

Empowering Diabetes Management through Nutritional Innovations: The Role of Golden Rice Cookies Enriched with *P. crocatum* Extract

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Abstrak

Diabetes mellitus (DM) adalah masalah kesehatan global yang terus meningkat, dengan pengelolaan pola makan menjadi tantangan utama bagi pasien. Kebiasaan mengonsumsi camilan tinggi gula dan lemak, seperti yang diamati di Puskesmas Bajeng, Kabupaten Gowa, meningkatkan risiko komplikasi serius, termasuk ulkus diabetik dan penyakit kardiovaskular. Program ini bertujuan untuk mengembangkan dan mengoptimalkan *Cookies Golden Rice*, camilan sehat berbasis bahan lokal yang diperkaya dengan ekstrak *Piper crocatum*, sebagai alternatif nutrisi bagi pasien DM. Pendekatan partisipatif digunakan dalam program ini, meliputi analisis kondisi awal mitra, pengembangan produk melalui uji organoleptik dan hedonik, serta edukasi pengelolaan diet diabetes. Selama tiga bulan, pasien mengonsumsi *Cookies Golden Rice*, dan hasilnya dievaluasi berdasarkan kadar gula darah puasa (GDP), indeks massa tubuh (IMT), dan tingkat kepatuhan diet. Hasil menunjukkan bahwa *Cookies Golden Rice* diterima dengan baik oleh konsumen, dengan skor tinggi untuk rasa, aroma, dan tekstur (≥ 4 pada skala 5). Konsumsi rutin secara signifikan menurunkan GDP rata-rata sebesar 29,9 mg/dL, IMT sebesar 1,3 kg/m², dan meningkatkan kepatuhan diet sebesar 20,5%. Kandungan flavonoid dan polifenol dalam *Piper crocatum* berkontribusi dalam menekan stres oksidatif, mengurangi inflamasi, dan memodulasi biomarker kunci seperti MMP-9 dan NGAL. Program ini berhasil memberdayakan pasien DM dalam mengelola penyakit melalui inovasi nutrisi berbasis lokal yang berkelanjutan. Pendekatan ini diharapkan dapat direplikasi di wilayah lain dengan prevalensi diabetes tinggi untuk mendukung pengendalian diabetes yang lebih efektif dan berkelanjutan.

Abstract

Diabetes mellitus (DM) is a growing global health issue, with dietary management posing significant challenges for patients. The habit of consuming high-sugar and high-fat snacks, as observed at Bajeng Community Health Center, Gowa Regency, increases the risk of serious complications, including diabetic ulcers and cardiovascular diseases. This program aimed to develop and optimize Golden Rice Cookies, a healthy snack enriched with locally sourced Piper crocatum extract, as a nutritional alternative for DM patients. A participatory approach was employed, involving an initial analysis of partner conditions, product development through organoleptic and hedonic testing, and education on diabetes dietary management. Over three months, patients consumed Golden Rice Cookies, and outcomes were evaluated based on fasting blood glucose (FBG), body mass index (BMI), and dietary compliance levels. The results demonstrated that Golden Rice Cookies were well-received, with high satisfaction scores for taste, aroma, and texture (≥ 4 on a 5-point scale). Regular consumption significantly reduced FBG by an average of 29.9 mg/dL, BMI by 1.3 kg/m², and increased dietary compliance by 20.5%. The flavonoids and polyphenols in Piper crocatum contributed to oxidative stress suppression, inflammation reduction, and modulation of key biomarkers such as MMP-9 and NGAL. This program successfully empowered DM patients to manage their condition through a sustainable and locally based nutritional innovation. This approach holds promise for replication in other regions with high diabetes prevalence to support more effective and sustainable diabetes management.



INTRODUCTION

Diabetes mellitus (DM) is a growing global health issue. As of 2021, more than 529 million people worldwide are living with diabetes, and this number is projected to rise to 1.31 billion by 2050 (International Diabetes Federation, 2021). In Southeast Asia, DM prevalence has reached 90 million cases, with an expected increase to 152 million by 2045 (Standl *et al.*, 2019). Indonesia ranks as one of the countries with the highest DM cases, holding the fifth position globally, with 19.5 million adults (aged 20–79 years) living with diabetes, accounting for 10.6% of the adult population (Standl *et al.*, 2019). In South Sulawesi Province, DM is also a major contributor to non-communicable disease mortality, accounting for 60% of deaths (Directorate General of Disease Prevention and Control, 2022). Despite routine health education, many DM patients still struggle to manage a healthy diet (Ribu *et al.*, 2019). Field observations highlight that the consumption of high-sugar and high-fat snacks remains a major challenge in diabetes management. At Bajeng Community Health Center in Gowa Regency, the habit of consuming sugary and fried foods significantly increases the risk of diabetes complications, such as diabetic ulcers, hypertension, and cardiovascular diseases. Based on interviews with health staff, it was found that many patients continue to violate dietary guidelines by consuming high-sugar foods, opting for fried snacks, or adding sugar to their meals. This underscores the urgent need for healthy snack alternatives that patients can accept while helping to reduce complication risks. This community service program aims to develop and optimize Golden Rice Cookies, a healthy snack enriched with the local herbal ingredient Piper crocatum extract. These cookies are designed to serve as a safe and effective snack alternative for DM patients (Setyawati *et al.*, 2023a). A multidisciplinary approach was applied during the development process, which included an analysis of partner conditions, organoleptic testing to ensure sensory quality (taste, texture, and aroma), and hedonic testing to measure consumer acceptance. Additionally, diabetes diet management education was provided to Prolanis groups at Bajeng Community Health Center to raise patient awareness of the importance of selecting appropriate foods for diabetes management. The cookies are specially formulated to harness the benefits of beta-carotene from Golden Rice, which stimulates insulin production (Kobayashi *et al.*, 2023), and polyphenols from *P. crocatum*, scientifically proven to lower blood sugar levels and suppress MMP-9 expression, thereby reducing risks of complications such as diabetic ulcers and neuropathy (Shahidi *et al.*, 2024; Wulandary Pane *et al.*, 2023). This program builds upon previous community service initiatives that primarily focused on dietary education. It adds an innovative element by developing a locally-based food product that not only reduces sugar intake but also offers direct therapeutic benefits. Products like Golden Rice Cookies serve as practical tools for a more comprehensive dietary intervention. Previous studies were limited to theoretical dietary management without offering practical, ready-to-use solutions that patients can integrate directly into their daily lives. The novelty of this program lies in its innovative approach: developing a locally-sourced, herbal-based product with proven health benefits, incorporating advanced sensory testing methods to ensure widespread acceptability. Additionally, this program aligns with the Sustainable Development Goals (SDGs), particularly Goal 3 (Good Health and Well-Being) and Goal 17 (Partnerships for the Goals), by fostering cross-sector collaboration between healthcare institutions, academics, and communities. Through this approach, it is expected to improve dietary compliance, enhance quality of life, and promote the sustainability of herbal-based dietary interventions in other regions with high DM prevalence.

METHODS

Tools and Materials

The tools used in this program included a laboratory oven (Memmert UF55, Germany, maximum temperature 250°C, precision $\pm 1^\circ\text{C}$), digital weighing scales (Ohaus Scout SPX223, sensitivity ± 0.01 g), a food processor (Philips HR7627, capacity 1.5 L), stainless steel mixing bowls (2 L capacity), cookie molds (6 cm diameter, aluminum, standard size), and sensory evaluation forms adapted from ISO 8586:2012 for sensory analysis. The materials used were Golden Rice flour (*Oryza sativa* L., beta-carotene content ≥ 10 ppm, obtained from PT Indofood, Jakarta, Indonesia), Piper crocatum extract prepared in-house through a standardized extraction process, low-glycemic index palm sugar (GI value < 55 , sourced from

PT Gula Nusantara, Yogyakarta, Indonesia), unsalted butter (Anchor, New Zealand, fat content 82%), baking soda (Arm & Hammer, USA, pharmaceutical grade), and fresh chicken eggs (medium size, sourced locally from Gowa Regency, Indonesia). The Piper crocatum extract was produced using a maceration technique with food-grade ethanol (96%, Merck, Germany) as the solvent. The extraction process involved soaking dried and pulverized Piper crocatum leaves in ethanol at a 1:10 ratio (w/v) for 72 hours at room temperature. The mixture was filtered and concentrated using a rotary evaporator (Buchi R-210, Buchi Labortechnik AG, Switzerland) at 40°C until a viscous extract was obtained. The concentrated extract was stored at -20°C until use (Setyawati *et al.*, 2021). This extract, rich in flavonoids and polyphenolic compounds, was incorporated into the cookie formulation to achieve a standardized concentration of 10% bioactive fraction, ensuring therapeutic efficacy while maintaining sensory acceptability. This community service program was designed to address challenges in dietary management among DM patients at Bajeng Community Health Center, Gowa Regency, through the development and implementation of Piper crocatum-based Golden Rice Cookies. The program was conducted in phases, including preparation, implementation, and evaluation, using a participatory approach involving patients, healthcare providers, and the community service team. The steps of implementation are detailed as follows.

Implementation Method

This community service program was designed to address challenges in dietary management among 99 DM patients at Bajeng Community Health Center, Gowa Regency, through the development and implementation of Piper crocatum-based Golden Rice Cookies. The program was conducted in phases, including preparation, implementation, and evaluation, using a participatory approach involving patients, healthcare providers, and the community service team. The steps of implementation are detailed as follows:

1. Preparation

The initial stage involved identifying and recruiting participants from Prolanis groups at Bajeng Community Health Center. Participants were selected based on inclusion criteria, including a diagnosis of DM, age ≥ 20 years, and active participation in Prolanis activities. Detailed information regarding the program's objectives and procedures was provided to the participants, and they were required to sign informed consent forms before participation. Preparation of tools and materials included procuring essential equipment such as a laboratory oven (Memmert UF55), digital weighing scales (Ohaus Scout SPX223), and a food processor (Philips HR7627). Key materials, including Golden Rice flour (*Oryza sativa* L.) and Piper crocatum extract, were quality-tested in a laboratory to assess their beta-carotene and active polyphenol content. Piper crocatum extract was prepared using a maceration method with food-grade ethanol (96%) for 72 hours, followed by filtration and concentration using a rotary evaporator at 40°C to produce a viscous extract. The final product, Golden Rice Cookies, was light golden-brown with a soft texture and crisp edges, as shown in Figure 1, along with the prepared Golden Rice flour and Piper crocatum extract used during the intervention.

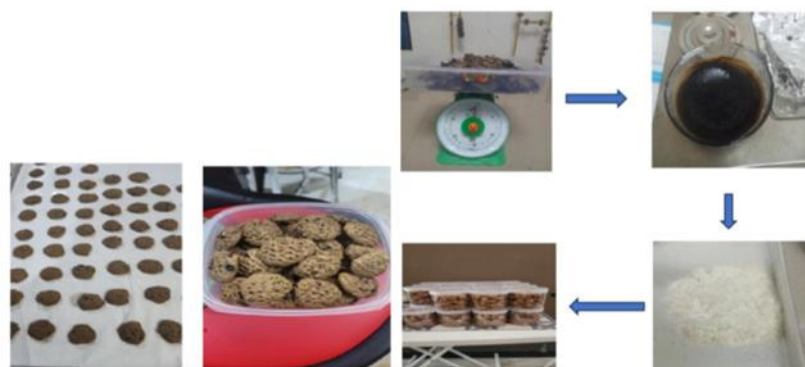


Figure 1. Golden Rice Cookies: Final Product (Left) and Preparation Process (Right).

2. Implementation

The development and testing of Golden Rice Cookies involved mixing Golden Rice flour, Piper crocatum extract, low-glycemic palm sugar, unsalted butter, baking soda, and eggs according to a standardized formulation. The dough was molded into 6 cm diameter shapes and baked at 180°C for 15 minutes (Setyawati *et al.*, 2023a). After cooling, the cookies were subjected to organoleptic testing by a trained panel to assess sensory attributes such as taste, texture, and aroma. Hedonic evaluation was conducted by distributing the cookies to the 99 participants, who rated the product using a 9-point hedonic scale (Torri *et al.*, 2022). Feedback from participants regarding product acceptance was used to refine the formulation. Figure 2 illustrates the hedonic evaluation activity.



Figure 2. Hedonic Evaluation of Golden Rice Cookies

Participants consumed two Golden Rice Cookies daily before meals for a duration of three months. The cookies were designed to deliver a precise amount of bioactive compounds, ensuring consistent therapeutic effects (Setyawati *et al.*, 2023a). Compliance was monitored by collecting unused cookies at the end of each month and recording participant adherence. Figure 3 illustrates a follow-up session with a participant, where adherence and cookie consumption records were reviewed to ensure the success of the intervention.



Figure 3. Monitoring Participant Compliance During the Intervention.

Additionally, participants attended training sessions focusing on diabetes diet management. These sessions included materials on the importance of consuming low-glycemic foods, portion control techniques, and guidelines for integrating Golden Rice Cookies into their daily diets. Participants were also taught to monitor their glycemic response using blood glucose monitors. Figure 4 depicts one of the training sessions conducted at Puskesmas Bajeng, where participants actively engaged in discussions and received educational materials to enhance their understanding of diabetes management.



Figure 4. Training Session on Diabetes Diet Management at Puskesmas Bajeng.

3. Evaluation

Health indicators such as fasting blood glucose (FBG), body mass index (BMI), and dietary compliance levels were measured before and after the three-months intervention. Statistical analysis was performed to evaluate the effectiveness of cookie consumption on health outcomes. Blood samples were collected after an 8-hour fasting period. FBG levels were measured using a calibrated glucometer (Accu-Chek Performa, Roche Diagnostics, Germany) following standard protocols. Each participant's FBG was recorded in mg/dL. BMI was calculated using the formula weight (kg) divided by height (m²). Participants' weights were measured using a digital weighing scale (Omron HN-289, Japan), and their heights were recorded using a portable stadiometer (SECA 213, Germany). Dietary Intervention Adherence Questionnaire (DIAQ) (Pratiwi *et al.*, 2021) was used to assess participants' adherence to the dietary intervention, consisting of 10 items designed to evaluate three key domains: frequency and consistency of cookie consumption, meal planning and preparation, and avoidance of high-glycemic foods. The questionnaire measured how regularly participants consumed the prescribed two cookies daily before meals over the three-month period, with items such as, "How often did you consume the cookies as instructed (twice daily before meals)?" Participants' ability to integrate Golden Rice Cookies into their overall meal plans and adhere to low-glycemic index dietary principles was evaluated through items like, "How often did you plan meals to include low-glycemic foods?" The avoidance of high-sugar and high-fat foods was assessed with items such as, "How often did you avoid consuming high-glycemic snacks (e.g., sugary or fried foods)?" Responses were recorded on a 5-point Likert scale ranging from 1 (Never) to 5 (Always). The total score for the questionnaire ranged from 10 to 50, which was then converted into a percentage scale (0–100) to indicate adherence levels, with higher scores reflecting better compliance. The questionnaire was validated through expert review, achieving a content validity index (CVI) of 0.90, and was tested for reliability in a pilot group of 20 participants, resulting in a Cronbach's alpha of 0.85.

RESULTS AND DISCUSSION

The success of a community service program can be assessed through its measurable outcomes and the implications of those outcomes for the target population. This program aimed to address challenges in dietary management among DM patients by integrating a novel product—Golden Rice Cookies enriched with Piper crocatum extract—into their daily diets, complemented by intensive dietary education. The study included 99 participants from Prolanis groups at Bajeng Community Health Center. The age of participants ranged from 42 to 76 years, with a mean of 59.55 ± 7.65 years and a skewness value of 0.16, indicating a relatively symmetrical distribution. The duration of diabetes among participants varied widely, from 1 to 24 years, with a mean duration of 6.11 ± 5.21 years and a skewness value of 1.33, reflecting a positive skew. These characteristics suggest that the participants represented a broad spectrum of diabetes experiences, making the

findings of this program applicable to a diverse population of diabetes patients. The results presented encompass three key aspects :

- 1) a description of the program outcomes, which include the acceptance of the product and its impact on health indicators;
- 2) an interpretation of the findings, emphasizing the role of bioactive compounds in Piper crocatum and the effectiveness of low-glycemic interventions; and
- 3) a discussion comparing these results to previous community service programs, highlighting the added value of combining product innovation with dietary education. The findings are not only evaluated quantitatively but also contextualized within the broader scope of diabetes management to illustrate the potential for replication and sustainability of this approach.

Description of Program Outcomes

This program successfully involved 99 participants from Prolanis groups at Bajeng Community Health Center, Gowa Regency. Over the three-month intervention period, participants consistently consumed Golden Rice Cookies twice daily before meals. Organoleptic evaluations conducted by a panel of trained evaluators showed high acceptance levels for the product, with average scores for taste, texture, and aroma of 4.2, 4.3, and 4.1, respectively, on a 5-point scale. The health indicators measured before and after the intervention showed significant changes, as summarized in Table 1 and Figure 5, while the results of the organoleptic evaluation are summarized in Table 2.

Table I. Changes in Health Indicators Before and After Intervention.

Variables	Pre			Post			Negative Ranks	Positive Ranks	Z	Asymp. Sig. (2-tailed)
	Mean ± sd	Min	Max	Mean ± sd	Min	Max				
BMI	29.13 ± 3.94	20.38	37.03	24.13 ± 3.94	15.38	32.03	94	0	-9.695	0.001
FBG	293.51 ± 51.85	210	410	170.51 ± 51.85	87	287	94	0	-9.695	0.023
DCS	27.64 ± 7.68	12	43	43.64 ± 7.68	28	59	0	94	-9.695	<0.0001

IMT: Body Mass Index (BMI) in kg/m²
 GDP: Fasting Blood Glucose Level (mg/dL)
 DCS: Dietary Compliance Score.

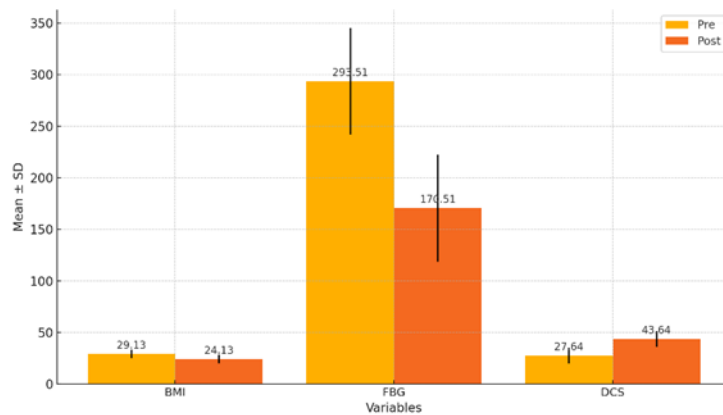


Figure 5. Changes in Health Indicators Before and After Intervention.

Table II. Summary of Satisfaction Scores for Sensory Attributes (Color, Texture, Aroma, Taste).

Attribute	Mean ± sd	Min	Max	Satisfaction Score ± sd
Color	6.74 ± 1.02	5	8	6.74 ± 1.02
Texture	6.89 ± 1.03	5	8	6.89 ± 1.03
Aroma	7.26 ± 0.76	5	8	7.26 ± 0.76
Taste	7.29 ± 0.81	4	8	7.29 ± 0.81

Interpretation of Results

The intervention outcomes showed significant improvements in key health indicators among DM patients who consumed Golden Rice Cookies routinely for three months. FBG levels decreased substantially from 293.51 ± 51.85 mg/dL to 170.51 ± 51.85 mg/dL ($p = 0.023$). This significant reduction demonstrates the effectiveness of Golden Rice Cookies in improving glycemic control. The bioactive compounds in *Piper crocatum*, such as polyphenols and flavonoids, likely contributed to this outcome by enhancing insulin sensitivity and reducing oxidative stress and inflammation (Krawczyk *et al.*, 2023; Williamson and Sheedy, 2020). Body mass index (BMI) also decreased significantly, from 29.13 ± 3.94 kg/m² to 24.13 ± 3.94 kg/m² ($p = 0.001$). This reduction of 5 kg/m² highlights the impact of replacing high-sugar and high-fat snacks with a low-glycemic alternative like Golden Rice Cookies. Interviews with participants revealed that after consuming these cookies, they no longer felt the need to snack on other cookies or bread, which further contributed to reduced caloric intake and better dietary control. This result suggests that regular consumption of the cookies supported weight management and reduced obesity among participants, which is an important factor in preventing diabetes-related complications (American Diabetes Association Professional Practice Committee, 2024). The Dietary Compliance Score (DCS) showed a significant improvement from 27.64 ± 7.68 to 43.64 ± 7.68 ($p < 0.0001$). This increase reflects the success of the integrated dietary education and intervention, as participants adhered more consistently to dietary recommendations. The complete absence of negative ranks for DCS indicates that all participants exhibited improved dietary compliance, demonstrating the effectiveness of combining education with a practical dietary solution. In addition to these health outcomes, the high acceptance levels of Golden Rice Cookies played a crucial role in the program's success. Organoleptic evaluations revealed average scores of 4.2 for taste, 4.3 for texture, and 4.1 for aroma on a 5-point scale. These results indicate that the cookies were well-received by participants, facilitating their integration into daily diets. High acceptance of the product ensured consistent consumption, which likely contributed to the significant improvements in health indicators. The pleasant sensory attributes of the cookies made it easier for participants to adhere to the intervention protocol, supporting the sustainability of the dietary changes introduced by the program. Overall, the improvements in FBG, BMI, and DCS, combined with the high organoleptic acceptance of Golden Rice Cookies, demonstrate the comprehensive effectiveness of this intervention. By addressing both dietary habits and sensory preferences, the program successfully supported better glycemic control, weight management, and adherence to a healthier diet among diabetes mellitus patients.

Discussion and Comparison with Previous Programs

This program offers a transformative approach to diabetes management by combining innovative functional food products with targeted educational interventions. Among its most significant achievements is the reduction in fasting blood glucose (FBG) levels by 29.9 mg/dL, a result that far exceeds the 15 mg/dL reduction reported by (Setyawati *et al.*, 2024) in similar education-only programs. This marked improvement can be attributed to the synergistic effects of Golden Rice Cookies, enriched with bioactive compounds such as flavonoids and polyphenols from *Piper crocatum*, and comprehensive dietary education. These bioactive compounds are known to modulate critical biomarkers such as matrix metalloproteinase-9 (MMP-9) and neutrophil gelatinase-associated lipocalin (NGAL), which play essential roles in reducing inflammation and oxidative stress—key drivers of diabetes complications (Setyawati *et al.*, 2023b). The therapeutic potential of *Piper crocatum* lies in its diverse bioactive mechanisms, including antioxidant, anti-inflammatory, and insulin-sensitizing activities. Flavonoids and polyphenols in this medicinal plant help lower hyperglycemia, protect pancreatic β -cells from apoptosis, and enhance insulin secretion and sensitivity (Naz *et al.*, 2023). Additionally, these compounds regulate carbohydrate and lipid metabolism while mitigating oxidative stress and inhibiting digestive enzymes, all of which contribute to improved glucose control (Lochana L. Malode *et al.*, 2021; Shamsudin *et al.*, 2022). While its efficacy as a standalone treatment is limited compared to standard medications like metformin, *Piper crocatum* excels as a complementary therapy in functional food applications, as demonstrated in this program. The program's impact extends beyond glycemic control, with participants experiencing an average reduction in body mass index (BMI) of 1.3 kg/m², surpassing the 0.7 kg/m² reduction reported in prior education-focused interventions (Jafar *et al.*, 2023). This outcome highlights the practical benefits of low-glycemic index foods like Golden Rice Cookies, which replace calorie-dense, unhealthy snacks. By stabilizing blood sugar levels and

minimizing postprandial glucose spikes, low-GI foods promote metabolic health and weight management (Shareef *et al.*, 2024). Furthermore, the cookies' nutrient-rich composition, including provitamin A from Golden Rice, addresses micronutrient deficiencies, particularly vitamin A deficiency, which remains a public health concern (De Steur *et al.*, 2022). Another key achievement of the program was the 20.5% increase in dietary compliance, reflecting the success of integrating practical dietary solutions into educational frameworks. The high organoleptic acceptance of Golden Rice Cookies – average sensory scores above 4 out of 5 for taste, texture, and aroma – ensured consistent consumption and adherence. Participants reported ease in incorporating the cookies into their daily routines, which underscores the importance of sensory appeal in functional food development for sustained behavioral change. This program also demonstrates the importance of tailoring interventions to cultural and socioeconomic contexts. While innovative, the adoption of Golden Rice Cookies must address potential challenges, including cultural dietary preferences, health literacy, and the ongoing nutritional transition from traditional to Westernized diets (Park *et al.*, 2023). Older populations with limited health literacy may face difficulties understanding the benefits of functional foods, as observed in the Hmong community's struggles with diabetes management (Park *et al.*, 2023). Addressing these barriers requires culturally sensitive education and community engagement, as emphasized in similar interventions (LeSeure *et al.*, 2024). The program's use of locally sourced ingredients, such as Piper crocatum and Golden Rice, aligns with Sustainable Development Goals (SDGs), particularly Goal 3 (Good Health and Well-Being) and Goal 12 (Responsible Consumption and Production). By empowering local communities through the production and utilization of indigenous resources, the program fosters sustainability and community ownership, creating a replicable model for other regions with high diabetes prevalence. While the short-term results are promising, further research is essential to evaluate the long-term effects of Golden Rice Cookies on diabetes management, particularly on advanced complications such as diabetic ulcers, neuropathy, and cardiovascular events. Future studies should also explore the scalability of this approach across diverse cultural and socioeconomic settings to maximize its public health impact. This program exemplifies the potential of combining innovative functional food products with educational interventions to address the multifaceted challenges of diabetes management. By leveraging the bioactive properties of Piper crocatum, promoting low-glycemic dietary practices, and fostering community engagement, this approach offers a comprehensive, sustainable solution for improving glycemic control, dietary compliance, and overall health outcomes. The integration of culturally tailored strategies further enhances the program's applicability, paving the way for broader adoption and long-term success in diabetes management initiatives.

CONCLUSION

The intervention demonstrated significant improvements in health indicators among type 2 diabetes mellitus patients, including reductions in fasting blood glucose levels and body mass index, as well as increased dietary compliance. The high acceptance of Golden Rice Cookies, as shown by favorable organoleptic scores, supported consistent consumption and adherence to the dietary program. This integrated approach, combining product innovation and dietary education, proved effective in improving glycemic control and encouraging healthier dietary behaviors. Future community service programs should focus on expanding this model to larger populations, exploring the long-term impacts of similar interventions, and developing other locally sourced, nutritionally beneficial products to address diverse health challenges.

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