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RESEARCH ARTICLE

Physicochemical Properties of Bread with the Addition of Green Peas (*Pisum sativum)*

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A B S T R A C T

The objective of this study is to investigate the physicochemical characteristics of bread with the addition of green peas (*Pisum sativum)*. In this study, three treatments, including 0% (control), 12.5% (T1), and 25% (T2) green peas puree, were added to the bread dough mixture and baked to analyze its physicochemical properties. Texture-wise, the addition of green peas did not show any significant effect (p>0.05) on the springiness of the bread. However, the bread crumbs' hardness, cohesiveness, and chewiness were significantly affected by the addition of green peas. Moreover, the color of bread in different treatments has distinguishable details. Green peas allowed the bread to become darker, but the different amounts of green pea puree added did not change the hues of the color. Furthermore, the moisture content of the bread added with the highest amount of green peas was shown to have the highest moisture content, and the difference between the moisture content of each treatment was rendered significant (p≤0.05). Green peas seem to have caused a decrease in loaf volume and height due to the high amount of fiber contained in them. Nevertheless, adding green peas did not significantly affect the bread's baking loss, loaf width, and length (p>0.05).

K E Y W O R D S

Green pea, Bread, Texture, Color, Moisture content

H I G H L I G H T S

- The addition of green peas significantly affects the texture, color, and moisture content of the bread.
- Addition of 25% green peas had the most significant effect on the physicochemical properties of bread yet it did not result in the most desirable product.
- Addition of 12.5% of green peas had the most similar physicochemical properties with a normal traditional white bread.

INTRODUCTION

Bread is a staple food that is a common part in people's daily lives as it is an important source of carbohydrate for the human body. The excellent source of carbohydrates allows bread to have a significant role in balancing blood glucose levels and providing adequate energy for humans. However, bread has a high glycemic index due to its relation to the increased secretion of insulin, which in turn, results in obesity. This high glycemic index could be reached due to the high carbohydrate and low fiber (Amaral et al., 2022).

Consumers' growing health awareness has sparked an interest in incorporating active ingredients like dietary fiber and phenolic compounds into bread. In addition, with the ongoing trend of consumers requiring healthy bread products, healthy functional ingredients such as vegetables will inevitably be incorporated into the product (Orfilla et al., 2019). However, some challenges arise concerning the physicochemical properties of the bread due to the use of active or functional components, which includes color, texture, and specific volume, (Mudau et al., 2021). For instance, fortifying fiber in bread may result in bread with lower volume, firmer texture, and darker color of crumb and crust (Ibrahim et al., 2015). As such, the baking industry has been trying to formulate bread with improved physicochemical characteristics using functional ingredients to achieve the consumer's high demand for healthy and high-quality bakery products. This research investigates the effect of adding vegetables such as green peas.

Green pea *(Pisum sativum*), as the *Fabaceae* family's second most necessary crop, contains significant quantities of macronutrients, such as protein (20-25%) and starch (24-49%) along with dietary fiber (60-65%) consisting of 10-15% insoluble fiber and 2-9% soluble fiber as the carbohydrate sources. Cooperating green peas with bread-making can have numerous health benefits since daily consumption of pea protein-rich foods has been reported to lower the chance of developing cardiovascular disease diabetes and induce protective effects against a variety of cancers, such as breast, renal, and colon cancer (Shanthakumar et al., 2022). Furthermore, studies conducted by Ge et al. (2020) showed that pea protein has antioxidant, anti-hypertensive, and anti-inflammatory properties, as well as the ability to modulate the activities of intestinal bacteria and lower cholesterol levels.

In one research conducted by Akbaş & Kılmaoğlu (2022), the effect of adding vegetables and fruits on the physicochemical properties of bread is observed. They utilized its extract in the experiment, which later showed that the moisture content of the bread was not significantly affected. In addition, despite the insignificant results, the specific volume (a measurement of the bread's volume relative to its weight) decreased with the addition of ingredients to the bread. Considering Akbaş & Kılmaoğlu (2022) research, fruits and vegetables can be used in bread enrichment and may become a healthy alternative for people who may oppose health conditions or nutritional adequacy. In this direction, this study aims to examine the physicochemical properties of the bread in addition to green pea puree. The measurement analysis will include the texture, moisture content, baking loss, bread dimension, and color.

MATERIALS AND METHODS

Study design

In this study, the bread dough and green peas purees were prepared before the other steps. Then, after the dough was prepared, the dough was proofed before baking. The room-temperature bread was observed and analyzed through different parameters, which include color, texture, bake loss, and moisture content. The sample was prepared in three batches.

Frozen green peas (Golden Farm, Indonesia), bread flour (Bogasari Cakra Kembar, Indonesia), margarine (Royal Palmia Butter Margarine, Indonesia), instant yeast (Fermipan, Indonesia), salt (Dolphin, Indonesia), chicken egg and sugar (Gulaku, Indonesia) were purchased from local supermarkets.

Methods

There were three formulations: control, treatment 1 (T1), and treatment 2 (T2). Different amounts of green peas puree will be added in treatments 1 and 2, and the physicochemical properties will be assessed after all three pieces of bread in one batch have been made. Three batches were made, and each batch was analyzed in triplicates for each parameter.

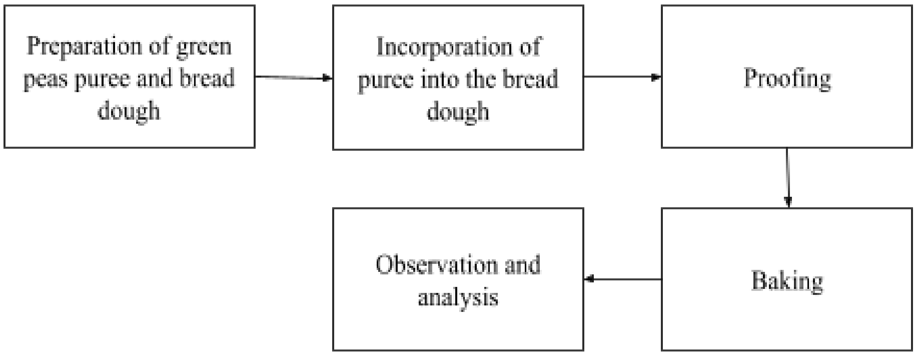

Figure 1. Methodology Flowchart

Green peas puree preparation

One thousand milliliters of water was measured into a pot. Then, the water was boiled in a pot until the temperature reached 80-100 degrees Celsius. Five hundred grams of green peas were added to the boiling water for 5 minutes. Afterward, the green peas were taken out of the water and strained. Furthermore, the green peas were mashed and put into a food processor (Philips Food Processor HR7627, Netherlands) to make green pea puree.

Bread preparation

The bread was prepared according to Table 1. The dry flour, sugar, and salt ingredients were mixed into a bowl. Then, wet ingredients such as dry yeast, water, and egg were mixed in a different bowl. Furthermore, wet and dry ingredients were added to a bowl and put in a stand mixer (Mixer KitchenAid Heavy Duty 5KPMEER, USA). Different masses of pureed green peas were added to the wet ingredients. Afterward, the mixture was kneaded for 5 minutes (2 speed), then 5 minutes (4 speed), and 30 grams of margarine was added. Then, the dough was further kneaded for another 5 minutes (4 speed). Lastly, a window test was performed to ensure the quality of the dough.

Table 1. Treatment for bread with different ingredients per one batch bread making.

Treatment	Water (ml)	Flour (g)	Sugar (g)	Egg	Yeast (tsp)	Salt (tsp)	Green peas puree (g)	Margarine (g)
Control (0%)	260	485	65	1	1	1/2	0	20
T1 (25%)	260	485	65	1	1	1/2	125	20
T2 (50%)	260	485	65	1	1	1/2	250	20

Incorporating green peas puree in the bread dough

The green peas were incorporated into the bread dough by combining the puree with the wet ingredients. The amounts of green peas were 125 (T1) and 250 (T2) grams of puree, respectively.

Baking

Afterward, the dough was put into a bowl and kept in the proofing chamber for 40 minutes at 35 degrees Celsius and 70% humidity. Then, the dough was removed from the proofing chamber and was kneaded to release the carbon dioxide. Subsequently, the weight of the bread before baking was recorded. The bread was shaped into a rectangular prism and portioned per the loaf pan used (with dimensions of 21 cm x 10 cm x 7 cm). The bread was then baked in an oven (Double Deck Gas Oven, India) at 180°C for 60 minutes. After it was done, it was removed from the oven, heated, and left to cool until it reached room temperature

Analysis

Color

The colorimeter (Spectral Colorimeter CS-410, China) was calibrated according to the brand's instructions. Then, the detector of the colorimeter was placed on the crumb of the bread to measure the L*, a*, and b* values. The crumb was measured instead of the crust, as the color of the crust may be affected by the uneven heating of the oven (Constantin et al., 2023). The color analysis could be described with L*, a*, and b*values. The L* value describes lightness within the range of 0-100. Meanwhile, the a* value indicates the red and green colors, with negative values indicating green hues and positive values indicating red hues. On the other hand, b* describes the color of the sample in terms of its blue and yellow hue, in the form of negative and positive values, respectively (Ly et al., 2020). All measurements were done in triplicate on one of the sides of the bread crumbs.

Texture (TPA)

The texture analyzer (Texture Analyzer TVT 6700, Sweden) was calibrated, and a suitable probe (10mm cylindrical probe) was used to measure the different parameters of the bread crumb, which include hardness, chewiness, cohesiveness, gumminess, and springiness. The bread was cut into two flat pieces, 4 cm x 4 cm, to accommodate the probe. The measurements were done in triplicate. The test was performed at 20% compression at a speed of 1 mm s^{-1} and a range of 1 s between the two cycles.

Bake loss

The dough's initial weight was measured using a kitchen scale before and after baking. Then, the bake loss can be calculated using the following formula:

$$Baking\ loss\ = \frac{initial\ weight - final\ weight}{initial\ weight}\ x\ 100\%$$

Moisture content

The moisture content was measured by grinding the bread into fine powder using a grinder. The oven (Dry Heat Sterilizer Oven FN055, Turkey) was preheated at 105 degrees Celsius for 3 hours. Afterward, the aluminum foil as a substitute for the crucible was put into the desiccator for 15-30 minutes and then weighed. Then, 2 grams of the sample was put onto the aluminum foil. The sample was put into the oven for 24 hours. After the oven process, the samples were weighed, and the measurements were duplicated.

$$Moisture\ content\ = \frac{(weight\ dried\ sample + aluminum\ foil) - (weight\ aluminum\ foil)}{initial\ sample\ weight} \times 100\%$$

Bread dimension

The bread's dimension was measured using a centimeter ruler. The dimensions measured were the dough's width, length, and height after baking. The measurement was done in duplicate. Henceforth, the volume was obtained by multiplying the width, length, and height.

Statistical analysis

The results were analyzed using variance analysis (ANOVA) on SPSS Statistics (IBM, USA). The post hoc test was further used to differentiate the specific group that caused the significant differences. The significance level of $p < 0.05$ was utilized to assess significant differences between mean values. The results of the study were presented as the average ± standard deviation.

RESULTS AND DISCUSSION

Color

Table 2 shows the mean color analysis of control bread, T1 and T2, after being measured using colorimeter. As shown in the table above, control bread had the highest L* and a* values, followed by T1 and T2, respectively. Nevertheless, the control had the lowest b* compared to other treatments. Regarding L*, only treatment 2 significantly affected the bread compared to other treatments, as its p-value is above 0.05. In regards to a* and b*, treatments 1 and 2 had a significant effect on the bread.

Table 2. Results for color, baking loss, moisture content, and volume of bread with different treatment.

Treatment	L*	a*	b*	Baking loss (%)	Moisture content (%)	Volume (cm)
Control	69.52 ± 2.03^{a}	1.82 ± 0.43^{a}	22.30 ± 1.06^{a}	5.70 ± 0.02^{a}	76.23 ± 0.03^{a}	2300 ± 23.4^{a}
T1	67.26 ± 2.25^{ab}	0.41 ± 0.38^{b}	27.27 ± 1.37^{b}	3.42 ± 0.01^{a}	86.75 ± 0.01^{b}	2130 ± 88.6^{ab}
T2	65.29 ± 2.23^{b}	– 0.22 ± 0.50^{c}	32.03 ± 1.10^{c}	1.75 ± 0.003^{a}	92.18 ± 0.01^{c}	1950 ± 8.75^{b}

*Different letters in the same column indicate significant ($p < 0.05$) differences between samples for the given parameter.

The values for L* and a* decreased as the concentration of green peas increased, and in contrast, the value of b* increased quite significantly with the increase in green peas. The decrease in a* value might be caused by green peas having a chlorophyll content of approximately 23.06 mg/100 mg (Kumar et al., 2013). Meanwhile, the decrease in L* and increase in b* value might be explained by the use of high baking temperatures, resulting in chlorophyll degradation (Gosavi et al., 2014). Degradation of chlorophyll could occur under high temperatures, forming pheophytins and pyropheophytin (Pumilia et al., 2014). In addition, Gui & Ryu (2014) also stated that the Maillard reaction caused by the baking process might create dark color pigments, decreasing the L* value.

Baking loss

The loss of moisture, primarily caused by evaporation, contributes to baking/weight loss throughout baking. High moisture losses throughout baking could result in unfavorable outcomes, including firmer texture, lower bread weight, increased crust thickness, and a faster rate of bread staling (Kotoki & Deka, 2010).

Table 2 also presented the weight loss of all of the bread after being baked in the oven compared to the weight of the dough prior to baking. It was observed that the control bread had the highest baking loss and bread with treatment 2 had the lowest. The results presented in Table 2 revealed that the bread with the highest green pea puree addition had the lowest baking loss among all breads, suggesting that green pea puree contributed to the conserved moisture of the bread. The green pea puree introduced a high amount of water to the bread dough, which enabled the bread to retain its moisture and reduced the baking loss throughout the baking process. According to Aydogdu et al. (2018), adding soluble fiber similar to the fiber found in green peas can enhance the bread's moisture level to reduce weight/baking loss. However, based on the statistical analysis results, there was no significant difference in using different treatments for the baking loss of the bread, since the p-value was higher than 0.05. Thus, the impact of different green pea concentrations on the weight/baking loss remains unclear.

Moisture content

Moisture in bread, which was highly influenced by the ingredients added to the dough and baking temperature, is an important property. It assists the lubrication and slows the crumbs' firming process and moisture loss during the storage period (Ibrahim et al., 2020).

Table 2 also revealed that the bread with treatment 2 had the highest moisture content and control bread had the lowest, indicating that the bread with treatment 2 had the highest water content. In contrast, control bread had the lowest water content. Additionally, adding green peas affected bread moisture content significantly, as presented in Table 2, in which a higher amount of green pea puree also had a higher moisture content. The high initial moisture content of approximately 70-75% in green peas and the blanching process allowed the green pea puree to increase the bread moisture content (Pandey et al., 2019).

Bread dimension

The last column of Table 2 displays the bread dimension, which consists of the bread volume obtained from different treatments. Based on Table 2, it can be seen that the smallest bread volume was found using treatment 2. Additionally, it can also be discerned that treatment 1 did not have a significant effect on the volume of the bread.

From Table 2, it was seen that only treatment 2 had a significant effect on the volume of the bread. The loaf volume of the bread decreased significantly ($p<0.05$) compared to the control as it decreased from 10.5 to 9.4 cm and from 2300 to 1950 cm^3. According to Salehifar et al. (2010), a stronger dough and larger loaf volume can be developed when the protein content is more than 11.5%, as they have higher water absorption due to stronger protein quality and content. Additionally, the more the protein content, the higher the gluten in the flour, resulting in a stronger gluten network in bread (Zou et al., 2022). A stronger gluten network indicates more gas retention during fermentation and baking, which allows the bread to rise vertically and spread out, causing a larger loaf volume (van Steertegem et al., 2014). However, the average protein content of green peas (*Pisum sativum)* is approximately 20-25%, as stated in Shanthakumar et al. (2022) research, yet the loaf height and volume obtained had a contradictory result. Nevertheless, a higher addition of protein content or utilization of distinct protein sources may result in a decrease in loaf volume, as mentioned by Prieto-Vázquez del Mercado et al. (2022).

Green peas are considered to be legumes, which makes them gluten-free and contain a high dietary fiber of approximately 6.4g/145 g (1 cup). Legumes are mainly composed of soluble proteins, including albumin and globulin, which might weaken the protein network in bread (Laleg et al., 2016; Didinger & Thompson, 2021). Also, green peas' bran and germ can decrease the loaf volume (Trindler et al., 2022). Bran can result in smaller gas cell sizes throughout the dough process, resulting in less CO_2 production during fermentation and a smaller final bread volume. Furthermore, bran particles impede bubble growth, notably their coalescence in the late stages of fermentation (Tsatsaragkou et al., 2023). The high amount of fiber in green peas can also dilute the gluten protein, which leads the fiber to compete with other polymers for water, disturbing the dough's viscoelastic properties and resulting in weak and inextensible dough (Khalid et al., 2017). The decrease in loaf volume may also be due to the interaction between the hydroxyl groups of fiber and water to form hydrogen bonding. Less water is available to form a starch-gluten network, resulting in an underdeveloped gluten network (Man et al., 2015).

Texture

Figure 2 shows the texture analysis of control bread, bread with treatment 1, and bread with treatment 2 after being analyzed using a texture analyzer. Figure 2 shows that bread with treatment 2 had the highest hardness, chewiness, and springiness value. Above all bread, bread with treatment 1 had the second highest in all those parameters, and control bread had the lowest.

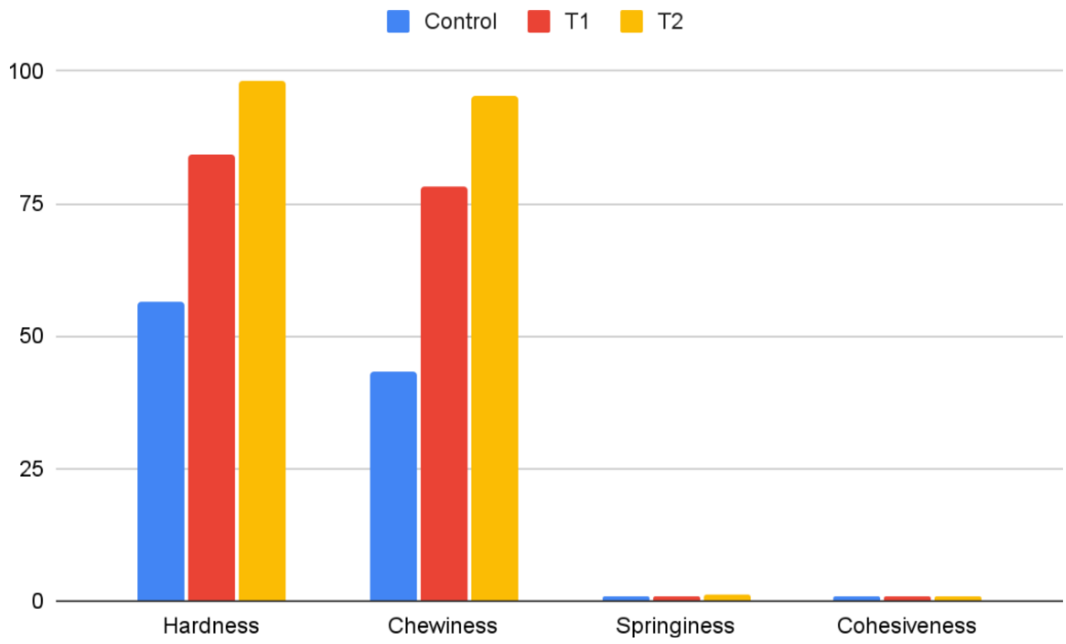

Figure 2. Texture (hardness, chewiness, springiness, and cohesiveness graph).

Table 3. Texture analysis of bread with different treatments.

Bread	Hardness	Chewiness	Springiness	Cohesiveness
Control	56.33 ± 9.10[a]	43.26 ± 6.93[a]	0.90 ± 0.17[a]	0.76 ± 0.11[a]
T1	84.33 ± 9.54[b]	78.18 ± 15.76[b]	1.00 ± 0.04[a]	0.92 ± 0.10[ab]
T2	98.22 ± 7.73[c]	95.26 ± 32.52[b]	1.10 ± 0.32[a]	0.86 ± 0.08[b]

*Different letters in the same column indicate significant ($p < 0.05$) difference between samples for the given parameter.

A table was also constructed to visualize the distinct treatments' significant effects on the bread's texture attributes. As seen in Table 3, the hardness and amylose content are significantly higher when compared to the springiness and cohesiveness of all treatments. It could also be seen that the hardness and chewiness increased along with the concentration of green peas, while springiness and cohesiveness remained roughly the same.

Nonetheless, there was a significant effect on the hardness of the bread caused by either treatment 1 or 2. The texture of the bread, which includes hardness, chewiness, cohesiveness, and springiness, is mostly affected by the starch, proteins, lipids, and water, as they are the main ingredients in bread making (Noroul-Asyikeen et al., 2018). Based on the findings presented in Table 3, the incorporation of varying quantities of green peas within the formulation causes a significant impact on the hardness of the bread, which is known to be highly influenced by the amylose and amylopectin present within the dough (Amin et al., 2019). Green peas contain 30 to 40% amylose and 60 to 70% amylopectin (Jezierny et al., 2017). With the addition of amylose and amylopectin from the green peas, the hardness of the bread will inevitably increase. This was also supported by Nivelle et al.'s (2020) research, which mentioned that crumb firmness increases with higher amylose or shorter amylose chains.

Treatments 1 and 2 significantly affected chewiness, yet there was no significant effects between treatments 1 and 2. According to Mu et al. (2019), chewiness is expressed as chewing intensity needed before swallowing. It is significantly affected by adding green peas, as attached in Table 3. The high amount of dietary fiber confers green pea with its strong chewiness and high water-swelling capacity, indicating that higher dietary fiber may be correlated with higher chewiness (Mu et al., 2017). This is also supported by Borkoles et al. (2022), who stated that fiber-rich foods are bulky and need extra chewing.

On the other hand, bread with treatment 1 had the highest cohesiveness value above all bread, bread with treatment 2 was the second highest in all of those parameters, and control bread was still the lowest. Additionally, only treatment 2 seemed to have a significant effect on the cohesiveness of the bread. The cohesiveness and structure of the bread generally originated from the gliadin protein, as it is the protein that helps form viscoelastic protein networks. However, as green peas mostly have globulins and albumins as their major groups, the increase in cohesiveness was not that drastic, which indicates more concentration of green pea puree need to be used to show a drastic increase in cohesiveness in the bread (Barak et al., 2014).

CONCLUSION

In conclusion, the incorporation of green peas into the food matrix of the bread itself has been shown to have a significant effect on texture, moisture content, and color profile. The hardness and chewiness of the bread were greatly impacted by the inclusion of green peas in the dough due to the high dietary fiber and amylose content in green peas. Adding green peas changed the bread's lightness, red-green hue, and blue-yellow hue, as there is chlorophyll and a high possibility of chlorophyll degradation to give a yellow-brown olive color. Moreover, the moisture content of the bread increases as the amount of green peas is added, possibly caused by the initially high moisture content (70-75%). Due to the green pea puree's higher water content, adding green peas helped the bread maintain moisture and reduced baking loss. Lastly, the green pea inclusion significantly reduced the bread's volume and loaf height, possibly due to protein content, gluten network, presence of bran and germ, and the large amount of dietary fiber in green peas. Changing the quantity of green peas added can alter the bread's color profile, texture, and moisture content.

For further research, it is suggested for the rheology properties and qualitative measurement, such as visual analysis of pore size of the individual treatment, to be measured along with sensorial evaluation to evaluate the consumer’s acceptability towards the addition of vegetables, specifically green peas towards bread. It is also recommended that each analysis be done according to the AOAC to enhance the reliability and validity of the results. Nevertheless, it is suggested that more concentrations of green pea puree to be used in this experiment to investigate the optimum or maximum concentration of green pea puree that can be used to avoid sodden bread.

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