

Effect of green spinach (*Amaranthus viridis* L.) and calcium hydroxide on the physicochemical characteristics of shirataki noodles prepared from porang flour

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Abstract

Shirataki noodles are a traditional Japanese food, and they are commonly made from konjac flour. But in Indonesia, it can be made from porang flour. Shirataki noodle production is designed for low-calorie and diet-purpose food with high fibre content. The addition of micronutrient content in shirataki noodles is needed to fulfil human nutrition needs. The nutritional content of Shirataki noodles can be improved by adding green spinach, while calcium hydroxide will improve the noodles' texture. This research aimed to determine the effect of green spinach and calcium hydroxide on shirataki noodles' physicochemical traits. Green spinach (2.5, 5, and 7 g) and calcium hydroxide (0.2, 1, and 1.5) were added to the shirataki noodle dough consisting of 10 g of Porang flour and 250 mL of water. Adding green spinach and calcium hydroxide concentration affects shirataki noodles' physicochemical properties. Shirataki noodles with 7.5 g green spinach and 1.5 g calcium hydroxide produced the best characteristics noodles with a water content of 94.10%, water absorption rate of 86.04%, lightness of 46.27, -a* colour space of -3.46, b* colour space of 30.08, hardness value of 60.77 g, 1% of deformation, 0.55 cohesiveness value, 1.07 mm springiness value, 33.30 g of gumminess value, 0.36 mJ of chewiness value, 0.45 mg of iron content and 21 kcal of calories per 100 g serving size.

1. Introduction

Unhealthy food, such as processed and fast food, leads to disease risks such as obesity. An obese person without a healthy lifestyle can lead to degenerative diseases such as high blood pressure, cholesterol, and diabetes. Fibre foods with low fat and carbohydrate content can prevent the risk of this disease. On the other hand, daily micronutrition intake must also be considered to meet daily micronutrition intake needs. Shirataki noodles are one of the healthy foods, especially for those who are obese and suffer from other diseases and need to pay attention to their calorie and micronutrition intake.

The shirataki noodle is originally a traditional food from Japan and it is commonly made from konjac flour. In Indonesia, shirataki noodles can be made from porang flour, which has 60-80% of glucomannan content. The high fibre content in glucomannan makes shirataki can be used as a diet food (Rahmawati *et al.*, 2021). Porang flour contains soluble and insoluble fibre, in which soluble fibre can decrease cholesterol levels by binding to the digestive system and excreting it, while insoluble fibre can help with digestive diseases. Glucomannan can

delay gastric emptying and accelerate consumers' satiety by modulating the absorption of sugar in the intestines, making it suitable for diets and diabetics (Setyadi *et al.*, 2022).

Shirataki noodles have a low-calorie content with high sodium and fibre content but almost no micronutrients. In addition, shirataki noodles are pale yellow in colour because of no food colouring addition. Adding green spinach is expected to improve the micronutrient content and the colour of shirataki. Green spinach with high iron content (3.9 mg of iron per 100 g of green spinach) has higher iron content than other green vegetables such as kale (2.5 mg), katuk (2.7 mg), and pak choy (2.5 mg) (Suhada *et al.*, 2019). In addition to the poor micronutrient content and pale colour, wet shirataki noodles usually have a soft texture, so an additional ingredient is needed to strengthen the texture of the resulting noodles. Previous research by Yang *et al.* (2017) reported that glucomannan would be firmer with calcium hydroxide addition, increasing the surface tension and strengthening the gel. This study aimed to investigate the effect of adding green spinach and

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calcium hydroxide on the physical characteristics of shirataki noodles and to analyse the nutrition resulting from the best composition treatment.

2. Materials and methods

2.1 Materials

Porang flour produced by Porang Research Centre Universitas Brawijaya Indonesia was used as the main raw material of shirataki noodles. Green spinach, an ingredient that enriches micro-nutrition was purchased from the market at Kendalsari District Malang City Indonesia, while food-grade calcium hydroxide produced PT. Niraku Jaya Abadi Indonesia was used to improve the texture.

2.2 Spinach solution preparation

Fresh spinach leaves were picked, washed, and drained. Spinach leaves (2.5, 5, and 7.5 g) were pureed in 250 ml water in a high-speed blender for 60 s. The spinach solution obtained was filtered to separate the spinach solution from the dregs.

2.3 Shirataki noodles preparation

Porang flour (10 g) was mixed manually with spinach solution for 15 mins and rested for 60 mins for more homogeneous water distribution. Then, calcium hydroxide (0.5, 1, and 1.5 g), which was dissolved in 10 ml of water, was added to the mixture and mixed. The forming of noodles was done manually using a pasta maker. Formed noodles were then boiled for 3 mins with occasional stirring. The cooked noodles were drained and placed in cold water so the noodle strands didn't stick and cooled quickly. Shirataki noodles are packaged in standing pouches and stored in the refrigerator at 15°C until further analysis. As a control, the noodles were prepared by adding 1 g of calcium without adding spinach extract.

2.4 Physicochemical analysis

The gravimetric method was utilized to obtain the noodles' water and ash content. Meanwhile, water absorption was determined by boiling 260 g in 1 litre for 3 mins, followed by draining and conditioning for 1 min, then weighing. The water absorption was obtained as the ratio of the weight of the noodles after and before boiling. FRU Colorimeter WF-30 was used to analyse the colour of noodles. Each sample was measured at 3 points on the surface of the shirataki noodles using 3 colour parameters L^* , a^* , b^* .

Texture analysis was conducted by using a Brookfield Texture Analyzer type CT3-1000. A probe type TA44 with a speed of 1 mm/s was used for the

measurement. The pretest speed used was 2 mm/s. The data generated from the texture test were the values of hardness, deformation, cohesiveness, gumminess, springiness, and chewiness.

Determination of fat and protein content was done using the Soxhlet and Kjeldahl methods, respectively, while the determination of carbohydrate content was by a method referring to AOAC (Nurfadilah *et al.*, 2019). The calorific (kcal per 100 g) of noodles was estimated by converting the macronutrient content (protein, fat, carbohydrates) into energy using a conversion factor of 4 kcal/g for protein and carbohydrates and 9 kcal/g for total fat. Calculation of energy content using Equation 1.

$$\text{Energy (cal)} = 4 (\text{protein content}) + 4 (\text{carbohydrate content}) + 9 (\text{fat content}) \quad (4)$$

Iron (Fe) content was analysed in shirataki noodles using the Atomic Absorption Spectrophotometer (AAS) method.

Statistical analysis was carried out by using Analysis of Variance (ANOVA) using Excel software at a test level of 5% to determine whether or not the two factors had a significant effect. Duncan's Multiple Range Test (DMRT) was applied as a post hoc test for a significant effect.

3. Results and discussion

3.1 Moisture content

The water content of shirataki noodles ranged from 92.07% to 94.39%, with the highest water content achieved at 7.5 g green spinach and 0.5 g calcium hydroxide, while the lowest water content was shirataki with 5 g green spinach and 1 g calcium hydroxide. Figure 1 shows that the water content of shirataki noodles increases with increasing concentration of green spinach, and decreases with increasing concentration of calcium hydroxide. The increase in water content in the noodles was due to the high water content in green

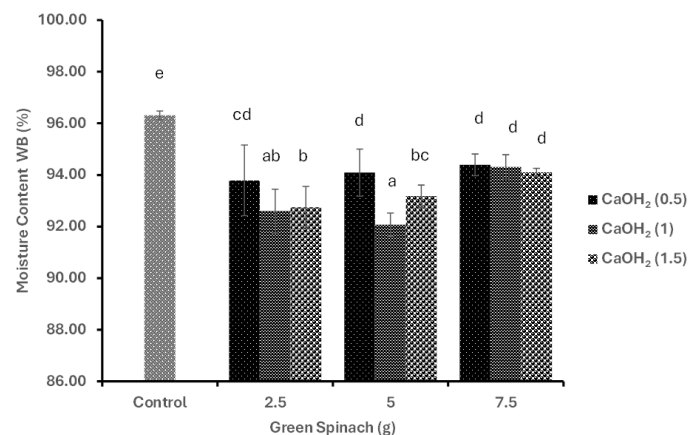


Figure 1. Moisture content of Shirataki noodles. Bars with different notations within the same treatment group are statistically significantly different ($p < 0.05$).

spinach (86.9% wb). This was in line with the research of Rahmat *et al.* (2020), who reported an increase in water content with green spinach concentrations. Various papers reported that the addition of calcium hydroxylates improved noodle texture, such as strength and firmness (Han *et al.*, 2014). In other words, adding calcium hydroxylate can maintain the noodles' shape or limit swelling during cooking. When the swelling is limited, the less space, the less water will enter the noodles. Besides that, Han's (2014) study also stated that adding calcium hydroxide to buckwheat noodles reduced cooking yields due to the cross-linked action between calcium ions with starch and protein, inhibiting swelling.

3.2 Water absorption

Shirataki noodles' water absorption ranges between 84.95% to 90.39%. In general, adding green spinach and calcium hydroxide decreased water absorption. Water absorption decreased with the addition of green spinach due to the higher water content in the noodles with the addition of more green spinach. For shirataki noodles with 5 and 7.5 g of green spinach, adding 1 and 1.5 g of calcium hydroxide absorbed water slightly lower than 0.5 g of calcium. The ability to absorb water can be related to the degree of noodle swelling when it is boiled. In line with the water content of the noodles, inhibition of swelling due to the presence of calcium hydroxide is suspected to be the cause of the low water absorption. Figure 2 shows the water absorption of shirataki noodles in various green spinach and calcium hydroxylate.

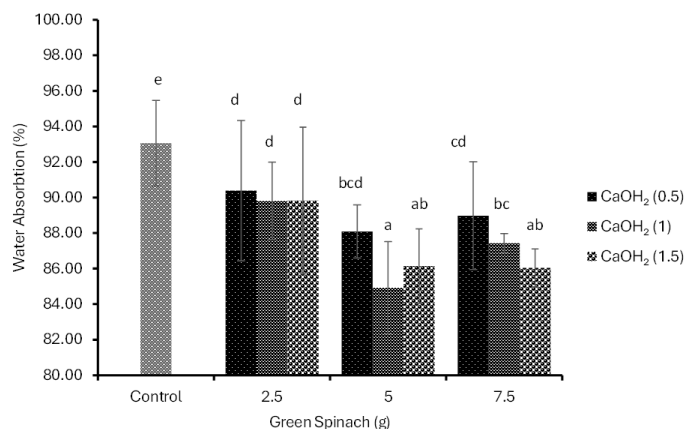


Figure 2. Water absorption of Shirataki noodles. Bars with different notations within the same treatment group are statistically significantly different ($p < 0.05$).

Water absorption indicates noodles' ability to absorb water in a short time span when the noodles are boiled. The higher the water absorption, the heavier the weight of the product. Dessaura *et al.* (2015) reported that water content and water absorption were reversely correlated. Higher water content on an ingredient will absorb less water. The amount of water absorbed by an ingredient was influenced by the shape of the dough, the moisture

content of noodles, and boiling time. Zhang *et al.* (2022) reported that gelatinized starch will loosen and affect the gel structure, causing water to be able to enter the noodle structure.

3.3 Colour

The colour of shirataki noodles was expressed in lightness (L^*), greenness (a^*) and yellowness (b^*). The lightness (L^*) of Shirataki noodles ranged from 44.60 to 50.03. The addition of green spinach caused a darker colour than the control, with a tendency for the colour to be lighter at higher calcium hydroxide addition. The average brightness of noodles with green spinach and calcium hydroxide was 47.04, darker than the control, with a brightness value of 56.48. Porang, as the main ingredient for shirataki noodles, is brown, and when used, it produces a pale colour. The addition of green spinach causes a decrease in the brightness of the noodles. Rahayu *et al.* (2013) reported that green spinach has a brightness value ranging from 19.36 to 27.00, triggering a darker colour. The brightness of shirataki noodles is presented in Figure 3.

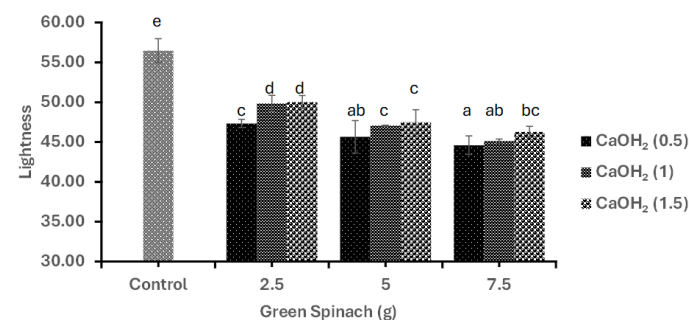


Figure 3. Lightness of shirataki noodles. Bars with different notations within the same treatment group are statistically significantly different ($p < 0.05$).

Shirataki noodles' greenness value ($-a^*$) ranges from -0.65 to -3.46. As the green spinach concentration increases, it results in a product with a deeper green colour as shown in Figure 4. Green spinach contains chlorophyll on the leaves (Riestamala *et al.*, 2021). This statement was further supported by Maulidyyah *et al.* (2022) who report that adding wet noodles has a deeper, prominent green colour because of higher chlorophyll content. The use of calcium hydroxide usage also colour causes the increase of green colour. According to Han *et al.* (2014), the addition of calcium hydroxide towards konjac glucomannan will result in a darker noodle.

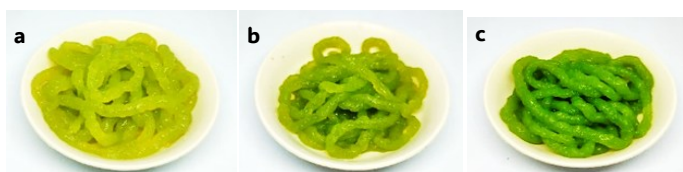


Figure 4. Greenness comparison chart. (a) Green Spinach concentration 1%, (b) Concentration 2%, (c) Concentration 3%.

Shirataki noodles' yellowness (b^*) colour space ranges from 24.16 to 31.55, averaging at 28.83 which was higher than control noodles at 19.55 b^* colour space value. Figure 5 shows that the b^* colour value increases as the green spinach concentration increases, while b^* colour value decreases as the calcium hydroxide concentration increases. The increase in b^* value could be related to the Maillard reaction between sugar and amino acids. Carboxyl bonds in sugars will react with amino acids producing noodles with a darker shade. An increase of calcium hydroxide added will decrease b^* colour value caused by calcium ions will easily enter ingredient bonds, creating a brighter colour shade (Asiah and Handayani, 2018).

Shirataki noodles' yellowness (b^*) colour space ranges from 24.16 to 31.55, averaging at 28.83, which was higher than control noodles at 19.55 b^* colour space value. Figure 5 shows that the b^* colour value will increase as the green spinach concentration increases, while the b^* colour value will decrease as the calcium hydroxide concentration increases. An increase in the b^* value could be related to the Maillard reaction between sugar and amino acids. Carboxyl bonds in sugars will react with amino acids, producing noodles with a darker shade. An increase of calcium hydroxide added will decrease the b^* colour value because calcium ions will easily enter ingredient bonds, creating a brighter colour shade (Asiah and Handayani, 2018).

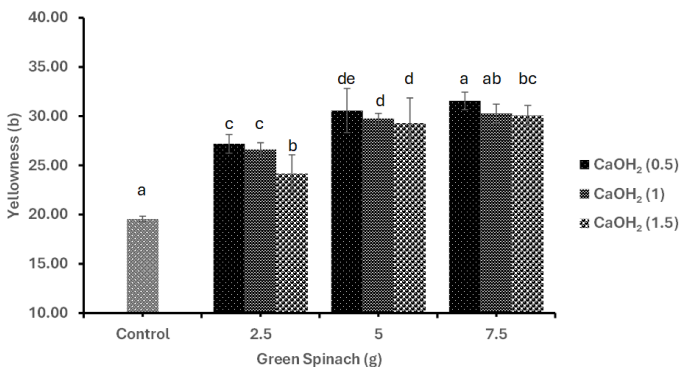


Figure 5. Yellowness comparison chart. Bars with different notations within the same treatment group are statistically significantly different ($p < 0.05$).

3.4 Texture

Hardness is the maximum load achieved in the first deformation cycle. A low hardness value indicates a soft texture of noodles. Shirataki noodles' hardness value range from 41.90 g to 83.87 g, as shown in Figure 6. Adding 2.5 and 5 g of green spinach with 0.5 g of calcium hydroxylate resulted in a lower hardness than the control, but adding 1 and 1.5 g of calcium hydroxylate for all additions of green spinach gave a higher hardness than the control. The addition of a small amount (0.5 g) is considered not enough to improve the strength of the noodles. The hardness value of a food is

related to the water content of the food. According to Rosiani *et al.* (2015), the lower the water content, the higher the hardness value. Then, according to Tuhuloula *et al.* (2013), fruits and vegetables contain pectin - whereas green spinach contains 11.58 g of pectin - pectin will react with calcium hydroxide, forming a more rigid texture.

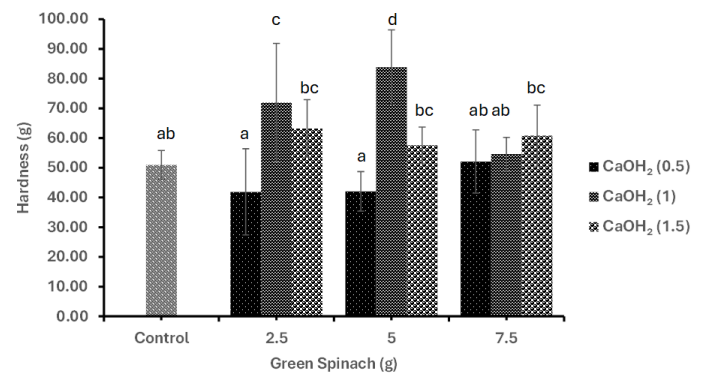


Figure 6. Hardness comparison chart. Bars with different notations within the same treatment group are statistically significantly different ($p < 0.05$).

Deformation is a percentage of shape changes due to application force. The deformation value of shirataki noodles ranges from 0.57 to 1%. Figure 7 show that 7.5 g green spinach showed a deformation increase as calcium hydroxide concentration decreased. Calcium hydroxide was able to strengthen the food. If shirataki noodles were rigid and force was applied, then less deformation would occur. Deformation influenced by the fibre-rich green spinach, where green spinach concentration increases will result in high deformation. This was confirmed by Iswara *et al.* (2019), who stated that fibre usage could increase the deformation of a food product.

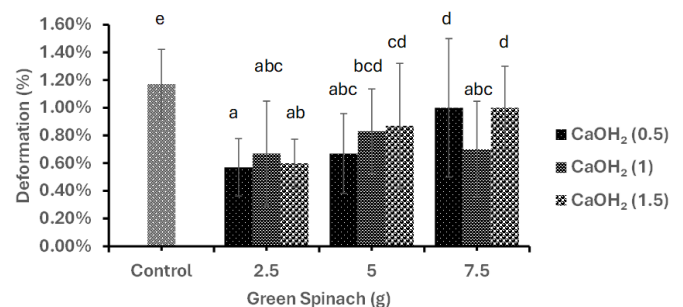


Figure 7. Deformation comparison chart. Bars with different notations within the same treatment group are statistically significantly different ($p < 0.05$).

Cohesiveness is described as the internal compactness of food if pressure is applied. Treatment of green spinach and calcium hydroxide concentration on shirataki noodles resulted in cohesiveness values that range from 0.52 to 0.56 as seen in Figure 8. High cohesiveness value showed that shirataki noodles have a solid and cohesive texture, and vice versa. Calcium hydroxide is widely used in food industries since it can strengthen food texture. Calcium hydroxide will form

calcium pectate if combined with pectin inside green spinach, forming a hard texture yet staying compact and cohesive if pressure is applied.

Springiness shows how much a deformed sample is able to go back to its original state, described as mm. The springiness of shirataki noodles ranges from 0.82 to 1.07 mm. Figure 9 shows that 7.5 g green spinach concentration results in increased springiness value as calcium hydroxide concentration increases. This results in shirataki noodles that quickly reverses to their original state after applying pressure. Shaliha *et al.* (2017) also reported that springiness value is also affected by temperature, with anything above 50°C affecting the elasticity and also with high fibre addition. The addition of green spinach concentration that's not balanced with calcium hydroxide addition will result in a mushy texture so it will take more time to return to its original state.

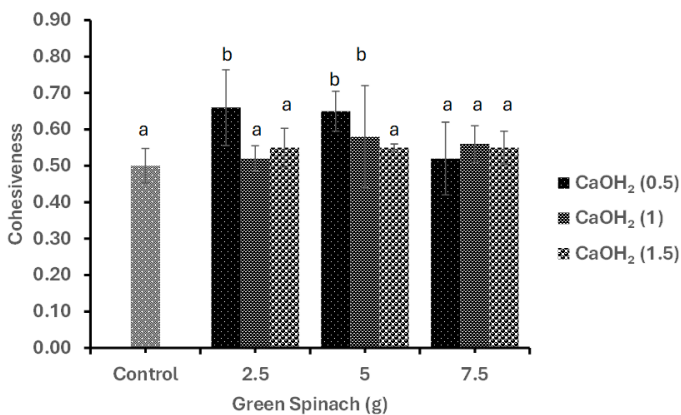


Figure 8. Cohesiveness comparison chart. Bars with different notations within the same treatment group are statistically significantly different ($p < 0.05$).

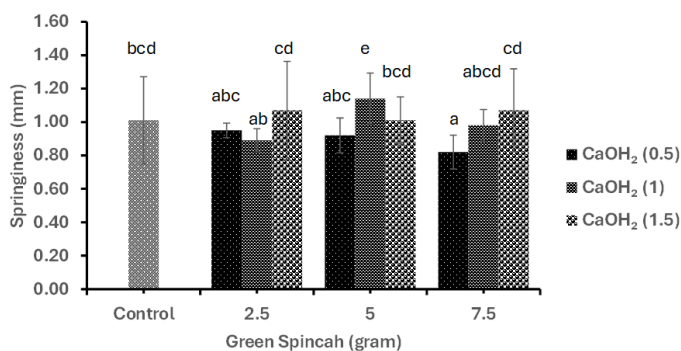


Figure 9. Springiness of shirataki noodles. Bars with different notations within the same treatment group are statistically significantly different ($p < 0.05$).

Figure 10 shows that 7.5 g green spinach and 1.5 g calcium hydroxide concentration will result in 33.30 g of gumminess value, which is higher than shirataki noodles with 7.5 g green spinach and 0.5 g calcium hydroxide concentration with 26.53% gumminess value. Dwiani and Rahman (2021) reported that calcium hydroxide is able to bind with water and strengthen the texture of the noodles. Hard and stiff texture is shown by the increase in gumminess levels (Rani *et al.*, 2022). However, 5 g

green spinach and 1 g calcium hydroxide treatment has the highest gumminess level, this is caused by gumminess levels being affected by hardness levels, and those components are directly proportional to each other – with hardness levels increasing, so does gumminess levels.

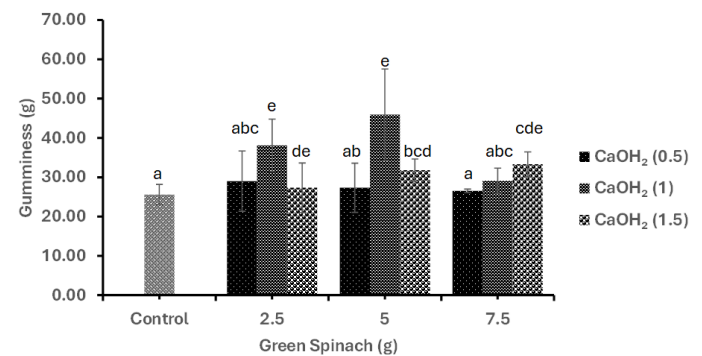


Figure 10. Gumminess of shirataki noodles. Bars with different notations within the same treatment group are statistically significantly different ($p < 0.05$).

Chewiness is a texture component that describes the energy needed to chew food until it's ready to swallow, where chewiness value is derived from gumminess and springiness value. Shirataki noodles with green spinach and calcium hydroxide treatment have a chewiness value that ranges from 0.21 to 0.52 mJ. Figure 11 shows that as green spinach concentration increases, chewiness value will decrease caused of green spinach's high water content, resulting in a softer noodle texture. As calcium hydroxide concentration increases, so does the chewiness value. This results in a harder texture, where Rani *et al.* (2022) stated that a harder noodle needs more force to deform food so it's ready to swallow, increasing chewiness value. Shirataki noodles with 2% green spinach and calcium hydroxide concentration have the highest chewiness value because they produce the highest gumminess and springiness value.

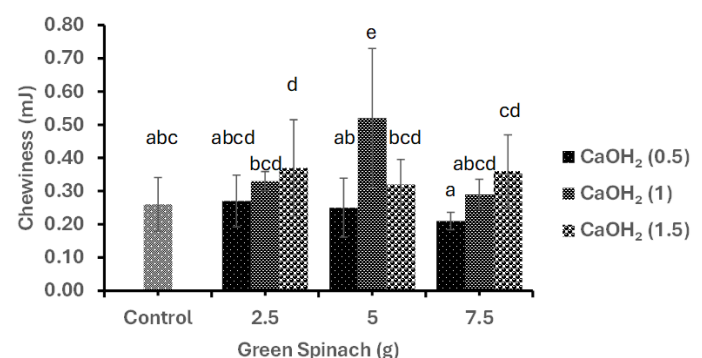


Figure 11. Chewiness of shirataki noodles. Bars with different notations within the same treatment group are statistically significantly different ($p < 0.05$).

3.5 Best results

The best results achieved the highest product score from 4 physic parameters where those parameters were

sorted by their most important priorities, with texture as the top priority, then colour, then water absorption, with water content being the last on the priority scale. Based on the physical parameters, the best results were achieved by 2.5 g green spinach and 1 g calcium hydroxide concentration, 5 g green spinach and calcium hydroxide concentration, and 7.5 g green spinach and calcium hydroxide concentration. Noodles with the best results then go through chemical analysis such as iron content and calorie content. Therefore, the mentioned best treatment gained the highest product value, as shown in Table 1.

Table 1. The assessment of the best treatment based on physical characteristics.

Treatment	Product value	Ranking
Green Spinach 2.5 g Calcium Hydroxide 1 g	2.15	6
Green Spinach 2.5 g Calcium Hydroxide 1.5 g	3.04	2
Green Spinach 2.5 g Calcium Hydroxide 0.5 g	2.70	4
Green Spinach 5 g Calcium Hydroxide 1 g	1.99	7
Green Spinach 5 g Calcium Hydroxide 1.5 g	4.23	1
Green Spinach 5 g Calcium Hydroxide 0.5 g	2.62	5
Green Spinach 7.5 g Calcium Hydroxide 1 g	1.72	9
Green Spinach 7.5 g Calcium Hydroxide 1.5 g	1.95	8
Green Spinach 7.5 g Calcium Hydroxide 0.5 g	2.78	3

3.6 Iron content

The variety of food consumption plays a major role in increasing iron content absorption inside the human body. The addition of green spinach concentration towards shirataki noodles creation is one of the alternate strategies that people can use to reduce iron deficiency. Shirataki noodles' iron content ranges from 0.34 mg to 0.45 mg, with noodles with the highest iron content achieved on the 7.5 green spinach and calcium hydroxide treatment. Table 2 shows that shirataki noodles with 7.5 g green spinach and calcium hydroxide treatment fulfil 1.56% iron content based on Recommended Daily Allowances (RDA/AKG) on a 2,150 kcal daily dietary plan. This result was higher if compared to noodles with 5 g green spinach and calcium hydroxide treatment and noodles with 2.5 g green spinach and 1 g calcium hydroxide treatment that only has 1.28% and 1.18% iron content, respectively.

The iron content increase in this research matches Sugiyarti *et al.* (2010) and Fitriyani (2013) who stated that the addition of spinach juice will increase iron content. Iron is an important parameter because when

consumed regularly it can increase the formation of red blood cells. Iron also plays a role in the body's defence system and functions for brain development (Novia *et al.*, 2022). Iron is one of the crucial parameters and if iron is consumed properly, it can help with haemoglobin formation. Iron also helps with the body's immune and also functions in brain development. Iron mineral component (Fe) ties well with oxygen that blood carries to the whole body, with iron deficiency can lead to a decrease in the body's immune and haemoglobin blood cells (Hastuty and Nitia, 2022). Someone with less than normal haemoglobin levels will have blood-related issues. If a human body does not have the needed energy, it will increase the fatigue rate.

Table 2. Iron content of shirataki noodles.

Treatment	Iron content (mg)	% RDA / AKG*
Green spinach 2.5 g Calcium hydroxide 1 g	0.34	1.18
Green spinach 5 g Calcium hydroxide 1 g	0.37	1.28
Green spinach 7.5 g Calcium hydroxide 1 g	0.45	1.56

*Percentage of the Recommended Daily Allowance based on a 2150 kcal daily diet calorie intake plan

3.7 Calorie

The number of calories in a certain food isn't just caused by the ingredients used, but also by the food additive used during the cooking process of said food. Table 3 shows that shirataki noodles with green spinach and calcium hydroxide concentration have a calorie content that ranges from 21-42 kcal/100 g noodles, with the calorie content derived from macronutrients by using proximate analysis such as ash, water content, fat, proteins, and carbohydrates.

Table 3 shows that the highest water content was achieved with 7.5 g green spinach and calcium hydroxide treatment, achieving 94.10% water content, which is higher than 5 g green spinach and calcium hydroxide treatment because said noodles experienced syneresis, so the water content decreased over time. According to Yanuriati *et al.* (2017), glucomannan gel syneresis is caused by temperature differences, especially after storage in cold and freezing temperatures, where noodle pores will enlarge caused by water volume increase as it changes to ice crystals, increasing syneresis rate. Then, the highest carbohydrate rate is achieved at 5 g green spinach and calcium hydroxide concentration. Pehlepi *et al.* (2022) reported that as the other macronutrients decrease in content, carbohydrate levels will increase. Water content, ash content, fat content, and protein content increase as green spinach increases and decreases as calcium hydroxide

Table 3. Food calorie ratio.

Food Type	Water (g)	Ash (g)	Fat (g)	Proteins (g)	Carbohydrate (g)	Calorie (kcal)
Green spinach 2.5 g + Calcium Hydroxide 1 g	92.63	0.45	0.02	0.11	6.79	28
Green spinach 5 g + Calcium Hydroxide 1 g	88.92	0.68	0.02	0.20	10.18	42
Green spinach 7.5 g + Calcium Hydroxide 1.5 g	94.10	0.66	0.05	0.16	5.03	21
White rice*	56.01	0.20	0.28	2.10	40.60	178
Bavaria bread [#]	38.40	0.97	0.95	7.28	50.00	242

*Mukti et al. (2018)

[#]Carocho et al. (2020).

concentration increases.

Shirataki noodles are one of the wet noodle types that are known to be low in calories so it's utilized as diet food. Shirataki noodles with 7.5 g green spinach and calcium hydroxide concentration only contain 21 kcal per 100 g serving size, which is lower than any other staple foods such as white rice (178 kcal) (Mukti et al., 2018) and bavaria bread (242 kcal) (Carocho et al., 2020). Porang flour as shirataki noodles' main ingredient is able to delay stomach emptiness and trigger satiation (Saputri et al., 2021). In addition, porang flour contains extremely low calories (Mahirdini and Afifah, 2016). Basically, fibre-rich foods can delay energy absorption by the human body for longer. Fibre also accelerates fat excretion, helping to reduce body weight (Taus et al., 2022).

The same opinion was also conveyed by Rianto and Ahmad (2017) who stated that the adequacy of fibre intake is now recommended to be higher, considering the many beneficial benefits for the health of the body. Fibre in food is useful for reducing calorie intake, and this fibre can be found in vegetables and fruit (Maryam, 2022). Hence, the addition of green spinach can improve the micro nutritional content of vitamins, minerals, and iron in shirataki noodles with an attractive green colour. Shirataki noodles with a concentration of green spinach can be consumed by all ages and are expected to be a solution for those on a low-calorie diet and for those who have a very high penchant for noodles but are able to consume vegetables on the daily menu. This is an advantage that cannot be obtained from shirataki noodles that are already on the market.

4. Conclusion

The concentration of additional green spinach and calcium hydroxide produces various characteristics of shirataki noodles. The best shirataki noodle result was found in the combination of 7.5 g green spinach and 1.5 g calcium hydroxide concentration. When the concentration of green spinach increases, it has a higher water content, but if the concentration of calcium hydroxide increases, the water content and water

absorption decrease. In addition, the increase in calcium hydroxide affects the increase in hardness, gumminess and chewiness values. On the other hand, calorie and iron levels showed an increase with increasing concentrations of green spinach and calcium hydroxide concentrations. In the future, this research will be expanded into the combination of other commodities for different micronutrient content and various natural sources of colour.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

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