Effect of baking conditions on the physical properties of bread incorporated with green coffee beans (GCB)

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Abstract. Most of nutrients can be found in normal breads but there is lack of antioxidant rich polyphenolic compounds. Green coffee bean (GCB) is chosen as functional ingredients to be incorporated in the bread as it contains high amount of phenolic acid namely chlorogenic acid which contributed to antimutagenic, anticarcinogenic and antioxidant activities. Therefore, GCB was chosen as natural sources in order to enrich the wheat bread with their phenolic antioxidant’s characteristics. The objective of this study is to investigate the effect of concentration of green coffee bean, baking temperature, and baking time on the physical properties of the incorporated bread. The physical properties such as moisture content, volume, colour, and texture were analysed. The data obtained were statistically analysed using Analysis of Variance (ANOVA). The results show that the incorporation of GCB has a positive influence on the physical properties of the bread especially on moisture content and volume. The factors with the largest effect on the moisture content were the baking temperature and GCB concentrations (p < 0.05). The use of high baking temperature causes higher moisture content and volume of bread after baking. While for bread crust and crumb colour, it was observed that increasing the baking temperature and time resulted in dark crust colour and reduced the colour saturation. For crumb colour, the addition of GCB powder caused a slight decrease in lightness and yellowness, whereas the redness of bread was almost unchanged. Nevertheless, the incorporation of green coffee bean had a little influence on the texture of the bread. High hardness of the bread demonstrated from the high baking temperature and high baking time. From optimization process, it could be concluded that the optimum baking temperature was found at 180°C, baking time of 40 minutes and GCB concentration of 1 wt% in order to get the better quality of the bread. In conclusion, GCB has a great potential as functional ingredient in bread. The addition of GCB does not only affect the antioxidant properties of the bread but also increase the quality of the bread itself.

1. Introduction

Bakery products are one of the sources for energy and nutrients such as proteins, carbohydrates, and minerals [1]. Because of their popularity and wide consumption, there has been much interest in the study of bakery products. There are various studies conducted in the optimizing of bakery products which involving in improving the quality, taste, and function of the foods. Through the combination of advanced food technology and nutritional sciences, functional food can be developed. Functional food describes as food with the addition of functional ingredients that can contribute to improve the quality, function, and can maintain people’s health.

One of the bakery products that popular around the world is bread. It is staple food mostly in Europe, Africa, and Middle East. Normal wheat bread nowadays is mostly lack of nutritional values especially in antioxidant characteristics. The antioxidant can be added in bread as it serves as natural preservatives.
of food from getting oxidise and to protect nutrients inside. Through today’s technology, synthetic antioxidant is commonly available, and it will have negative impact towards the human health with prolong consumption. Therefore, it is better to have natural ingredients for bread that is rich in antioxidant and other nutrients. In order to enrich nutritional characteristics in bread, antioxidant that rich either in spices, herbs, and green plants are explored. One of the most popular beverages that consumed by many societies is coffee. Coffee has rich source of bioactive constituents, non-enzymatic and antioxidant capacity [2]. In this study, green coffee bean (GCB) was chosen as functional ingredient to be incorporated in bread.

Coffee is widely used as beverage and ingredients for foods due to its unique flavour [3]. Coffee has rich source of bioactive constituents, non-enzymatic and antioxidant capacity [2]. Therefore, coffee can be considered as functional ingredient. Normally, the beans that used in black coffee are being roasted to some degrees which it can change the chemical structure, aroma, colour, taste and nutrients of the beans [4]. But for unroasted, it is called as green coffee as they are still immature coffee beans. Green coffee bean (GCB) contains higher concentrations of nutrients. This is because the process of roasting for coffee beans will reduce the amount of chlorogenic acid [5]. Level of chlorogenic acid in GCB is higher when compared to the roasted coffee beans [2]. Chlorogenic acid that contains more in the green coffee is considered to have benefits on human health [6]. Therefore, green coffee that rich in bioactive compounds can be used to develop bread.

In bread study, baking is one of the processes that received an interest due to the application of heat in transforming dough into bread. Several reactions occur during baking that can change in rheological properties of the bread [7]. When choosing bread, the consumer choice is influence by the quality features of the bread itself. It is related to the appearance such as the moisture, texture, colour and volume of the bread. Moisture content is an important parameter that needs to be measured and considered as it will influence the chemical and physical aspects of the food including bread. Moisture content also related with the freshness of the food, the stability for a long period of food storage. Next, texture of the bread is analysed for the evaluation of physical and mechanical properties of the bread structure. Texture can be measured by mechanical methods in units such as force since texture is a property that related to the sense of touch [8]. Mechanical texture is one of the most important quality aspects that will affect sensory perception and shelf life of bread. Thus, the assessment of product quality through texture analysis is an essential tool for bread products development and production. Visual colour is always closely related to the consumer perception and therefore colour became one of the most important quality attributes for food products. Colour of bread can be measured using L a b colour system where it is stand for lightness, redness, and yellowness. Lastly for volume, it is an important issue in the processing of food product, which can correlate on giving the information relating to the density of food specifically on the bread crumb and the gluten strength in the flour [9].

Various studies of food that incorporated by green coffee bean have been conducted. Dziki [2] had conducted a study on incorporated GCB in bread from different countries such as Ethiopia, Brazil, Kenya, and Colombia as a functional ingredient. Results demonstrated that phenolic compounds in bread that incorporated with GCB powder were highly mastication-extractable, which indicate their high in bioavailability and bio accessibility. The GCB powder addition strongly affects the content of phenolic in bread. The findings showed that ground coffee beans powder can be used directly for food supplementation without undergo the extract preparation. This is because bread that supplemented with GCB powder can possessed high antiradical activity rather than the control sample.

Another study did by Dziki [10], investigated the effects of addition green coffee (Coffea arabica) beans (GCB) was investigated on the quality and antioxidant properties of the incorporated bread. It was found that bread enriched with GCB had a little effect on the bread volume. Volume of bread was higher when 3 and 4 wt% of GCB flour were incorporated. Furthermore, the bread crumb texture such as hardness, cohesiveness, elasticity, and chewiness were slightly changed. However, the bread crumb colour lightness was slightly decreased. For the evaluation of antioxidant activities, it was found that the GCB addition significantly enhanced the antioxidant activities as many previous researches were done [11,12,13]. In addition, the antiradical activity of the bread also significantly increased. Therefore, the idea of incorporating GCB in bread will give a great potential in producing functional bread with health benefit.
In addition to having high antioxidant content, physical properties are also important for a bread in attracting customer attention. Therefore, the objective of this study was to investigate the effect of green coffee concentration, baking temperature and baking time towards the physical properties of the incorporated bread such as moisture content, volume, colour, and texture.

2. Methodology

2.1. Materials
Green coffee beans types of *Liberica* was purchased from My Liberica Coffee Sdn. Bhd, Johor. Other materials used such as wheat flour, instant yeast, salt, sugar, and butter were procured from the local market. *Liberica* green coffee beans powder was prepared using heavy duty grinder. The green coffee beans were ground by using a coffee grinder (model KitchenAid). Then, sieving process was carried out to obtain the fine green coffee powder.

2.2. Bread Preparation
Dough were prepared using laboratory-scale mixer (model Berjaya). Type of bread produced was loaf bread. The wheat flour was replaced with green coffee powder at concentrations of 1wt%, 2wt%, 3wt%, 4wt%, and 5wt% of total flour by weight basis. The overall flour weight was 200 g. 4 g of instant yeast, 6 g of sugar, 3 g of salt, 8 g of butter and 120 g of water were used for the preparation of dough. Those ingredients were mixed in a food mixer and kneaded for 10 minutes. After that, the dough was proofed for 15 minutes at 28°C and 85% relative humidity. The dough was kneaded again before proofed for 15 minutes. The dough then was baked at baking temperature of 180°C, 200°C and 220°C and baking time of 20, 30 and 40 minutes, respectively in a baking oven. After baking, the bread was left to cool at room temperature for 30 minutes before sent for further analysis. The control bread was prepared without the addition green coffee bean powder.

2.3. Moisture Content Determination
The moisture content of bread crumb was analysed using Moisture Analyzer (MA-35, Sartorius). 3 g of bread crumb sample was distributed evenly on the aluminium sample pan before the analyser started heating to the drying temperature of 105°C for about 10 minutes.

2.4. Volume Determination
The bread volume was determined using seed displacement method, in which the amount of green coffee seeds packing around the loaf in a standard container were measured.

2.5. Colour Determination
The colour of bread crumb and crust were measured using CR-400 Chromameter (Konica Minolta). Bread colour was obtained by placing the chromameter probe directly onto the surface of the bread. The analyses were based on L* a* b* system, where L* represent the colour lightness, a* represent the colour redness and b* represent the colour yellowness [8].

2.6. Texture Determination
For bread texture analysis, compression test was carried out using Texture Analyzer (Stable Micro System). The bread crumb samples (6cm, 5cm, 3cm) from the centre of bread were two times compressed with a test speed of 5.00 mm/sec. A p-7 compression probe with 75 mm platen was used. The parameters recorded were hardness and springiness.

2.7. Statistical Analysis
The experimental data obtained were subjected to statistical evaluation by using Design-Expert software version 6.0. Analysis of variance (ANOVA) was used to analyse the effects of green coffee concentrations, baking temperature and time towards the physical properties of incorporated bread.
3. Results and Discussion

3.1. Moisture Content

Regression analysis showed that the coefficient of determination ($R^2 = 0.7461$) for moisture content was satisfactory to validate the significance of the model and indicated that only 3.96% of the total variations were not explained by the model. The value of the adjusted determination coefficient ($R^2_{adj}$) was 0.5176, which also confirmed that the model was significant [14]. The factors with the largest effect on the moisture content were the quadratic of baking temperature and GCB concentrations ($p<0.05$). Therefore, the moisture of the bread crumb could be predicted by the equation for the experimental area under consideration as shown by equation (1) ($A =$ baking temperature, $B =$ baking time and $C =$ concentration of GCB).

$$\text{Moisture content} = 33.40 + 0.66 A^2 + 0.57 C^2$$

Figure 1 shows the 3D plot of the response surface for the moisture content as related to 3 wt% of GCB concentration, baking time and baking temperature. It demonstrates that the increase in baking temperature resulted in higher moisture content. Results from the baking tests showed that baking temperature has greater influence on bread properties compared to baking time.

Moisture in bread is important because moisture helps to moisten and lubricate the bread and potentially helps in slowing down the crumb firming process. Increasing baking temperature at constant baking time will retain higher moisture in bread crumb where else increasing baking time reduces moisture in crumb. This trend potentially caused by two factors which are degree of starch gelatinization and early crust formation [15]. The author highlighted that baking temperature and time affects the degree of starch gelatinization. Starch gelatinization absorbs moisture therefore if higher temperature and time applies, higher degree of gelatinization occurs. Thus, higher moisture retains in bread. Besides that, an early formation of crust due to high temperature and time also may prevent moisture from evaporating. Breads with high initial moisture content has the advantage in experienced slower moisture loss during storage.

![Figure 1](image)

**Figure 1.** Effect of baking temperature and time on moisture content at 3wt% of GCB

The acceptable range of moisture content of normal bread is between 35-45% for one day storage [16]. Figure 2 show four (4) bread samples for both control and incorporated bread were compared in terms of moisture content at different baking conditions. Bread supplemented with green coffee powder; the moisture content of the bread is higher compared to the normal bread. This result demonstrated that GCB addition has a positive influence on the moisture content of the bread and the range of moisture content is 32 – 36% which considered acceptable. There are many factors that can affect the moisture
content of bread such as type of flour used, the ingredients used and the processing variables [17,18]. Moisture loss can occur through the evaporation during baking process, process of drying out during storage and equilibration of moisture between crust and crumb. Therefore, those factors can affect the moisture content in bread itself [19]. Besides that, high moisture also can loss in dough through evaporation during baking process. Moreover, moisture content of the bread also changed influence by the duration of the bread storage.

![Graph showing moisture content between control and incorporated bread](image)

**Figure 2.** Moisture content between control and incorporated bread

### 3.2. Volume of Loaf Bread

Regression analysis showed that the coefficient of determination ($R^2 = 0.9853$) for volume was satisfactory to validate the significance of the model and indicated that only 0.01% of the total variations were not explained by the model. The value of the adjusted determination coefficient ($R^2_{adj}$) was 0.9721, which also confirmed that the model was significant. It was also seen that the linear terms of baking temperature, baking time and GCB concentrations are the factors with the largest effect on the volume of bread ($p<0.05$). The quadratic terms of baking temperature and GCB concentration ($p<0.05$) also had positive effects on volume of the bread. Therefore, the volume of the bread crumb could be predicted by the equation for the experimental area under consideration as shown by equation (2) ($A$ = baking temperature, $B$ = baking time and $C$ = concentration of GCB),

$$\text{Volume} = 749.93 + 9.67A + 19.60B + 35.78C - 5.73A^2 - 22.52C^2$$ (2)

Figure 3 shows the 3D plot of the response surface for the volume as related to 3 wt% of GCB concentration, baking time and baking temperature. It demonstrated that the increase in baking temperature and time resulted in high volume.

Loaf volume can be considered as the most important bread characteristic since it provides a quantitative measurement of baking performance [20]. Loaf volume is high considered to have positive economic effect on bread. This is because consumers always attracted to the higher volume and weight of bread loaf as they believe those bread is more attractive but at the same price with others bread. Lack of volume generally indicates the use of weak flour, or one low in enzyme activity. Loaf volume is also affected by the quantity and quality of protein in the flour, baking parameters, and proofing time [18]. Since the bread samples studied here have been produced from the same proofing time, the variation in loaf volume could be attributed mainly to different baking temperature and time as well as the functional ingredient flour incorporation. The increase in the volume of breads with green coffee powder may be due to the improvement brought by green coffee powder in the balance of tenacity and extensibility of the dough.
3.3. Colour of Bread Crust and Crumb
The colour of bread crust and crumb samples were measured using the CIE L*, a*, b* colour system, where L* is lightness, a* is redness, and b* is yellowness. Colour parameters that measured in this study such as the brightness, L* is range from 0 (black) to 100 (white), colour redness, a* from -50 (green) to 50 (red) and colour yellowness, b* from -50 (blue) to 50 (yellow).

Regression analysis showed that the coefficient of determination R² for bread crust are L* = 0.7268, a* = 0.4962 and b* = 0.7331 were satisfactory to validate the significance of the model. The value of the adjusted determination coefficient (R²adj) for L*, a*, b* values are 0.6756, 0.4017, and 0.4928 respectively, confirmed that the model was significant. The factors with the largest effect on the L*, a*, b* values were the baking temperature and baking time (p<0.05).

Figure 4 shows the 3D plot of the response surface for the colour of bread crust as related to 3 wt% of GCB concentration, baking time and baking temperature and the model equations are as shown by equation (3), (4) and (5) (A = baking temperature, B = baking time and C = concentration of GCB),

\[
L^* = 59.81 - 7.29A - 6.08B \\
a^* = 9.17 + 2.99A + 2.69B \\
b^* = 28.54 - 1.05B - 1.09B^2
\]  

This implies that increasing in the baking temperature and time darkens the crust colour and reduces the colour saturation. Increasing temperature and time can cause an increment or reduction for a* and b* values probably due to the dependency of Maillard reaction towards baking temperature and time. Maillard reaction is a reaction between amino acid and sugar that contains in wheat flour which contributes to the development of bread surface colour [21].

Next, regression analysis showed that the coefficient of determination (R² = 0.5753, 0.7689, and 0.7223) for L*, a*, b* of bread crumb and the value of the adjusted determination coefficient (R²adj) were 0.3793, 0.4017, and 0.5941, respectively. The p-value of the model was less than 0.05, indicating that the model was significant and can be used to optimize the independent variables under study. From the results obtained in bread crumb colour, the baking temperature, baking time and GCB concentration (p<0.05) had influence on L*, a*, b* values of the bread crumb.
Figure 4. Effect of baking temperature and time on bread crust colour at 3wt% of GCB

(a) L*  (b) a*  (c) b*

Figure 5 shows the 3D plot of the response surface for the bread crumb as related to 3 wt% of GCB concentration, baking time and baking temperature and the model equations are as shown by equation (6), (7) and (8) (A = baking temperature, B = baking time and C = concentration of GCB),

\[
L^* = 69.94 + 2.63 \times BC \tag{6}
\]

\[
a^* = -2.09 - 0.71C \tag{7}
\]

\[
b^* = 18.03 + 0.21A + 0.44AC \tag{8}
\]
According to Sabanis et al. [22], the crumb colour may be influenced by the colour of the substituted green coffee flour because the crumb does not reach as high of a temperature as the crust. The addition of GCB powder into wheat flour can also cause a slight decrease in colour lightness and yellowness of bread crumb respectively, whereas the colour redness of the bread crumb was almost unchanged.

3.4. Texture of Bread Crumb
Texture profile analysis was “two-bite” test, which includes the first and second compression cycles. The first and second compression cycles indicated the force vs. time data during the first and second compression of the product by the instrumental probe. The parameters recorded were hardness and springiness.

Regression analysis showed that the coefficient of determination ($R^2 = 0.8678$) for hardness was satisfactory to validate the significance of the model and indicated that only 0.23% of the total variations were not explained by the model. The value of the adjusted determination coefficient ($R^2_{adj}$) was 0.7488, which also confirmed that the model was significant. It was seen that the baking time and GCB...
concentrations become the factors with the largest effect on the hardness of bread (p<0.05). Therefore, the hardness of the bread could be predicted by the equation for the experimental area under consideration as shown by equation (9) (A = baking temperature, B = baking time and C = concentration of GCB),

\[ \text{Hardness} = 1256.43 + 248.70B^2 + 156.77C^2 - 180.44BC \] (9)

Figure 6 shows the 3D plot of the response surface for the hardness of bread crumb as related to 3 wt% of GCB concentration, baking time and baking temperature. It demonstrated that the high baking temperature and high baking time resulted in high hardness, as losing part of the moisture in baking process. The longer time of bread storage also caused an increase of bread hardness [23].

Next, springiness explains the bread elasticity by determining the extent of recovery between the first and second compression. The springiness of the bread could be predicted by the equation for the experimental area under consideration.

![Figure 6](image6.png)

**Figure 6.** Effect of baking temperature and time on hardness at 3wt% of GCB

Figure 7 shows the 3D plot of the response surface for the springiness of bread crumb as related to 3 wt% of GCB concentration, baking time and baking temperature. In the case of springiness, there are no significant model terms. The addition of green coffee powder had no significant influence on the bread springiness.

![Figure 7](image7.png)

**Figure 7.** Effect of baking temperature and time on springiness at 3wt% of GCB

3.5. Process and Experimental Validation

The result of overall physical properties is contributing to the optimisation of baking parameters. Hence, from the optimisation process, optimum value for baking temperature is 180°C, baking time is 40 minutes and GCB concentration is 1.00 wt%. These parameter values are found to be the optimum parameters for the baking process in order to get good quality of the bread.

After getting the optimum values, experimental validation was conducted. The predicted (values from model equation) and experimental values of physical properties of incorporated bread are presented in Table 1.
Table 1. Comparison between predicted and experimental values of bread physical properties

|                    | Predicted | Experimental | Percentage error |
|--------------------|-----------|--------------|------------------|
| Moisture content (%) | 35.82     | 37.06        | 3.45             |
| Volume (ml)        | 693.28    | 700.00       | 0.96             |
| Bread crust L*     | 62.67     | 65.60        | 4.67             |
| a*                 | 9.09      | 8.87         | 2.49             |
| b*                 | 29.67     | 28.54        | 3.82             |
| Bread crumb L*     | 68.12     | 66.41        | 2.51             |
| a*                 | -1.35     | -1.17        | 13.12            |
| b*                 | 18.03     | 18.81        | 4.32             |
| Hardness           | 1960.14   | 1928.29      | 1.62             |
| Springiness        | 0.94      | 0.95         | 0.53             |

4. Conclusion
In this study, the effects of different green coffee powder concentration, baking temperature and time on the physical properties of the bread were analysed. From the comparison between the control and the green coffee bread, the results showed that GCB addition has a positive influence on the physical properties of the bread especially moisture content and volume. The factors with the largest effect on the moisture content were the baking temperature and GCB concentrations (p<0.05). The usage of high baking temperature causes the higher moisture content in bread after baking. Volume of loaf bread showed that the increasing in baking temperature and time resulted in high volume. The analysis of crust and crumb colour were focused on three elements which are L*, a* and b* values. It was found that the factors with the significant effect on the crust colour were the baking temperature and baking time (p<0.05) except for b* value that largest effect was baking time. For crumb colour, the baking temperature, time and GCB concentration (p<0.05) had positive effects on crumb colour. The addition of green coffee had a little influence on the texture of the bread. High hardness of the bread demonstrated from the high baking temperature and high baking time whereas for springiness, there are no significant model terms observed. The result of overall physical properties was contributed to the selection of optimization in baking parameters. Hence the baking temperature which is 180°C, baking time of 40 minutes and GCB concentration 1.00 wt% are found to be optimum parameters for baking process in order to get the good quality of the bread.

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