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Chemical, physical and hedonic characteristics of green tea powder fortified oatmeal cookies

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Abstract

Fortification of oatmeal cookies with ingredients that are physically more attractive and functional is an interesting breakthrough for improving oatmeal cookies to be a favourite healthy food. Green tea was considered to be a food fortification because of its phytochemical content, which is beneficial to health. This study was aimed at getting more insight into the effect of green tea powder (GTP) fortification on physical (texture and colour), chemical (moisture, fat, ash, protein, carbohydrates, crude fibre content, and calories) and hedonic characteristics of oatmeal cookies. The treatments in this study were 5 levels of GTP fortification (each repeated 4 times) i.e., 0, 2, 4, 6, and 8% into the cookie's dough. There was a significant effect ($p \leq 0.05$) of GTP fortification on the texture, colour, ash, fat, crude fibre, and total calorie products. The 2% GTP fortification in oatmeal cookies was the most preferred by the panellists, because the higher percentages of GTP affected the more bitter taste and harder texture. Fortification of oatmeal cookies with 6% GTP produces the final product, namely green tea oatmeal cookies (GTOC), which are low in fat and carbohydrates but high in fibre and protein content. GTP fortification can improve the oatmeal cookie's functional properties

1. Introduction

Over centuries, oatmeal cookies have been consumed as a healthy alternative snack. However, because of their sensory constraints such as colour and flavour, cookies are not as attractive as regular cookies. Cookies are a popular snack among the general population, ranging from children to the elderly, and thus being produced from soft dough blended with a variety of components such as flour, eggs, sugar, margarine, and other food additives. According to Dinkar and Mishra (2020), based on statistical data gathered from various research on cookies, the percentage of cookie consumption is 17.3%, making cookies the second most consumed bakery type food after bread.

Nowadays, Green tea is a popular tea commodity in Indonesia. It is due to the numerous health advantages of green tea. Green tea is produced without any fermentation process. As a result, the antioxidant content of green tea is higher than other varieties of tea (Namita *et al*., 2012). Catechin, the potential antioxidant component in green tea, is the most abundant. Catechins are flavanols derived from flavonoid polyphenol molecules. Green tea contains flavonoid components in concentrations ranging from 300 to 400 mg/g. Green tea catechins consist of four main essential compounds, specifically: epigallocatechin-3-gallate (EGCG), epigallocatechin (EGC), epicatechin-3gallate (ECG), and epicatechin (EC), with the total catechins in tea reaching 80%.

EGCG has the highest catechin level, accounting for approximately 59% of total catechins. The EGC content then varies from 19 to 13.6%, the ECG content from 6.4 to 13.6%, and the EC content from 6.4 to 13.6% (Steinmann *et al*., 2013). Previous research has shown that EGCG combined with bile salts can lower blood cholesterol levels via the fat emulsion mechanism, resulting in cholesterol that is unable to be absorbed by the intestines and is subsequently excreted through the feces (Momose *et al*., 2016).

In the previous research by Ahmad *et al.* (2015), there was no further study related to the chemical properties, especially in the nutritional value of green tea

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oatmeal cookies (GTOC). This study aims to determine the effect of the addition of GTP on chemical, physical, and hedonic characteristics in oat cookies. The benefit of this research is to develop functional food products, namely healthy cookies, enhanced by adding green tea powder.

2. Materials and methods

2.1 Materials

The materials used in this study were 100% GTP (Lansida, Indoplant, Yogyakarta), oatmeal (Quaker, United States), margarine, refined sugar, eggs, vanilla flavouring, green tea flavouring, all-purpose wheat flour, baking soda, and salt purchased from the nearby grocery market.

2.2 Methods

The experiment was performed in a completely randomized design with a single factor of five treatments which each treatment was repeated four times (20 trial units). Treatments were the addition of GTP in the cookie’s dough such as 0, 2, 4, 6, and 8% (w/w).

2.2.1 Preparation of green tea oatmeal cookies (GTOC)

GTOC production was carried out in three stages such as dough mixing, printing and roasting. First of all, the ingredients are shown in Table 1 (except flour, baking powder, and green tea flavour) were mixed for 5 mins until the dough was homogenous. Oatmeal, flour, baking powder, and green tea flavour was added later into the dough. Then, GTP was fortified into the dough according to the treatments that have been mentioned and the dough was mixed gently for 3 mins. The dough was moulded with 5 g in each weight and then baked at 180°C for 25 mins (Oven, Modena Profilo B02663, Italy). GTOC was chilled for 10 mins at room temperature before being packaged for further analysis.

2.2.2 Analysis of chemical properties

Chemical properties analysis in this study were separated into moisture, protein, fat, ash, carbohydrate, and crude fibre content. Furthermore, the total calorie of the products was also calculated.

2.2.2.1 Moisture content

The percentage of water content in the oatmeal cookies was calculated using the method mentioned by Langkong *et al.* (2019) with a dry oven base. First, a porcelain cup was prepared and placed in the oven at 100°C for 1 hr then the porcelain cup was placed in a desiccator and weighed. The samples were macerated and weighed as much as 3 g. After that, the samples were put in the oven at a temperature of 105°C for 3 hrs then the sample was placed on the desiccator for 15 mins then the samples were weighed.

2.2.2.2 Protein content

The percentage of protein content in the oatmeal cookies was calculated using the method as described by Kolawole *et al.* (2020) with the Kjeldahl method by multiplying the 6.25 conversion factor. The Kjeldahl method consists of 3 stages, namely the destructive stage, the distillation stage, and the titration stage. Initially, as much as 0.5 g of the sample was weighed, then the sample was inserted into a 100 mL Kjeldahl flask and then inserted with 0.5 g of selenium catalyst and 10 mL of H_2SO_4 concentrate. After that, the Kjeldahl flask was placed in a destructive cupboard, then it was heated over low heat. The destructive process is stopped when the discolouration of the solution becomes clear greenish. The destructive sample was cooled first, then transferred into the distillate flask and 100 mL of aquadest and 45% NaOH 40 mL was added. The samples were distilled with traps made of 4% H_3BO_4 5 mL and 2 drops of MRMB indicator solution until they obtained a distillate of as much as 40-50 mL. The resultant distillate was then penetrated using HCl 0.1 N until there was a discolouration of the distillate to a purplish-blue.

Table 1. Green tea oatmeal cookies formulation

Materials	Compositions				
	T_0	T_1	T_2	T_3	T_4
Margarin (g)	200	200	200	200	200
Refined Sugar (g)	200	200	200	200	200
Egg (item)	2	2	2	2	2
Vanilla Extract (mL)	5	5	5	5	5
Green Tea Flavouring (mL)	7.5	7.5	7.5	7.5	7.5
All Purpose Flour (g)	180	180	180	180	180
Baking Powder (g)	5	5	5	5	5
Salt (g)	2.5	2.5	2.5	2.5	2.5
Quick Cooking Oats (g)	250	250	250	250	250
Green Tea Powder (%)	0	2	4	6	8

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2.2.2.3 Fat content

The percentage of fat content in the oatmeal cookies was calculated using the method described by Ladi *et al*. (2020). First, the filter paper was dried in an oven at 100°C for 1 hr. 2 g of samples were weighed and placed in a paper strain, then dried at an oven temperature of 105°C for 4 hrs. After that, the sample was put into a desiccator and it was weighed 15 mins later. The sample was dried at an oven temperature of 105°C for 1 hour, then its constant weight was noted. The sample diluted in n-hexane (500 mL) was inserted into the soxhlet and boiled for 14 hours. After 14 hrs, the sample is removed from the pumpkin and left in the open air until the solvent completely evaporates. Then, the sample was dried in the oven at 95°C for 1 hr, then put in a desiccator and the resulting weight was weighed.

2.2.2.4 Ash content

The percentage of ash content in oatmeal cookies were calculated following the method shown by Langkong *et al.* (2019) with the furnace method. As much as 5 g of samples were inserted into the porcelain cup with a known weight. Then the sample was placed overnight in an oven at a temperature of 105°C and then it was put in a desiccator. After that, the sample was put in an electric furnace at 550°C for 24 hrs or until it became white ash. The acquired ash was cooled in a desiccator for 15 mins and weighed to a constant weight.

2.2.2.5 Carbohydrate content

The percentage of the carbohydrate content in oatmeal cookies were calculated following the method showed Ate *et al.* (2017) using by difference method, which is to reduce the total number of components (100%) with moisture, protein, fat, crude fibre and ash.

2.2.2.6 Crude fibre content

The percentage of crude fibre on oatmeal cookies were calculated following the method adapted from Bulbula and Urga (2018). Initially, up to 2 g of the material was extracted using the Soxhlet technique and diluted three times in the organic solvent (n-hexane). After drying, the sample was put in a 500 mL Erlenmeyer flask and 50 mL of 1.25 percent H_2SO_4 solution was added. Using an upright cooler, the sample simmers for 30 mins. Later, 50 mL of 3.25 percent NaOH was added and left to boil for 30 mins before filtering under hot circumstances with a Buchner funnel. The deposits were cleaned with H_2SO_4 1.25% heat, hot water, and 96% ethanol in a row. The deposits are then placed in a known porcelain cup and dried at 105°C before being cooled and weighed to a consistent weight.

2.2.2.7 Total calorie

The total calorie on oatmeal cookies was determined following the method shown by Lestari *et al.* (2017) using the Atwater method (4-9-4) based on the calculation of crude protein, crude fat and carbohydrate.

2.2.3 Physical properties testing

Physical properties analysis in this study were separated into the colour test and texture test on oatmeal cookies.

2.2.3.1 Colour test

Colour testing on oat cookies using colorimeter tool refers to Žilić *et al.* (2017). The sample was placed under the lens of the colourimeter camera then closed. The sample will be visible on a computer and the colour measurement will result based on the blue, red and green colour components of the light absorbed by the object or sample. This colour measurement will result in L*, a* and b* values.

2.2.3.2 Texture test

Texture testing in oat cookies was done by using a texture analyser referring to the research by Mudgil *et al.* (2017). Texture test in oat cookies with the addition of green tea powder includes hardness value test, springiness, adhesiveness and cohesiveness. First, the samples were prepared and the height of the object table was set. The probe was installed according to the analysis to be performed. The test was set at 0.5 g trigger, deformation 3 mm and speed 1 mm/s. Then the start button was pressed.

2.2.4 Hedonic test

Panellist preference test to the product was carried out by hedonic testing method according to Salleh *et al.* (2020). Hedonic testing on oat cookies with the addition of green tea powder was carried out using 25 semi-trained panellists. Panellist preference assessment was conducted on some hedonic attributes such as taste, flavour, texture, colour, and overall. Each panellist tasted 5 kinds of indicated cookies, with a three-digit code for each. They gave their assessment based on the scoring method available on the hedonic test form. The scores were determined as 1, 2, 3, and 4, which mean "liked," "quite liked," "slightly liked," and "disliked" respectively. This hedonic testing was aimed at determining the best treatment of all oat cookies treatments with the addition of green tea powder.

2.2.5 Statistical analysis

Chemical and physical analysis data were analysed using the parametric analysis of variance (ANOVA) test. Parametric testing was carried out using the SPSS 26.0 application at a significance level of ≤ 0.05. If there is an effect of treatment, the test is continued with the Duncan Multiple Range Test (DMRT) to find the mean value of the difference. Data analysis on the hedonic test used the non-parametric Kruskal Wallis test followed by the Mann Whitney test.

3. Results and discussion

3.1 Chemical characteristic of GTOC

The chemical composition of a product determines its nutritional aspect, which is necessary to ensure food quality (Floros *et al.,* 2010). In this study, GTP was employed as food fortifiers on making oatmeal cookies, resulting in green tea oatmeal cookies (GTOC). Based on the result, it is known that the addition of GTP to oatmeal cookie dough substantially affected the chemical properties, which include fat, carbohydrate, and energy content (Table 2). Up to 8% of GTP concentrations that were added to the dough considerably decreased the fat, carbohydrate, and calorie content of oatmeal cookies while also increasing the crude fibre and ash level.

Green tea has a high concentration of phytochemicals, particularly catechins, which are secondary metabolites generated naturally by plants and belong to the flavonoid class (Rasouli *et al*., 2019). The presence of an aromatic ring is the basic chemical structure of flavonoids (Shi *et al*., 2012). GTP fortification of oatmeal cookies resulted in GTOC with lesser fat than control cookies not fortified with GTP. This is due to the catechin's fat-binding abilities in the cookie dough. Catechin is an antioxidant molecule that creates a complicated bond between its aromatic rings and the lipids in oatmeal cookies (El-Beltagi and Mohamed, 2013). This binding was also caused by the baking process's high temperature (180°C). Heat can reduce GTP's antioxidant activity, which is triggered by weak catechins in oxygen binding, causing the fat to be oxidized. The presence of oxidized fat resulted in decreased readable fat level tests (Navaratne and Senaratne, 2014).

GTOC also had a lower carbohydrate content than the control cookies ($p<0.05$). The more GTP added to the batter, the lower the carbohydrate level of the resulting oatmeal cookies. The lowest carbohydrate compound of GTOC was shown in the GTOC by adding the highest percentage of GTP (8%) in the dough ($p<0.05$). The decrease in carbohydrate content in GTOC is considered due to the fall in sugar level during the baking process. High temperatures allow catechins in GTP, particularly epigallocatechin gallate (EGCG), to be oxidized and participated in the caramelization reaction by reducing sugar so that it can influence the lowering sugar level in cookies (Fu *et al.,* 2018).

Generally, low levels of fat and carbohydrates can affect the energy total of the products (Kulthe *et al*., 2014). This is demonstrated by the fact that oatmeal cookies with up to 8% GTP addition have significantly fewer calories than oatmeal cookies without GTP (Table 2). Although GTOC is low in calories, its quality still conforms to the standard of oatmeal cookies as a product with ideal nutrition wherein it must contain a minimum number of 400 kcal of energy/100 g (van Tongeren *et al.,* 2020). The energy of GTOC in this study is in the range between 463-439 kcal/100 g as a result of GTP fortification into the cookie dough by 2-8% (Table 2). Thus, GTP fortification in oatmeal cookies can be an effort to produce healthier cookies which have the potential to be a functional food or as a special diet to decrease the obesity problem in society.

Furthermore, GTOC significantly showed higher ash content than control cookies ($p<0.05$). Ash content indicates the presence of minerals in a food product (Musundire *et al*., 2014). GTP used as cookies fortification in this study contains several minerals such as manganese, copper, chromium and fluorine (Pastoriza *et al.,* 2017). In addition, the increase in ash content of GTOC is due to the presence of high levels of antioxidant compounds in GTP (Kumari *et al*., 2018).

Table 2. Chemical characteristics of green tea oatmeal cookies with the addition of green tea powder of different concentrations

Parameters	Treatments				
	T_0	T_1	T_2	T_3	T_4
Fat (%)	22.15±0.17^{a}	21.45±0.58^{b}	20.63±0.47^{c}	20.48±0.66^{cd}	19.92±0.50^{d}
Ash Content (%)	1.60±0.05^{a}	1.80±0.05^{b}	1.85±0.10^{bc}	1.90±0.11^{bc}	1.95±0.10^{c}
Protein (%)	14.10±4.73	14.45±5.51	14.58±4.54	14.64±4.88	15.10±4.44
Moisture (%)	3.32±0.26	3.55±0.73	3.70±0.71	3.97±0.03	4.03±0.67
Carbohydrates (%)	54.80±5.23^{a}	53.01±4.63^{a}	51.32±4.29^{a}	50.00±5.71^{b}	49.86±4.79^{b}
Crude Fibre (%)	4.03±0.44^{a}	5.76±0.31^{b}	7.93±0.83^{c}	9.02±0.40^{c}	9.13±0.55^{c}
Calories (100g/kcal)	474.95±4.88^{a}	462.84±4.68^{b}	449.17±9.35^{c}	442.76±3.86^{cd}	439.18±4.02^{d}

$T_{0\text{-}4}$ is GTP addition of 0, 2, 4, 6, and 8% respectively. Values are presented as mean±SD. Values with different superscripts in the same row are significantly different ($p<0.05$).

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Besides being rich in minerals, GTOC also contains high fibre. The addition of GTP up to 6% has been able to increase the crude fibre of oatmeal cookies optimally ($p<0.05$). Effectively, adding green tea powder to oat cookies has a significant effect ($p<0.05$) on the content of crude fibre cookies. The crude fibre content in GTOC (5.76-9.13%) is higher than the standard in nutrition (0.5%). The high content of crude fibre in GTOC is related to the chemical characteristics of GTP, which is rich in crude fibre (13.58-15.55%). Fibre is defined as food residue left after heating with strong acids, strong bases and alcohol, which is also included as dietary fibre. The main components contained in crude fibre are polysaccharides derived from plants consisting of cellulose, hemicellulose and lignin (Dhingra *et al*., 2012).

3.2 Physical characteristic of GTOC

Physical characteristics evaluated on GTOC consist of texture (hardness, adhesiveness, cohesiveness, and springiness) as shown in Table 3 and colour appearance as shown in Table 4. Cookies are usually baked until crisp. That is why texture is an important physical characteristic to observe in this study. Oatmeal cookies with the addition of GTP in different percentages of the dough significantly affected its texture in comparison to the control. The greater the concentration of GTP addition, the harder the oatmeal cookies ($p<0.05$). The texture of GTOC was influenced by GTP hygroscopicity, which is the ability to absorb water from its environment (Zokti *et al.,* 2016). GTP addition in the dough also binds water, causing the cohesion value to increase and the cookies to become harder (Falcó *et al.,* 2019). That is why GTOC in this study possessed a higher cohesiveness value than the control cookies ($p<0.05$), and as a consequence, GTOC became harder in texture. In addition, antioxidant compounds in GTP, especially phenol, evidently compete with the wheat starch granules of the dough for binding water (Fu *et al*., 2018).

Meanwhile, the adhesiveness value of GTOC was also increased as much as the increasing number of GTP additions in this study ($p<0.05$). Adhesiveness elucidates the stickiness of the mixture of ingredients of dough, which inhibits the expansion or increasing volume of the cookies (Pozo *et al.,* 2018). The increase of adhesiveness value is thought to correlate with the existence of hydroxyl groups in GTP which can weaken the gluten matrix of the dough that makes it unstable. Finally, this produces a harder final product (Li *et al*., 2012). In contrast, the springiness value of GTOC was decreased as a result of GTP addition ($p<0.05$). The low springiness value indicates that GTOC is less elastic in the texture and feels dense and soggy when it is bitten (Ma and Ryu, 2019). Phenolic compounds contained in GTP have affected the viscoelasticity of the final product due to the weakening of gluten in the flour and also that high amounts of added β–glucans are able to provide a strong and cohesive texture (Lee *et al.,* 2009).

Furthermore, the addition of GTP into the dough showed a significant effect on the colour intensity of the oatmeal cookies ($P<0.05$). Increasing the GTP percentages significantly increased the intensity of a* (greenness) colour in GTOC. On the contrary L* (lightness) and b* (yellowness) colour was significantly decreased (Table 4). Discolouration of GTOC is associated with the chlorophyll content in the GTP was responsible for producing the green colour of green tea leaves (Ošťádalová *et al.,* 2015). The increasing percentage of ash content in GTOC (Table 2) also affects

Table 3. Texture characteristics of oatmeal cookies with the addition of green tea powder of different concentrations

Parameters	Treatments				
	T_0	T_1	T_2	T_3	T_4
Hardness (N/mm^2)	697.50±63.0^a	1123.50±343.63^b	1237.10±517.30^b	1620.40±538.76^c	2378.70±782.72^d
Adhesiveness (N/mm^2)	0.10±0.005^a	0.16±0.008^b	0.21±0.011^c	0.22±0.019^c	0.61±0.008^d
Cohesiveness (Ratio)	0.04±0.00^a	0.05±0.01^a	0.14±0.01^b	0.14±0.03^b	0.18±0.01^c
Springiness (%)	3.05±0.06^a	2.85±0.06^a	2.55±0.29^b	2.15±0.06^c	1.90±0.00^d

T_{0-4} is GTP addition of 0, 2, 4, 6, and 8% respectively. Values are presented as mean±SD. Values with different superscripts in the same row are significantly different ($p<0.05$).

Table 4. Colour characteristics of oatmeal cookies with the addition of green tea powder of different concentrations

Parameters	Treatments				
	T_0	T_1	T_2	T_3	T_4
L*	48.47±2.42^a	42.74±2.09^b	39.58±1.74^c	39.23±1.51^c	37.76±0.72^c
a*	-2.09±1.42^a	-2.93±1.77^{ab}	-3.72±0.21^{abc}	-4.22±0.16^{cd}	-4.72±0.56^d
b*	32.12±2.16^a	29.66±0.90^b	27.08±0.57^c	26.21±0.36^c	25.00±0.32^c

T_{0-4} is GTP addition of 0, 2, 4, 6, and 8% respectively. L*, a*, and b* are lightness, chromatic redness/greenness, and chromatic blueness/yellowness respectively. Values are presented as mean±SD. Values with different superscripts in the same row are significantly different ($p<0.05$).

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Table 5. Results of hedonic testing of green tea oatmeal cookies with the addition of green tea powder of different concentrations

Parameters	Treatments				
	T_0	T_1	T_2	T_3	T_4
Aroma	3.20±0.76	3.32±0.76	2.96±0.97	2.84±0.85	2.92±0.81
Texture	3.68±0.56^a	3.68±0.56^a	2.92±0.86^b	2.60±0.87^b	2.12±0.93^c
Taste	3.24±0.78^a	3.28±0.93^a	3.20±0.76^a	2.44±0.87^b	2.28±0.98^b
Color	2.76±0.78^{bc}	3.28±0.68^a	2.84±0.80^{ab}	2.32±0.85^{cd}	1.88±0.78^d
Overall	3.20±0.91^a	3.24±1.01^a	3.16±0.47^a	2.56±0.76^b	2,16±0.55^b

$T_{0\text{-}4}$ is GTP addition of 0, 2, 4, 6, and 8% respectively. Values are presented as mean±SD. Values with different superscripts in the same row are significantly different (p<0.05).

the colour intensity of the product. The higher value of ash content in the food product, the darker its colour will be (Nakov *et al.,* 2020).

3.3 Hedonic characteristic

GTP addition in the process of oatmeal cookies making affected almost all of the attributes of hedonic profiles of GTOC, except aroma ($p<0.05$). The higher the GTP percentage in the cookie's dough, the lower the acceptance level of the panellist from the aspects of texture, taste, and colour of products (Table 5). The lower preference of the panellist was due to the harder texture, bitter taste, and darker green colour of GTOC. Green tea contains some active compounds such as tannins and chlorophyll, which cause a bitter taste and a green colour, respectively, when they are added to the ingredients (Sánchez-Muniz, 2012).

4. Conclusion

The addition of green tea powder as oatmeal fortification up to 6% in the dough produces green tea oatmeal cookies (GTOC) high in fibre and ash content but low in fat, carbohydrate, and calories. Despite the fact that GTOC has a firm texture and a dark green colour, its texture and colour are still in the panellist's preferred range.

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