Journal of Health and Nutrition Research
Vol. 4, No. 2, 2025, pg. 718-726, https://doi.org/10.56303/jhnresearch.v4i2.461
Journal homepage: https://journalmpci.com/index.php/jhnr/index

e-ISSN: **2829-9760**

Evaluation of Dietary Fiber, Antioxidant Capacity, Physicochemical Properties, and Consumer Acceptability of a Green Okra (*Abelmoschus esculentus* L.) Pudding

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ORIGINAL ARTICLES

Submitted: 25 May 2025

Accepted: 1 July 2025

Keywords:
Abelmoschus esculentus, Diabetes mellitus type 2, Green Okra, Pudding

ABSTRACT

Green okra is obtained from the planting process and harvested after 3 months of cultivation. Analysis was carried out in the form of Dietary fiber, Microbial Content, Physical properties tests, and Antioxidant Capacity Analysis. This green okra pudding product study employed a Completely Randomized Design (CRD). The formula comparison treatment was divided into three treatment levels, namely the comparison of mucilage addition (10, 15, and 20 ml). The response variable of this study was the organoleptic properties of okra pudding. There are 3 (three) stages in making green okra pudding, consisting of blanching green okra fruit, extracting green okra (mucilage), and making pudding. Based on the results of this study, the selected green okra pudding formula from the hedonic test is formula 3 which contains 1.24% dietary fiber, no Staphylococcus aureus and contamination by Escherichia coli bacteria is very minimal, pH of 7.21, aroma and texture were rated as typical SNI 01-2891-1992 standard and IC_{50} result of 24.27% indicates the concentration of the product needed to inhibit 50% of free radical activity, which means that this product has indicating notable antioxidant effectiveness. Conclusion: Green okra pudding with the addition of 20 ml mucilage has the potential to control fasting blood glucose.

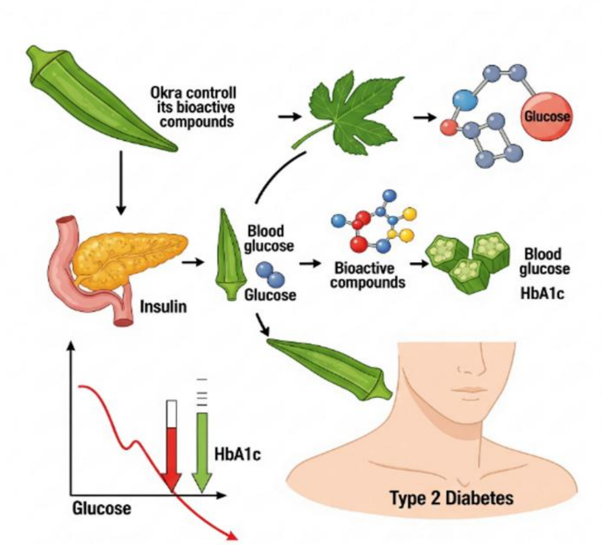
Key Messages:

- Formula 3 (addition of 20 ml of green okra mucilage) has the potential to control fasting blood glucose in type 2 Diabetes Mellitus.

GRAPHICAL ABSTRACT

Evaluation of Dietary Fiber, Antioxidant Capacity, Physicochemical Properties, and Consumer Acceptability of a Green Okra (*Abelmoschus esculentus* L.) Pudding

Formula 3 (addition of 20 ml of green okra mucilage) has the potential to control fasting blood glucose in type 2 Diabetes Mellitus.



INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) is one of the most common metabolic disorders worldwide and its development is caused by a combination of two main factors: impaired insulin secretion by pancreatic cells and the inability of insulin-sensitive tissues to respond to insulin (1). Insulin release and action must precisely meet metabolic needs because the molecular mechanisms involved in insulin synthesis and release, as well as insulin response in tissues, must be tightly regulated. Therefore, disruption of any of the mechanisms involved can cause metabolic imbalances that lead to the pathogenesis of T2DM (2). The burden of DMT2 is increasing globally. Around 462 million people suffered from DMT2 in 2017, equivalent to 6.28% of the global population (4.4 million people aged 15-49 years, 15 million people aged 50-69 years and 22 million people aged ±70 years) (3). The International Diabetes Federation (IDF), the prevalence of DMT2 in Indonesia is estimated at 6.2% in 2019 and 10.8% in 2021, ranked among the top 10 countries with the highest prevalence of DMT2 and accompanied by a rapid increase (4). According to the 2018 Basic Health Research (RISKESDAS) in Indonesia, 10.9% of the population aged ≥15 years suffer from DMT2. Most also experience acute or chronic complications (5).

The components of antihyperglycemic agents (drugs to lower blood glucose levels) consist of several main groups that work with different mechanisms to control DMT2, namely biguanide, sulfonylurea, α-glucosidase inhibitors, Dipeptidyl Peptidase-4 (DPP-4) inhibitors, Sodium-Glucose Transporter 2 (SGLT2) inhibitors, Amylin and Glinide analogues. Long-term use of anti-diabetic drugs can cause certain side effects. The most common side effects are gastrointestinal disorders such as nausea and diarrhea, followed by an increased risk of hypoglycemia, especially in the use of sulfonylurea drugs. However, serious side effects such as liver damage or cardiovascular problems occur in lower proportions (6).

In both T1DM and T2DM, blood glucose levels are not properly controlled, so they increase to abnormal levels over a long period of time. This chronic hyperglycemia is a characteristic of diabetes and a major cause of various complications (7). Free radicals are chemical species with unpaired electrons in their valence shell, unstable and reactive, which interact with damaging cellular biomolecules (proteins, lipids, DNA, and carbohydrates) (8). Substances that can delay or inhibit the oxidation of other molecules are called antioxidants. Antioxidant therapy is becoming increasingly important in the health sector because it can be used to treat several diseases, such as T2DM (9).

Okra (*Abelmoschus esculentus* L.) contains bioactive components that act as antioxidants. Okra skin

https://doi.org/10.56303/jhnresearch.v4i2.461

or seed extract can optimize blood glucose and improve hyperlipidemia, as well as insulin levels. Okra contains bioactive components such as quercetin-3-O-gentiobiose, iso-quercetin, and other polyphenol and flavonoid components (10). Pudding is one type of food that is favored by many people of all ages. Okra is a type of vegetable that is rich in fiber, vitamins, and minerals. Okra contains antioxidants that play a role in warding off free radicals, but has a fairly unpleasant taste and aroma, so an alternative to processing okra is to process it into pudding, the texture former of pudding can use agar-agar flour (11). Polyphenols from young okra fruit have antioxidant activity by reducing MDA (malondialdehyde) levels and increasing SOD (superoxide dismutase) and glutathione peroxidase (GSH-Px) levels (12). The main phenolic compounds found in okra fruit are quercetin-3-O-gentiobioside, quercetin-3-O-glucoside (iso quercetin), quercetin derivatives, protocatechuic acid, and catechin derivatives, among which quercetin-3-O-gentiobioside is the most abundant phenolic compound. The main contributor to antioxidant capacity is quercetin-3-O-gentiobioside. It also shows inhibitory effects on digestive enzymes such as lipase, α-glucosidase, and α-amylase (13).

The slimy texture and strong aroma of okra are often a barrier to its acceptance by many people (11). Therefore, processing innovation is needed so that okra is more popular, one of which is by making it into pudding. Pudding, as a popular dessert thanks to its sweet taste and soft texture (usually made from agar-agar through boiling), is often enriched with additional fruits or vegetables to increase its nutritional value (14). Based on the background that supports the objectives of this study, namely to develop green okra pudding of the Naila variety as a functional food and to analyze the dietary fiber content, antioxidant capacity, and acceptability with hedonic testing, this study was conducted.

METHODS

The research was conducted in April-September 2024. The stages of planting Okra seeds to harvesting were carried out in April-September at the Puuwatu, Kendari, Southeast Sulawesi. The Hedonic Test was conducted in August at the Integrated Laboratory of the Faculty of Public Health, Halu Oleo University, Kendari, Southeast Sulawesi. Dietary fiber and Microbial Content were conducted in September 2024 at the Center for Agro Industry (BBIA) of the Ministry of Industry of the Republic of Indonesia. Physical properties tests and Antioxidant Capacity Analysis were conducted in September 2024 at the Mbrio Bogor Food Laboratory (under supervision of Prof. Dr. F. G. Winarno). This green okra pudding product research used a Completely Randomized Design (CRD). The formula comparison treatment was divided into three treatment levels, depended on of mucilage addition, namely formula P1 (10 ml of mucilage), formula P2 (15 ml of mucilage), and formula P3 (20 ml of mucilage). The response variable of this study was the organoleptic properties of okra pudding.

There are 3 (three) stages in making green okra pudding, consisting of blanching green okra fruit, extracting green okra (mucilage) and making pudding. The first stage is blanching green okra fruit. Blanching is a cooking technique by adding fruit or leafy vegetables in boiling water quickly, to this case green okra fruit is blanched for 30 seconds then drained and stored in special plastic in a vacuum. The second stage is taking green okra extraction to the form of mucilage using the liquid extraction method. Green okra fruit is washed then sliced thinly. The mashed fruit is soaked in water to a ratio of 1:3 then left for 12 hours for the process of pulling mucilage from green okra fruit into water. The third stage is making green okra pudding. The ingredients used are 1 g of agar powder, 1.5 g of sorbitol, 75 ml of water, 25 g of fine green okra (frozen green okra is thinly sliced and then pureed using a blender), 15 ml of liquid skim milk and 15 ml mucilage (the mucilage is used to smooth the okra (not including the variation in the addition of mucilage to each formula)). Put the thinly sliced frozen green okra into the blender, then puree it. After that, add mucilage, puree it again with the green okra until it is completely smooth. Then, after the blended green okra has been smooth, take and weigh 25 g. The next step, put 75 ml of water into the pan, then simultaneously add 1 g of agar powder and 1.5 g of sorbitol, after mixing then turn on the stove with low heat. While waiting for the agar mixture to cook, stir until evenly mixed and there are no lumps. After evenly mixed, then add 25 g of fine okra, stir until completely mixed using a balloon whisk. Then, add mucilage according to the amount of treatment to each formula (10, 15 and 20 ml) and liquid skim milk are added. Stir until evenly mixed. When it has been mixed evenly, it is lifted and poured into a pudding cup

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and weighed. Cooled until set, then ready to be distributed (15,16; with modifications in the form of using green okra and not adding dragon fruit and strawberries).

Organoleptic assessment, there are seven types of panels, namely individual panels, limited panels, trained panels, semi-trained panels, consumer panels and children's panels. This study used a semi-trained panel consisting of 30 people. The general requirements to become a panelist are to have attention and interest to organoleptic testing activities, to addition, panelists must be able to provide special time for assessment and have the required sensitivity.

CODE OF HEALTH ETHICS

The Ethical Approval Letter using humans as research subjects with the number 1384/UN29.20.1.2/PG/2024 was issued by the Institute for Research and Community Service, Health Ethics Commission, Halu Oleo University.

RESULTS

The green okra used was planted by researchers with simple land and equipment. Black polybags were used as seedbeds that had been filled with planting media (soil and compost). The total number of green okra seedlings planted was 45 with (two) planting waves (wave 1 consisted of 30 seedlings and wave 2 consisted of 15 seedlings). The green okra planting process carried out is presented in Figure 1.

(a) (b) (c) (d) (e)

Figure 1. Preparation for Planting and Harvesting Green Okra

Table 1. Results of the One-Way ANOVA test on the overall acceptability of the green okra pudding formula.

Parameter	Significance (*p-value)*
Colour	0,770
Taste	0,789
Aroma	0,630
Texture	0,000
Aftertaste	0,439
Overall acceptance	0,262

The descriptive test results of the three formulas (Formula 1, Formula 2, and Formula 3) showed different results in each aspect. Formula 2 had the best acceptance in the parameters of taste, aroma, and overall acceptance, followed by formula 3 which was also well accepted, especially in aftertaste and overall acceptance. Formula 1 excelled in texture, but needed improvement in taste, aroma, and aftertaste, which tended to get lower acceptance than the other two formulas. Overall, formula 2 and formula 3 were preferred in many aspects, although formula 1 showed very good performance in texture (Figure 2). The results of the One-Way ANOVA test (Table 1) showed no significant differences between the three formulas (Formula 1, Formula 2, and Formula 3) in the parameters of color, taste, aroma, aftertaste, and overall acceptance (PK), because the p value>0.05. However, there were significant differences in the texture parameters, where formula 1 showed much better acceptance than formula 2 and formula 3. Overall,

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although there were no significant differences in most parameters, formula 1 was superior in texture, while the other formulas (formula 2 and 3) had quite good acceptance in all aspects. It can be concluded that formula 2 has the best acceptance, followed by formula 3, and formula 1 (Table 1).

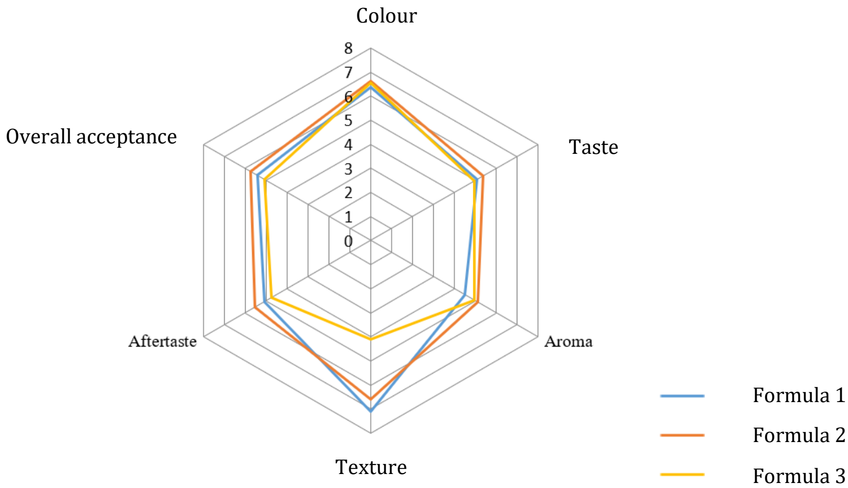

Figure 2. Panelists Acceptability of the Overall Green Okra Pudding Formula

The results of the physical properties test on the selected formula, this product has a pH of 7.21 which indicates an almost neutral acidity level. The aroma and texture assessment of the product were also declared normal. This test was carried out by following the SNI 01-2891-1992 standard (Table 2).

Table 2. Physical Properties, Physical Properties, Dietary Fiber, Microbial Content, and Antioxidant Capacity of Green Okra Pudding in Selected Formulas

Parameter	Results
pH	7,21*
Odor/aroma	Normal*
Texture	Normal*
Dietary fiber	1,24%*
Escherichia coli	<3 APM/g**
*Staphylococcus aureus**	0 Colony/g**
DPPH	41.45 % inhibition*
AEAC	11.55 mg vit C/100g*
IC_{50}	24.27%*

*) Primary data, 2024 (Test results at the MBRIO Food Laboratory)
**Primary data, 2024 (Test results at the Laboratory of the Center for Standardization and Agro Industry Services, Ministry of Industry of the Republic of Indonesia)

The dietary fiber content of the selected formula was recorded at 1.24% that this product contains relatively low fiber. The dietary fiber content test was carried out in accordance with SNI 01-3552-1994, point 5.3, which is the Indonesian national standard for the analysis of dietary fiber in food products. The results of the microbial content test on the selected formula, this product is microbiologically safe. Escherichia coli was detected at a very low level, which is less than 3 APM/g, indicating that contamination by these bacteria is very minimal. In addition, no Staphylococcus aureus was found in the product, with a result of 0 colonies/g, the product is free from bacteria that cause food poisoning. This test was carried out in accordance with the applicable standards in BAM 2017, Chapter 4 and BAM 2016, Chapter 12, ensuring that the product meets the microbiological requirements that are safe for consumption. The results of the antioxidant capacity test on the selected formula that product have the ability to inhibit free radicals quite well. The DPPH value of 41.45% is a significant level of inhibition against free radicals at a sample concentration of 20%, this product has strong antioxidant activity. In addition, the AEAC of 11.55 mg vit C/100g sample product is equivalent to 11.55 mg vitamin C per 100 gr sample in terms of antioxidant

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capacity, providing an idea of how effective the product is in counteracting free radicals. The IC_{50} result of 24.27% indicates the concentration of the product needed to inhibit 50% of free radical activity, which means that this product has good effectiveness although not maximally. All of these tests were carried out using the spectrophotometric method in accordance with IKK/P-9 Point G, which is a recognized standard for measuring antioxidant capacity in samples (Table 2).

DISCUSSION

Planting seedlings (Sowing 30 seedlings on May 5, 2024). On May 8, 2024, in green okra seedlings began to show germination with the emergence of shoots. After all the seedlings had grown and were strong, they were prepared to be transferred to the land. The transfer of seedlings to the land should have been carried out in June 2024, but due to the weather conditions which often rained heavily (the land was affected by flooding so that the beds were remade). The seedlings were successfully transferred in July 2024. In green okra harvest has been carried out 28 times. The first harvest was carried out on August 2, 2024. The results of the harvest are divided into two, namely for mucilage preparations and fine in green okra. The pudding process begins with blanching at a temperature of 90-97°C for 30 seconds. Then, some of the okra is macerated using distilled water (1:3) for 12 hours, and some is pureed using a blender. The next step is to make the pudding mixture by mixing agar powder, sorbitol, milk, and water, then the fine okra and its mucus are added to the pudding mixture. After the pudding mixture is finished cooking, the heat is turned off. After the pudding mixture is warm, it is put into cups to be served. Cooled until set, then ready to be distributed. It was made into pudding and then a hedonic test was conducted to obtain the selected formula. There was no significant difference in color, taste, aroma, aftertaste, and overall acceptance of pudding because sensory assessment was greatly influenced by individual preferences. If panelists have very varied or inconsistent assessments in assessing color, taste, aroma, or aftertaste, this can cause very small differences between formulas that are not detected in statistical analysis. Then the green okra pudding tested used almost the same ingredients or recipes in all formulas, the differences in color, taste, aroma, and aftertaste may not be large enough to show significant differences. Based on the results of the hedonic test, formula 3 was the selected formula. In product development, especially those that emphasize functional aspects such as antioxidant activity, formula selection does not only depend on sensory preferences or consumer acceptance. Although the hedonic test indicated that formula 2 had the highest acceptability (most preferred by panelists), the decision to choose formula 3 as the superior product was based on more objective scientific parameters that were relevant to the product's functional claims, antioxidant activity.

The results of the physical properties test on the best formula, this product has a pH of 7.21 which indicates an almost neutral acidity level, indicating that the product is not too acidic or alkaline. The aroma and texture assessment of the product were also declared normal, meaning both are in accordance with the expected standards without any abnormalities or striking problems. This test was carried out by following the SNI 01-2891-1992 standard, which uses the potentiometric method for pH measurement and the organoleptic method for odor and texture assessment, ensuring the product quality is in accordance with expectations. The dietary fiber content of this product is recorded at 1.24%, indicating that this product contains relatively low fiber. Although dietary fiber plays an important role in maintaining digestive health and regulating blood sugar levels, this low fiber content means that product recommended daily fiber intake. The 1.24% dietary fiber content in this green okra pudding, although perhaps not as high as raw vegetables, still makes a significant contribution to daily fiber intake. Dietary fiber, especially the abundant soluble fiber in okra (mucilage), has potential in gut and microbiota health, as well as glucose metabolism. Okra is indeed known as a source of fiber, especially water-soluble polysaccharides such as pectin and mucilage. Research continues to highlight the potential of okra fiber. Okra (*Abelmoschus esculentus* L.) is a popular vegetable crop with good nutritional significance, along with certain therapeutic values, which makes it a potential candidate in the use of a variety of nutraceuticals. Different parts of the okra fruit (mucilage, seed, and pods) contain certain important bioactive components, which confer its medicinal properties. The phytochemicals of okra have been studied for their potential therapeutic activities on various chronic diseases, such as type-2 diabetes, cardiovascular, and digestive diseases, as

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well as the antifatigue effect, liver detoxification, antibacterial, and chemo-preventive activities. Moreover, okra mucilage has been widely used in medicinal applications such as a plasma replacement or blood volume expanders. Overall, okra is considered to be an easily available, low-cost vegetable crop with various nutritional values and potential health benefits (17).

The results of the antioxidant capacity test showed that green okra pudding has a significant ability to inhibit free radicals. The DPPH indicates strong free radical scavenging activity. Furthermore, the AEAC value of 11.55 mg Vit C/100g sample confirms that this product is equivalent to 11.55 mg Vitamin C in its antioxidant capacity, providing a concrete picture of its effectiveness in counteracting free radicals. Although the IC50 value of 24.27% indicates a relatively low concentration required to achieve 50% inhibition (indicating good effectiveness), the presence of this antioxidant activity is crucial in the context of blood glucose management. Radical inhibition figure indicates that this okra pudding has moderate to good free radical scavenging activity. This indicates that the product has the potential to contribute to the reduction of oxidative stress in the body. Its physiological effects include cellular protection and anti-inflammatory. Antioxidant activity varies widely. In comparison, several studies on other plant extracts such as fruits and berries, contain flavonoids (kaempferol, catechin, resveratrol) and phenolic acids (p-coumaric, cinnamic acid) that promote glucose uptake, inhibit carbohydrate-digesting enzymes, and reduce inflammatory pathways; garlic display a broad spectrum of therapeutic actions such as antioxidant, anti-inflammatory, anti-obesity, hypolipidemic, anti-hyperglycemia (anti-diabetic), anti-atherosclerotic and anti-coagulant activities; and Catechins/polyphenols of green tea can positively regulate PPARα and PPARγ as well as act as potent antioxidant/glycation (anti-AGEs) anti-inflammatory, hypolipidemic, anti-obesity as well as regulate various insulin signaling pathways (AMPK and Akt/PI3K via nuclear factor erythroid 2 related factor 2; Nrf2) thereby increasing insulin secretion, insulin-mimetic action, decreasing insulin resistance/tolerance (increasing GLP-1) and decreasing gluconeogenesis as well as inhibiting sodium dependent glucose transporters (SGLT-1/2) (18).

In diabetes management, especially to control high fasting blood glucose, the role of antioxidants is very vital. Diabetes mellitus is often accompanied by increased oxidative stress, an imbalance between the production of free radicals and the body's ability to neutralize them (16). This oxidative stress can cause damage to pancreatic beta cells (which produce insulin) and trigger insulin resistance, where the body's cells become less responsive to insulin (19). Antioxidant compounds, such as those found in okra, work by neutralizing free radicals, thereby protecting pancreatic beta cells from damage and improving insulin sensitivity (20). Thus, although the total fiber content of this pudding may not be a major contributor, the significant antioxidant activity of okra in this product has the potential to provide protective and ameliorative effects on glucose metabolism, which may ultimately contribute to the control of fasting blood glucose levels.

CONCLUSION

The developed green okra pudding, particularly Formula 3 (with 20 ml mucilage), exhibited notable antioxidant capacity. These findings suggest its potential as a functional food ingredient that may contribute to strategies for managing fasting blood glucose, primarily through its antioxidant action. Further research can be done to determine the content of bioactive compounds and can reveal those found in the seeds, fruit flesh and mucilage of green okra.

FUNDING

This research was funded by The Indonesian Education Scholarship Center for Higher Education Funding and Assessment (Beasiswa Pendidikan Indonesia).

ACKNOWLEDGMENTS

The author would like to thank (1) The Indonesian Education Scholarship (ID Number: 202101122671) Center for Higher Education Funding and Assessment (Beasiswa Pendidikan Indonesia), (2) Ministry of Higher Education, Science, and Technology of the Republic of Indonesia and (3) Endowment Fund for Education Agency, Ministry of Finance of the Republic of Indonesia for financial support through

https://doi.org/10.56303/jhnresearch.v4i2.461

the 2021 Indonesian Education Scholarship.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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