	60.63 ± 1.99^{a}	56.94 ± 2.22^{a}
pH (Raw)	5.86 ± 0.02^{a}	5.87 ± 0.03^{a}	5.79 ± 0.03^{b}	5.84 ± 0.01^{ab}	5.85 ± 0.02^{ab}	5.81 ± 0.02^{ab}
pH (Cooked)	6.04 ± 0.02^{ab}	6.02 ± 0.01^{ab}	5.97 ± 0.02^{ab}	5.96 ± 0.03^{b}	6.05 ± 0.05^{a}	6.05 ± 0.04^{a}

[1]Different letters on the same row indicate a significant difference (*P*≤ 0.05) by Tukey's test.
*PWO = Patties with Oregano; PWC = Cloves; PWCI = Cinnamon; PWT = Turmeric; PWGT = Green Tea.

Table 3. Colour of cooked sardine fish patties incorporated with different spices and green tea

Parameter	Samples					
	Control	PWO	PWC	PWCI	PWT	PWGT
Lightness (*L**)	40.52 ± 1.46^{bc}	44.83 ± 0.47^{ab}	47.55 ± 1.14^{a}	38.30 ± 4.19^{c}	48.51 ± 2.73^{a}	42.63 ± 0.80^{abc}
Redness (*a**)	5.87 ± 0.40^{a}	4.89 ± 0.22^{bc}	6.10 ± 0.16^{a}	5.44 ± 0.10^{ab}	4.17 ± 0.48^{c}	4.64 ± 0.20^{bc}
Yellowness (*b**)	10.12 ± 0.46^{b}	11.00 ± 0.14^{b}	9.30 ± 0.16^{b}	8.40 ± 2.14^{b}	14.14 ± 0.84^{a}	8.90 ± 0.44^{b}

[1]Different letters on the same row of colour parameters indicate a significant difference (*P*<0.05) by Tukey's test.
*PWO = Patties with Oregano; PWC = Cloves; PWCI = Cinnamon; PWT = Turmeric; PWGT = Green Tea.

Table 4. Texture profile analysis (TPA) of cooked sardine fish patties incorporated with different spices and green tea

Parameter	Samples					
	Control	PWO	PWC	PWCI	PWT	PWGT
Hardness (kg)	8.88 ± 5.27[a]	12.46 ± 1.50[a]	9.96 ± 3.14[a]	8.59 ± 6.85[a]	10.97 ± 4.12[a]	14.86 ± 3.51[a]
Adhesiveness(g/cm)	-0.96 ± 0.47[a]	-0.54 ± 0[a]	-4.37 ± 4.66[a]	-0.66 ± 0.65[a]	-1.87 ± 0.04[a]	-1.08 ± 0.65[a]
Springiness	0.88 ± 0.01[a]	0.89 ± 0.05[a]	0.88 ± 0.01[a]	0.92 ± 0.06[a]	0.86 ± 0.03[a]	0.88 ± 0.01[a]
Cohesiveness	0.84 ± 0.06[a]	0.78 ± 0.03[a]	0.77 ± 0.02[a]	0.90 ± 0.12[a]	0.83 ± 0.07[a]	0.76 ± 0.04[a]
Gumminess	7234.94 ± 3880.33[a]	9718.50 ± 218.43[a]	7683.19 ± 2358.20[a]	7254.94 ± 5475.39[a]	8921.59 ± 2837.73[a]	11225.17 ± 2177.35[a]
Chewiness	6354.03 ± 3360.74[a]	8665.44 ± 442.67[a]	6751.49 ± 2111.73[a]	6435.52 ± 4739.31[a]	7666.14 ± 2605.85[a]	9917.06 ± 1912.48[a]
Resilience	0.47 ± 0.08[ab]	0.44 ± 0.02[ab]	0.36 ± 0.02[b]	0.57 ± 0.09[a]	0.44 ± 0.02[ab]	0.41 ± 0.02[b]

[1]Different letters on the same row of texture parameters indicate a significant difference (*P*<0.05) by Tukey's test.
*PWO = Patties with Oregano; PWC = Cloves; PWCI = Cinnamon; PWGT = Green Tea; PWT = Turmeric.

Table 5. Sensory evaluation of cooked sardine fish patties incorporated with different spices and green tea

Parameters[2]	Samples					
	Control	PWO	PWC	PWCI	PWT	PWGT
Appearance	5.57 ± 1.83[a]	5.83 ± 1.44[a]	5.50 ± 1.55[a]	5.93 ± 1.36[a]	5.80 ± 1.71[a]	5.43 ± 1.52[a]
Aroma	5.53 ± 1.76[ab]	5.13 ± 2.10[ab]	4.37 ± 1.77[b]	5.23 ± 1.65[ab]	5.87 ± 1.66[a]	6.13 ± 1.25[a]
Colour	5.20 ± 1.83[a]	5.77 ± 1.76[a]	5.03 ± 1.75[a]	5.60 ± 1.57[a]	5.83 ± 1.64[a]	5.63 ± 1.79[a]
Fishy Smell	5.43 ± 2.13[a]	5.00 ± 1.95[a]	4.63 ± 1.85[a]	5.27 ± 1.64[a]	5.60 ± 1.65[a]	5.93 ± 1.66[a]
Flavour	5.57 ± 2.05[a]	5.53 ± 2.10[a]	3.40 ± 1.94[b]	5.70 ± 1.86[a]	6.10 ± 2.11[a]	6.63 ± 1.43[a]
Texture	5.63 ± 2.01[ab]	5.73 ± 1.72[ab]	4.47 ± 2.00[b]	6.03 ± 1.45[a]	5.87 ± 2.06[ab]	6.07 ± 2.05[a]
Overall Acceptability	5.90 ± 1.56[a]	5.83 ± 1.95[a]	4.13 ± 2.19[b]	5.53 ± 1.63[a]	6.27 ± 1.76[a]	6.50 ± 1.46[a]

[1]Different letters on the same row of sensory attributes indicate a significant difference (P<0.05) by Tukey's test.
[2]Nine-point hedonic scale (9-liked extremely; 8-liked very much; 7-liked moderately; 6-liked slightly; 5-neither liked nor disliked; 4-disliked slightly; 3-disliked moderately; 2-disliked very much 1-disliked extremely).
PWO = Patties with Oregano; PWC = Cloves; PWCI = Cinnamon; PWT = Turmeric; PWGT = Green Tea.

Table 6. TBA value of cooked sardine fish patties incorporated with different spices and green tea during chilled storage (4 °C)

Samples	Days of storage			
	1	3	6	12
Control	0.033 ± 0.008[ax]	0.012 ± 0.005[ax]	0.028 ± 0.008[ax]	0.052 ± 0.038[ax]
PWO	0.021 ± 0.007[abxy]	0.005 ± 0.005[ay]	0.008 ± 0.009[ay]	0.041 ± 0.010[ax]
PWC	0.029 ± 0.008[ax]	0.026 ± 0.009[ax]	0.031 ± 0.019[ax]	0.027 ± 0.012[ax]
PWCI	0.035 ± 0.007[ax]	0.026 ± 0.017[ax]	0.024 ± 0.018[ax]	0.028 ± 0.018[ax]
PWT	0.027 ± 0.008[abx]	0.017 ± 0.001[ax]	0.022 ± 0.011[ax]	0.042 ± 0.016[ax]
PWGT	0.007 ± 0.008[by]	0.015 ± 0.001[axy]	0.021 ± 0.016[axy]	0.045 ± 0.017[ax]

[1]Different letters (a, b) on the same day indicate a significant difference (*P*<0.05) by Tukey's test.
[2]Different letters (x, y) on the same treatment across the days of storage indicate a significant difference (*P*<0.05) by Tukey's test.
*PWO = Patties with Oregano; PWC = Cloves; PWCI = Cinnamon; PWT = Turmeric; PWGT = Green Tea.

Table 7. Percentage of scavenging activity of cooked sardine fish patties incorporated with different spices and green tea during chilled storage (4 °C)

Samples	Days of storage			
	1	3	6	12
Control	1.09 ± 0.68[bx]	1.23 ± 1.97[bx]	4.80 ± 9.65[cx]	4.93 ± 5.29[cx]
PWO	5.34 ± 4.46[bx]	8.63 ± 13.11[bx]	17.17 ± 7.28[cx]	4.05 ± 5.74[cx]
PWC	61.19 ± 7.18[ay]	59.58 ± 8.20[ay]	81.66 ± 3.34[ax]	75.32 ± 4.73[axy]
PWCI	19.97 ± 1.43[bx]	8.10 ± 5.74[bx]	17.12 ± 3.70[cx]	14.47 ± 7.98[cx]
PWT	6.30 ± 4.20[bx]	9.21 ± 6.65[bx]	8.79 ± 1.93[cx]	7.75 ± 4.99[cx]
PWGT	46.43 ± 14.40[ax]	53.35 ± 22.33[ax]	52.17 ± 9.53[bx]	42.43 ± 17.85[bx]

[1]Different letters (a, b, c) on the same day indicate a significant difference (*P*<0.05) by Tukey's test.
[2]Different letters (x, y) on the same treatment across the days of storage indicate a significant difference (*P*<0.05) by Tukey's test.
*PWO = Patties with Oregano; PWC = Cloves; PWCI = Cinnamon; PWT = Turmeric; PWGT = Green Tea.

The addition of the cloves reduced the pH value of the fish patties, as compared with the control. This reduction in pH value would be due to the inhibitory effect of the antimicrobial agents of the cloves on the growth and proliferation of spoilage microorganisms that involve in amino acid metabolism (Zhang *et al*., 2016). Meanwhile, the slight increase in pH value in all patties after cooking was in line with studies by Reihani *et al*. (2014), Hazra *et al*. (2012) and Naveena *et al*. (2008), that demonstrated the pH of cooked beef patties, ground buffalo meat patties and chicken patties, respectively, incorporated with antioxidants showed a relatively higher value compared to the raw patties. The rise of the cooked meat pH could be due to the formation of ammonia from amino acids during protein denaturation (Zahid *et al*., 2020; Ahmed *et al*., 2022).

Colour properties

Colour influences the palatability, freshness, and wholesomeness of meat and meat products. It has been demonstrated that the addition of cloves and turmeric increased the lightness (L^*) of the fish patties. Similar observations were also reported by Augustyńska-Prejsnar *et al*. (2021) and Hleap-Zapata *et al*. (2020), who demonstrated the increased lightness of the cooked duck burgers incorporated with turmeric extract and paste, and chorizo incorporated with turmeric powder, respectively. However, it has been reported the reduction in lightness of the raw beef burgers after being treated with 2% of clove powder (Ahmed *et al*., 2022), while no effects of raw and cooked beef patties after being treated with 0.1% of clove extract (Zahid *et al*., 2019; Zahid *et al*., 2020;). Thus, this data variation suggested that the lightness could be affected by the interaction between the concentration, the presence of the pigment of the clove and heat intervention (cooking process) that would cause myoglobin denaturation, and modification of free water in the meat matrix (Sen *et al*., 2014; Sayas-Barberá *et al*., 2020; Ahmed *et al*., 2022). In addition, Fernández-López *et al*. (2005), suggested that the colour of the products will be lightened, as the number of antioxidants increased, and would delay the metmyoglobin formation, which is responsible for the darker colour of meat products.

Meanwhile, the redness (a^*) values of patties incorporated with oregano, turmeric and green tea were reduced. These data agree with previous studies that reported a significant reduction of redness after the incorporation of Moringa seeds on beef burgers and green tea on hamburgers (Al-Juhaimi *et al*., 2016; Fachinello *et al*., 2018). Meanwhile, other authors demonstrated a slight reduction of redness after the incorporation of oregano essential oil into beef burgers (Leite *et al*., 2022), and turmeric powder into chorizo (Hleap-Zapata *et al*., 2020). The addition of turmeric also increased the yellowness (b^*) of the fish patties, and this agreed with the study by Mancini *et al*. (2015), who showed a significantly higher yellowness value in turmeric treated-rabbit burgers. Duck burgers treated with turmeric powder also had a higher yellowness value as compared to untreated control, due to the yellow colour characteristic of turmeric (Augustyńska-Prejsnar *et al*., 2022). The bright yellow pigment of turmeric could be explained by the presence of curcumin, which is the principle curcuminoid, along with demethoxycurcumin and bisdemethoxycurcumin (Joshi *et al*., 2009).

Texture profile analysis (TPA)

The current study demonstrated that was no effect of the treatments on the textural properties of the sardine fish patties. However, the patties incorporated with green tea showed a higher hardness, which is in line with Cho and Chung (2010), who demonstrated that the hardness of pork meat patties increased with the addition of green tea powder. In addition, the incorporation of green tea into fish patties also resulted in obtaining the highest value in gumminess and chewiness. Gumminess, which is defined as the energy required to disintegrate or break down the food for swallowing and chewiness, which is defined as the energy for munching the patties for swallowing were assumed to be related to the parameter of hardness. Patties with green tea were the hardest, thus causing the samples to require higher energy to break up and masticate. A similar observation was also reported by Reihani *et al*. (2014) as beef patties incorporated with green tea extract showed the highest values in gumminess and chewiness.

Sensory evaluation

Sensory evaluation is a quantitative assessment regarding the panellist's acceptance of the meat products, according to their organoleptic properties (Ruiz-Capillas *et al*., 2021). Our study demonstrated that cloves addition reduced the flavour and overall acceptability of the patties while demonstrating a lower score compared with other treatments. These findings were in line with a study by Zahid *et al*. (2019), as clove extract showed significantly lower scores for flavour and odour of the treated beef patties. In addition, the fresh chicken sausages also demonstrated a lower score for flavour after the incorporation of clove oil, which might be due to its pungent and condensed aroma given by the volatile molecules present in it (Sharma *et al*., 2015). Meanwhile, it has been reported that clove extract-treated pork patties showed significant discolouration and off-flavour scores (Kong *et al*., 2010). This was also could be reflected in the effect of clove treatment in increasing the lightness of the patties. The main active ingredient in clove is eugenol, which is responsible for the antioxidant capacity of clove, as shown by the inhibition of metmyoglobin formation in the meat (Allen & Conforth, 2010). Meanwhile, our study also demonstrated the increase in antioxidative ability in the clove-treated patties. However, it could be suggested that metmyoglobin formation would be increased after 12 days of storage and would affect the colour score evaluation of the patties. In addition, the colour score was not significant in all treatments. However, the colour score for the patties treated with clove was the lowest numerically, as it might be affected by the strong antioxidative capacity of the eugenol in the clove, as compared with other active ingredients in other treatments. A study by Ahmed *et al*. (2022) demonstrated that the higher concentration of clove powder (6%) reduced colour acceptability due to colour changes to brownish colour on beef burgers. However, the same author also indicated that the concentration of 2% to 4% of the clove powder incorporated into beef burgers could improve its organoleptic properties. However, patties incorporated with green tea showed a high score in almost all the parameters. It has been reported that 0.2% of green tea extract incorporated into chicken patties secured higher scores for its flavour, juiciness, tenderness, and overall acceptability (Reddy, 2017). However, the addition of green tea in chevon patties by Nath *et al*. (2016)

did not show a good sensory result and was in contrast with the present study, probably due to the high percentage (3%) of green tea added in the formulation, which might affect the organoleptic properties of the patties.

TBARS and DPPH assays

Our study suggested that green tea is effective in lowering lipid oxidation in fish patties. Evaluation of the TBARS values on pork patties, beef patties, leg lamb chop and chevon patties with the incorporation of various extracts were implemented earlier and the results showed that green tea was the most effective antioxidant to inhibit lipid oxidation, due to the presence of catechins in the green tea (Mc Carthy *et al*., 2001; Banon *et al*., 2007; Lorenzo *et al*., 2014; Nath *et al*., 2016; Bellés *et al*., 2017). Meanwhile, the TBARS values of all treated patties were observed to be increased across storage days, which could be due to the common factor caused by the deterioration of meat, resulting in an increase in the oxidation of lipids during storage (Vaithiyanathan *et al*., 2011).

However, regarding the antioxidant capacity, as referred to in the DPPH assay assessment, our results suggested that patties treated with cloves and green tea had the greatest antioxidizing ability. In addition, the high scavenging activity in cloves and green tea agreed with results published by El-Maati *et al*. (2016), Alappat *et al*. (2015), and Suresh *et al*. (2015). Our result also demonstrated that scavenging activity was at the optimum level between days 3 and 6 of storage time before depletion after that, suggesting that six days of storage could be the optimum storage time. Hawashin *et al*. (2016) reported that the optimum scavenging activity of the raw meat burger treated with destoned olive cake occurred on the 7th day. During the initial storage time, the increase in antioxidative capacity could be due to polyphenol polymerization, which would reduce the availability of oligomers for charge delocalisation. However, the higher molecular complexity and steric hindrance cause the polymerization to exceed its critical value after a few days of storage, thus reducing the presence of hydroxyl groups to react with the DPPH radicals (Pinelo *et al*., 2004).

CONCLUSION

Regarding the measurement of lipid oxidation, green tea showed huge potential as an antioxidant agent according to TBARS analysis and scavenging activity on the treated patties, as compared to different spices used. In addition to that, no significant difference in the cooking properties was observed in sardine fish patties. In terms of sensory, the fish patties incorporated with green tea also appeared to have a good score in overall acceptability. Thus, among all the treatments, this study suggested green tea has the potential to be introduced into the market as a natural preservative, to improve shelf life as well as the physical and eating quality of the fish patties during storage.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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