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Formulation and nutritional evaluation of kepilor instant cereal (soybean sprout, plantain banana, and moringa leaves) as functional food for type 2 diabetes mellitus

Formulasi dan evaluasi nilai gizi sereal instan kepilor (kecambah kedelai, pisang kepok, dan daun kelor) sebagai pangan fungsional untuk diabetes melitus tipe 2

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Poltekkes Kemenkes Aceh

Fitria Dhenok Palupi[1*], Indri Hapsari[2], Muhammad Hasan Wattiheluw[3]

Abstract

Background: Type 2 diabetes mellitus (T2DM) is a global health problem with a continuously increasing prevalence and is strongly influenced by dietary patterns, particularly high energy intake, excessive simple sugars, and low fiber intake, which contribute to elevated postprandial glycemic responses. Effective management requires low-glycemic, nutrient-dense dietary interventions; however, commonly consumed processed foods, including instant cereals, often have high glycemic impacts. Therefore, the development of functional foods based on local ingredients such as plantain banana, soybean, and moringa leaves offers a promising strategy to support glycemic control

Objectives: This study aimed to formulate and evaluate an instant cereal based on plantain banana flour, soybean sprout flour, and moringa leaf flour (kepilor) that meets the dietary requirements for diabetes mellitus.

Methods: This study employed a Completely Randomized Design (CRD) with three levels of plantain flour substitution (20%, 30%, and 40%), each conducted in triplicate. The parameters analyzed included organoleptic properties, yield, energy values, nutrient compositions, and energy densities. Nutrient composition was determined using standard methods (gravimetric, dry ashing, micro-Kjeldahl, Soxhlet, and carbohydrate by difference). Organoleptic evaluation was conducted using a 9-point hedonic scale with 30 semi-trained panelists, and the best treatment was determined using an effectiveness index test with 10 other trained panelists. Data were analyzed using ANOVA or Kruskal-Wallis test with $p < 0.05$

Results: The results showed that formulation variations did not significantly affect protein, fat, carbohydrate, and fiber contents ($p>0.05$), with values ranging from 5.57–5.65 g, 2.83–2.90 g, 17.92–18.12 g, and 0.21–0.29 g per serving, respectively. However, significant differences were observed in total energy (119.40–120.63 kcal), energy density (0.597–0.603 kcal/mL), and taste ($p<0.05$), with taste being the only sensory attribute significantly affected by formulation. The formulation containing 30% plantain banana flour (T2) was identified as the best treatment, providing 120.63 kcal per serving, 5.65 g protein, 2.90 g fat, 17.98 g carbohydrates, 0.29 g fiber, and an energy density of 0.603 kcal/mL

Conclusion: In conclusion, kepilor instant cereal has potential as a low-energy-density functional snack suitable for the dietary management of individuals with diabetes mellitus.

Keywords
Diabetes Mellitus, Instant Cereal, Moringa Leaf, Plantain Banana, Soybean Sprouts

Abstrak

[1] Prodi Sarjana Terapan Gizi dan Dietetika, Jurusan Gizi Politeknik Kesehatan Kemenkes Malang, Malang, Indonesia.
E-mail: fitria.dhenok@poltekkes-malang.ac.id
[2] Prodi Sarjana Terapan Gizi dan Dietetika, Jurusan Gizi Politeknik Kesehatan Kemenkes Malang, Malang, Indonesia.
E-mail: indri_hapsari@poltekkes-malang.ac.id
[3] Prodi Analisis Farmasi dan Makanan, Jurusan Analisis Farmasi dan Makanan, Politeknik Kesehatan Kemenkes Malang, Malang, Indonesia.
E-mail: hasan.wattiheluw@poltekkes-malang.ac.id

Penulis Koresponding
Fitria Dhenok Palupi: Prodi Sarjana Terapan Gizi dan Dietetika, Jurusan Gizi Politeknik Kesehatan Kemenkes Malang, Malang, Indonesia.
E-mail: fitria.dhenok@poltekkes-malang.ac.id

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Latar Belakang: Diabetes melitus tipe 2 (DMT2) merupakan masalah kesehatan global dengan prevalensi yang terus meningkat dan sangat dipengaruhi oleh pola makan, khususnya asupan energi tinggi, konsumsi gula sederhana berlebih, serta rendahnya asupan serat yang berkontribusi terhadap peningkatan respons glikemik postprandial. Pengelolaan yang efektif memerlukan intervensi diet dengan indeks glikemik rendah dan padat zat gizi; namun, pangan olahan yang umum dikonsumsi, termasuk sereal instan, seringkali memiliki dampak glikemik yang tinggi. Oleh karena itu, pengembangan pangan fungsional berbasis bahan lokal seperti pisang kepok, kedelai, dan daun kelor menjadi strategi yang menjanjikan untuk mendukung pengendalian glikemik

Tujuan: Penelitian ini bertujuan untuk memformulasikan dan mengevaluasi sereal instan berbasis tepung pisang tanduk, tepung kecambah kedelai, dan tepung daun kelor (kepilor) yang sesuai dengan persyaratan diet diabetes melitus.

Metode: Penelitian ini menggunakan Rancangan Acak Lengkap (RAL) dengan tiga tingkat substitusi tepung pisang kepok (20%, 30%, dan 40%) yang dilakukan dalam tiga ulangan. Parameter yang dianalisis meliputi sifat organoleptik, rendemen, nilai energi, komposisi zat gizi, dan densitas energi. Analisis komposisi zat gizi dilakukan dengan metode standar (gravimetri, pengabuan kering, mikro-Kjeldahl, Soxhlet, dan karbohidrat by difference). Uji organoleptik dilakukan menggunakan skala hedonik 9 poin dengan 30 panelis semi terlatih, sedangkan penentuan perlakuan terbaik menggunakan uji indeks efektivitas dengan 10 panelis terlatih, Data dianalisis menggunakan uji ANOVA atau Kruskal–Wallis dengan tingkat signifikansi $p < 0,05$

Hasil: Hasil penelitian menunjukkan bahwa variasi formulasi tidak berpengaruh signifikan terhadap kadar protein, lemak, karbohidrat, dan serat ($p>0,05$), dengan rentang nilai berturut-turut sebesar 5,57–5,65 g, 2,83–2,90 g, 17,92–18,12 g, dan 0,21–0,29 g per sajian, Namun, terdapat perbedaan signifikan pada total energi (119,40–120,63 kkal), densitas energi (0,597–0,603 kkal/mL), dan atribut rasa ($p<0,05$), dengan rasa menjadi satu-satunya atribut sensorik yang dipengaruhi secara signifikan oleh formulasi, Formulasi dengan 30% tepung pisang kepok (T2) ditetapkan sebagai perlakuan terbaik, dengan kandungan energi sebesar 120,63 kkal per sajian, protein 5,65 g, lemak 2,90 g, karbohidrat 17,98 g, serat 0,29 g, dan densitas energi 0,603 kkal/mL.

Kesimpulan: Sereal instan kepilor berpotensi dikembangkan sebagai alternatif snack fungsional rendah kepadatan energi yang sesuai untuk diet penderita diabetes melitus.

Kata Kunci
Daun kelor, Diabetes Melitus, Kecambah Kedelai, Pisang Tanduk, Sereal Instan

Introduction

Diabetes mellitus (DM) is a major global health problem, including in Indonesia. The International Diabetes Federation (IDF) reported that in 2024, approximately 589 million adults worldwide were living with diabetes, and this number is projected to increase to 853 million by 2050, with Southeast Asia expected to experience a prevalence increase of more than 70% (IDF, 2025). According to the International Diabetes Federation (IDF), in 2025, the number of diabetes cases in Indonesia reached approximately 20.4 million, with an age-adjusted prevalence of 11.3%, which is higher than the Southeast Asia regional average. This indicates that more than one in nine adults in Indonesia lives with diabetes. This condition is expected to continue increasing in line with changes in lifestyle, dietary patterns, physical inactivity, and genetic factors (IDF, 2025). Indonesia is among the ten countries with the highest number of diabetes cases globally, the majority of which are type 2 diabetes mellitus (T2DM) cases. T2DM is a chronic metabolic disorder characterized by hyperglycemia due to insulin resistance and progressive pancreatic β-cell dysfunction. The rising prevalence of T2DM is strongly associated with abdominal obesity, sedentary lifestyle, high-calorie dietary patterns, and population aging (American Diabetes Association, 2024).

Postprandial glycemic fluctuations, accompanied by elevated insulin and lipid levels, play a significant role in the development of non-communicable diseases, particularly T2DM (Schwingshackl et al., 2018). Modern dietary patterns characterized by high energy intake, excessive simple sugars, and low fiber contribute to high postprandial glycemic responses and an increased risk of T2DM and cardiovascular diseases (Mirrahimi et al., 2012). In contrast, low glycemic index (GI) diets are associated with improved insulin sensitivity and better glycemic control (Jenkins et al., 2021; Livesey & Livesey, 2019). Therefore, long-term nutritional interventions are emphasized as a cornerstone of diabetes management (IDF, 2025).

Food processing has become an integral part of modern dietary habits and significantly influences starch digestibility and metabolism. Processing methods such as heating and cooling can modify starch structure, affect gelatinization, alter physical properties, and influence interactions between starch and other food components, thereby determining the glycemic response (Wu et al., 2020). Increased consumption of certain instant cereal products has been linked to a higher risk of T2DM (Chanson-Rolle et al., 2015; Sun et al., 2019), highlighting the need for product reformulation to create diabetes-friendly alternatives to these products.

Dietary management of diabetes includes increasing the intake of resistant starch, essential amino acids, vitamins, minerals, and antioxidant compounds. Starch is the primary carbohydrate source in daily diets, contributing approximately 45–60% to the total energy intake. Carbohydrate quality, particularly low-GI carbohydrates, plays a crucial role in reducing cardiometabolic risk (Livesey & Livesey, 2019; Martínez-González et al., 2020). Foods rich in slowly digestible starch (SDS) and resistant starch have been shown to reduce postprandial glycemic and insulinemic responses in both healthy individuals and those with insulin resistance (Boers et al., 2019; Breyton et al., 2021; Muchtadi, 2002; Normand et al., 2017)

Plantain banana (Musa paradisiaca var. (corniculate) is a promising source of resistant starch type 2. Modified plantain flour reportedly contains up to 19% resistant starch (Palupi et al., 2024). Resistant starch escapes digestion in the small intestine and is fermented by colonic microbiota into short-chain fatty acids (SCFAs), such as acetate, propionate, and butyrate ((DeMartinoa & Cockburna, 2019; Dobranowski & Stintzi, 2021; Tan et al., 2019; Włodarczyk & Slizewska, 2021). These metabolites improve insulin sensitivity, stimulate the secretion of glucoregulatory hormones such as GLP-1 and PYY (Psichas et al., 2015), and contribute to improved glycemic stability(Barclay et al., 2021).

Soybean (*Glycine max*) also demonstrates potential as a complementary dietary component for T2DM management. Soy consumption has been associated with reduced hyperglycemia and lower T2DM incidence, particularly in Asian populations (Chauhan et al., 2021; Rowaiye et al., 2024). These benefits are attributed to bioactive compounds, such as isoflavones, which contribute to improved insulin sensitivity. Germination further enhances the nutritional quality of soybeans by increasing the bioavailability of bioactive compounds while reducing antinutritional factors (Nolasco et al., 2023; Zhou et al., 2024).

Moringa leaves (Moringa oleifera) are also recognized for their strong antidiabetic properties owing to their high polyphenol and flavonoid (quercetin and kaempferol) content, as well as vitamins and minerals (Ahmad et al., 2019; Anwer et al., 2021; Leone et al., 2015; Mthiyane et al., 2022; Nova et al., 2020; Xiao et al., 2020; Xu et al., 2019). Experimental and clinical studies suggest that moringa supplementation can reduce fasting blood glucose and HbA1c levels through antioxidant, anti-inflammatory, and insulin-sensitizing mechanisms (Crisan et al., 2025; Thanikachalam et al., 2025).

Based on the functional potential of these three local food sources, the development of an instant cereal product tailored for individuals with diabetes is necessary. Formulating an instant cereal based on modified plantain flour, soy (including germinated soy), and moringa leaves may provide a practical functional food alternative that is rich in resistant starch, plant protein, isoflavones, and antioxidants. However, few studies have evaluated the development of instant cereal products combining plantain flour, germinated soybean, and moringa leaves. Furthermore, the development of functional cereal products specifically designed to support the dietary management of T2DM using local ingredients remains underexplored. Therefore, this study aims to develop and evaluate a functional instant cereal based on plantain flour, germinated soybean, and moringa leaves by assessing its sensory properties, nutritional composition, and identifying the optimal formulation for T2DM dietary management

Methods

This study was conducted as an experimental research using a Completely Randomized Design (CRD) consisting of three treatment levels representing different proportions of plantain flour substitution in the formulation of Kepilor instant cereal. The experimental units were the Kepilor instant cereal products obtained from each treatment formulation. Each treatment was prepared in triplicate, resulting in nine experimental units. The order of treatment preparation was randomized to minimize potential bias during processing, and each treatment batch was independently prepared in separate production runs under the same controlled conditions. All formulations incorporated plantain, germinated soybean, and moringa leaf flours.

The formulation was developed based on the nutritional recommendations for individuals with diabetes mellitus. These guidelines include a carbohydrate intake of 45–60%, protein 10–20%, fat less than 35%, and fiber of at least 5 g per 1000 kcal (Forouhi et al., 2018). In addition, the formulation was based on the Indonesian dietary guidelines for patients with type 2 diabetes mellitus, which recommend protein intake of 10–20%, carbohydrates 45–65%, fiber 20–35 g per 2000 kcal, and fat 20–25% (BPOM, 2020). The detailed compositions of each formulation are presented in Table 1.

The study will be conducted from May to November 2025. The preparation of raw flour materials was carried out at the Laboratory of CV Striata Grup. The production of the instant cereal and organoleptic evaluation were performed at the Food Technology Laboratory of the Health Polytechnic of the Ministry of Health Malang, Indonesia, while nutrient content analysis was conducted at the Food Technology Laboratory of Brawijaya University, Malang, Indonesia.

Tabel 1. Formulation of Kepilor instant cereal at each treatment level

Ingredients (grams)	T1 (20%)	T2 (30%)	T3 (40%)
Flakes formulation			
Plantain flour	20	30	40
Moringa leaf flour	3	3	3
Germinated soybean flour	14	15	15
Skim milk powder	10	10	10
Chicken egg	23	22	21
Tapioca flour	18	12	6
Wheat flour	10	6	3
Soybean oil	2	2	2
Instant cereal formulation			
Kepilor flakes	10	10	10
Skim milk powder	5	5	5
Non-Dairy Creamer	1	1	1
Full Cream Milk Powder	10	10	10
Granulated sugar	1	1	1

The primary raw materials used in this study included mature-green plantains obtained from a traditional market in Trenggalek Regency, young moringa leaves, and locally produced Wilis soybean variety sourced from a traditional market in Malang. Raw materials were selected based on specific criteria, including freshness, maturity level, and uniformity of size and quality. Additional ingredients for instant cereal production included wheat flour, skim milk powder, full-cream milk powder, chicken eggs, tapioca flour, and soybean oil. The materials used for organoleptic testing included Kepilor instant cereal samples, mineral water, and evaluation questionnaires. Proximate analysis utilized standard laboratory chemicals, including Kjeldahl tablets, concentrated H_2SO_4, NaOH-thio 60% solution, 4% boric acid solution with MR-BCG indicator, 0.02 N HCl solution, chloroform solvent, and filter paper. The study began with the preparation of moringa leaf flour, germinated soybean flour, and plantain flour. Moringa leaf flour was produced by blanching at 80°C for 5 min, drying at 50°C for 6 h, milling, and sieving through an 80-mesh sieve (Kurniawati et al., 2018). Germinated soybean flour was prepared by soaking soybeans for 12 h with water replacement every 6 h, germinating for 12 h under moist conditions, boiling for 30 min, drying at 70°C for 12 h, milling, and sieving through an 80-mesh sieve (Palupi et al., 2022). Plantain flour was produced from mature-green plantains that were steamed for 20 min, cooled for 10 min, frozen for 48 h, sliced (30 × 30 mm), dried at 60°C for 12 h, milled, and sieved using an 80-mesh sieve (Palupi et al., 2024).

Kepilor instant cereal was produced by mixing all the flakes ingredients, such as eggs, skim milk, tapioca flour, soybean oil, moringa leaf flour, germinated soybean flour, and plantain flour, followed by the addition of water until a thick batter was formed. The batter was molded using a semprong mold and cooked until it was done. The cooked flakes were crushed and blended with skim milk and full cream milk powder to produce instant cereal. The formulation was adapted and modified from the method described (Sholihah et al., 2017).

The independent variable was the proportion of plantain flour substituted in the Kepilor instant cereal formulation. The dependent variables included moisture, ash, protein, fat, and carbohydrate contents and organoleptic acceptability (color, aroma, taste, and texture). The controlled variables included raw material type, processing method, drying temperature and time, and analytical procedures. Chemical analyses were conducted as follows: moisture was determined using the gravimetric method, ash using dry ashing, protein using micro-Kjeldahl, fat using Soxhlet extraction, and carbohydrate by difference. Organoleptic evaluation was performed using a 9-point hedonic scale with 30 semi-trained panelists aged 18–45 years who were healthy and free from food allergies. Samples were presented in a randomized order using random number sequences and labeled with three-digit codes to ensure that the panelists were blinded to the treatment groups. The best treatment was determined using an effectiveness index test involving ten trained panelists.

Data were processed using Microsoft Excel 2020 and SPSS (version 25). Statistical analysis included the Shapiro–Wilk normality and Levene's homogeneity tests. Organoleptic variables (color, aroma, taste, and viscosity) were analyzed using the Kruskal–Wallis test as non-parametric data, whereas nutrient composition and energy-related variables (energy, protein, fat, carbohydrate, fiber, moisture, and ash content) were analyzed using one-way ANOVA as parametric data. Parametric data were analyzed using one-way ANOVA followed by Duncan's Multiple Range Test (DMRT) when significant differences were detected, while non-parametric data were analyzed using Kruskal–Wallis followed by Mann–Whitney tests. Statistical significance was set at a 95% confidence level ($p < 0.05$), applying a one-way ANOVA model consistent with a Completely Randomized Design. Nutrient composition analysis was conducted in triplicate to ensure data reliability, and the best treatment was determined using an effectiveness index method

Results

Product Characteristics

The instant cereal developed in this study consisted of a fine powder blended with small flakes that readily rehydrated upon the addition of water. The formulations primarily comprised germinated soybean flour, moringa leaf flour, and plantain flour. The variation in the proportion of plantain flour influenced the sensory profile of the final product, particularly its aroma and taste attributes. This is supported by the sensory evaluation results (Table 3), where the aroma and taste scores ranged from 6.80–7.53 and 6.10–7.17, respectively.

An increase in plantain flour substitution enhanced the pleasant roasted-flake aroma and intensified the distinctive flavor of plantain. In formulations containing lower levels of plantain flour, a slightly bitter aftertaste associated with moringa leaves was perceptible. However, higher proportions of plantain flour effectively masked or substantially reduced residual bitterness, resulting in a more balanced and palatable flavor profile (Figure 1). This trend is reflected in the higher mean taste score of T2 (7.17 ± 1.11) compared with T1 and T3 (Table 3).

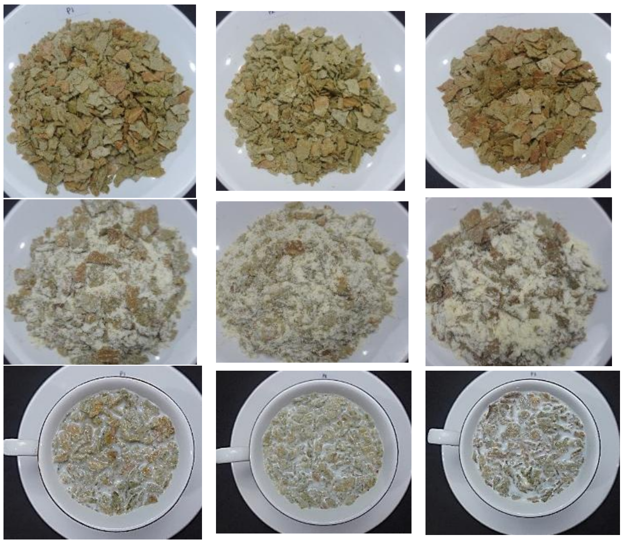

Figure 1. Kepilor instant cereal at each treatment level

From a physical standpoint, the flakes exhibited a crisp texture and relatively mild flavor. When reconstituted with water, the product transformed into a ready-to-serve instant cereal with a sweet and savory taste profile and viscosity comparable to commercially available instant cereals. The color of the prepared cereal was yellowish-green, resulting from the natural pigments of moringa leaves and plantain flour. The color intensity became more pronounced as the proportion of the plantain flour increased.

Overall, the sensory and physical properties of the instant cereal formulated from germinated soybean, plantain, and Moringa leaves (Kepilor) demonstrate promising potential for further development as a locally based functional cereal product. The yields of the flakes used in the instant cereal beverage are presented in Table 2. Increasing the proportion of plantain flour tended to enhance the overall flakes yield.

Table 2. Yield of flakes for Kepilor instant cereal beverage

Treatment	Yield (%)
T1	74.8%
T2	76.7%
T3	80.4%

Organoleptic Evaluation

Sensory testing was conducted to assess the panelists' acceptance of the Kepilor instant cereal beverage in terms of color, aroma, taste, and viscosity across all formulations. Based on the mean scores (Table 3), overall acceptability ranged from "slightly liked" to "liked." The color attribute obtained average scores between 6.43 and 6.73, corresponding to the "slightly liked" category. Aroma received higher ratings, ranging from 6.80 to 7.53, placing it within the "liked" to "very liked" range. Meanwhile, taste and viscosity showed mean scores of 6.10–7.17 and 6.60–6.93, respectively, indicating responses from "slightly liked" to "liked."

When considering the mode values, all attributes across the treatments achieved a minimum score of 7. This finding suggests that most panelists expressed favorable perceptions of the Kepilor instant cereal product at every treatment level.

Table 3. Mean and mode of preference scores for Kepilor instant cereal beverage

Treatment	Color		Aroma		Taste		Viscosity	
	Mean ± SD	Mode	Mean ± SD	Mode	Mean ± SD	Mode	Mean ± SD	Mode
T1	6.43 ± 1.79[a]	7	6.80 ± 1.47[a]	8	6.10 ± 1.71[a]	7	6.67 ± 1.42[a]	7
T2	6.73 ± 1.68[a]	7	7.30 ± 1.14[a]	7	7.17 ± 1.11[b]	7	6.93 ± 1.17[a]	7
T3	6.53 ± 1.61[a]	7	7.53 ± 0.82[a]	8	6.23 ± 1.61[a]	7	6.60 ± 1.61[a]	7
p-value*	0.654		0.162		0.025		0.802	

*Note: *) ased on the Kruskal–Wallis test (p < 0.05), followed by post-hoc analysis. Values followed by the same superscript letter within the same column indicate no statistically significant difference according to the Mann–Whitney post hoc test at α = 5%.*

Statistical analysis indicated that increasing the proportion of plantain flour did not significantly affect the color, aroma, or viscosity of the Kepilor instant cereal beverage ($p > 0.05$). However, a significant effect was observed on the taste attribute ($p = 0.025$).

Taste scores differed significantly among the treatments, with T2 achieving the highest mean preference score (7.17 ± 1.11), which was significantly different from T1 and T3. Despite this significant variation in the mean values, the mode for taste across all treatments remained at a score of 7. This suggests that the panelists generally expressed favorable acceptance of the product's taste in all formulations.

Energy Value and Nutrient Composition

Table 4 presents the analysis of energy content and nutrient composition of Kepilor instant cereal per 100 g, examined using a One-Way ANOVA test. The findings indicate that variations in formulation (T1, T2, and T3) did not result in statistically significant differences ($p > 0.05$) in the energy, protein, fat, carbohydrate, fiber, or ash content. The energy values ranged from 309.69 to 313.75 kcal/100 g, protein from 20.63 to 20.92 g, fat from 4.92 to 5.19 g, carbohydrates from 66.60 to 67.10 g, fiber from 0.79 to 1.08 g, and ash from 4.65 to 4.77 g. These results suggest that altering the proportion of ingredients in the instant cereal formulation did not substantially modify its primary macronutrient profiles.

In contrast, the moisture content differed significantly among the treatments ($p = 0.030$). Treatment T3 exhibited the highest moisture level (3.33 ± 0.22%) compared to T1 (2.57 ± 0.45%) and T2 (2.60 ± 0.07%). This variation may be attributed to the differences in the ingredient compositions across the formulations. The relatively high moisture content observed in T3 could potentially influence the product texture and storage stability.

Table 4. Energy value and nutrient composition of Kepilor instant cereal per 100 gram

Treatment Level	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrates (g)	Fiber(g)	Moisture(g)	Ash(g)
T1	313.75 ± 3.08[a]	20.64 ± 0.22[a]	5.04 ± 0.23[a]	67.10 ± 0.28[a]	0.79 ± 0.16[a]	2.57 ± 0.45[a]	4.65 ± 0.07[a]
T2	313.12 ± 2.22[a]	20.92 ± 0.20[a]	5.19 ± 0.26[a]	66.60 ± 0.19[a]	1.08 ± 0.94[a]	2.60 ± 0.07[a]	4.69 ± 0.12[a]
T3	309.69 ± 1.60[a]	20.63 ± 0.37[a]	4.92 ± 0.13[a]	66.69 ± 0.48[a]	1.05 ± 0.47[a]	3.33 ± 0.22[b]	4.77 ± 0.08[a]
p-value*	0.820	0.398	0.353	0.160	0.820	0.030	0.334

*Note: *) Based on the One-Way ANOVA test (p < 0.05), followed by a post hoc test. Values followed by the same superscript letter within the same column are not significantly different according to Duncan's Multiple Range Test at α = 5%.*

The nutritional composition per 100 g of Kepilor instant cereal generally complies with the Indonesian National Standard for flakes (SNI 4270:2021), particularly regarding the protein (minimum 5 %) and carbohydrate (minimum 60.7 %) contents. In addition, the product does not contain artificial sweeteners, such as saccharin.

However, several parameters do not conform to the SNI requirements, namely, ash content (maximum 4%), moisture content (maximum 3%), and crude fiber content (maximum 0.7%). The moisture levels in treatments T1 and T2 fell within the acceptable limit, whereas T3 exceeded the specified standard.

The fiber content surpassed the SNI maximum limit because the formulation was adjusted to align with dietary fiber recommendations for Special Dietary Foods for individuals with diabetes, as stipulated in BPOM Regulation No. 24 of 2020, which requires 1–1.75 g of fiber per 100 kcal. Nevertheless, when evaluated according to the PKMK criteria, the fiber content does not fully meet the established standard.

Table 5. Energy and nutrient composition of Kepilor instant cereal per serving (27 g instant cereal and 1,5 g / ¼ teaspoon soybean oil)

Treatment Level	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrates (g)	Fiber(g)	Energy Density (kcal/ml)
T1	120.51 ± 0.73^{a}	5.57 ±0,59^{a}	2.86 ± 0,06^{a}	18.12 ± 0.07^{a}	0.21 ± 0.04^{a}	0.602 ± 0.003^{a}
T2	120.63 ± 0.34^{a}	5.65 ± 0,54^{a}	2.90 ±0,07^{a}	17.98 ± 0.05^{a}	0.29 ± 0.25^{a}	0.603 ± 0.001^{a}
T3	119.40 ± 0.10^{b}	5.57 ± 0,99^{a}	2.83 ± 0,03^{a}	17.92 ± 0.17^{a}	0.28 ± 0.13^{a}	0.597 ± 0.0005^{b}
p-value*	0.036	0.398	0.353	0.160	0.820	0.036

*Note: *) Based on the One-Way ANOVA test (p < 0.05), followed by a post hoc analysis. Values followed by the same superscript letter within the same column are not significantly different according to Duncan's Multiple Range Test at α = 5%)*

The results of the energy and nutrient analysis of Kepilor instant cereal, presented in Table 5, indicate that the energy content per serving differed significantly among treatments, ranging from 119.40 to 120.63 kcal. Treatment T2 had the highest energy value, whereas T3 had the lowest. In contrast, protein (5.57–5.65 g), fat (2.83–2.90 g), carbohydrates (17.92–18.12 g), and dietary fiber (0.21–0.29 g) contents did not differ significantly across treatments ($p > 0.05$), suggesting that variations in the proportion of plantain flour did not substantially affect the macronutrient composition.

Energy density differed significantly, with T3 exhibiting the lowest value compared to T1 and T2. One serving of Kepilor instant cereal consisted of 27 g of cereal powder dissolved in 180 mL of warm water at approximately 80°C, yielding approximately 200 mL of cereal beverage. The recommended serving suggestion includes the addition of 1.5 mL of soybean oil (equivalent to ¼ tsp in household measurements) to enhance the intake of polyunsaturated fatty acids.

Table 6. Comparison of the percentage of nutrients in Kepilor instant cereal per serving (27 g instant cereal and 1,5 g/ ¼ teaspoon soybean oil) compared with standards

Treatment Level	Protein (%)	Fat (%)	Carbohydrates (%)
T1	18.50 ± 0.25^{a}	21.36 ± 0.34^{a}	60.13 ± 0.12^{a}
T2	18.73 ± 0.24^{a}	21.64 ± 0.46^{a}	59.63 ± 0.24^{a}
T3	18.66 ± 0.26^{a}	21.31 ± 0.26^{a}	60.03 ± 0.56^{a}
PKMK Standard*	10-20%	20-25%	45-65%
Diabetes Melitus Diet**	10-20%	<35%	45-60%
p-value	0.622	0.523	0.271

*Keterangan: **)Based on BPOM Regulation No 24 of 2020; *) Based on Forouhi et al. 2018*

Table 6 presents the macronutrient distribution of the Kepilor instant cereal. The protein proportion across the three treatments ranged from 18.50% to 18.73%, with no significant differences observed (p = 0.622). The fat content was consistent among the formulations, ranging from 21.31% to 21.64% (p = 0.523). Carbohydrate levels varied between 59.63% and 60.13%, showing no statistically significant difference (p = 0.271). All macronutrient values fell within the PKMK

standards (10–20% protein, 20–25% fat, and 45–65% carbohydrates) and aligned with dietary recommendations for type 2 Diabetes Mellitus (10–20% protein, <35% fat, and 45–60% carbohydrates) as outlined by BPOM (2020) (BPOM, 2020).
Therefore, all three Kepilor instant cereal formulations demonstrated a macronutrient profile that complied with national standards and dietary recommendations for diabetes management, indicating that differences in plantain flour proportion did not significantly influence the overall macronutrient distribution of the product.

Best Treatment Level

Based on the effectiveness index calculation, the most critical parameters of the instant cereal, ranked in order of importance, were energy, carbohydrate, taste, protein, viscosity, aroma, color, fat, moisture, and ash contents.

The formulation identified as the optimal treatment was T2, which achieved the highest total effectiveness score of 0.832. The best-performing formula contained 30% plantain flour (w/w) of the total solid ingredients.

For serving, 27 g of Kepilor instant cereal (T2) was prepared with 180 mL of water and supplemented with ¼ tsp of soybean oil. Each serving of T2 provided approximately 120 kcal of energy, 5.65 g of protein, 2.9 g of fat, 17.92 g of carbohydrates, 0.29 g of fiber, and an energy density of 0.63 kcal/mL.

This formulation complies with the PKMK requirements for diabetes-specific foods and dietary recommendations for individuals with diabetes mellitus.

Discussion

Yield

Table 2 indicates that increasing the proportion of plantain flour led to a higher yield of Kepilor instant cereal flakes. This improvement in yield is likely associated with the substantial starch and fiber content of the plantain flour, which supports the formation of a more stable flake structure during cooking and drying processes.

Table 2 indicates that increasing the proportion of plantain flour led to a higher yield of Kepilor instant cereal flakes. This improvement in yield is likely associated with the substantial starch and fiber content of the plantain flour, which supports the formation of a more stable flake structure during cooking and drying processes. This finding is consistent with previous studies on instant cereal products, which reported that yield is strongly influenced by starch and water content of raw materials, where higher starch levels contribute to greater solid formation and product yield (Muharsyaida et al., 2026)

Starch plays a crucial role in developing the product matrix through gelatinization during heating, thereby reducing material loss during processing (Fitriani V Permana L Setiaboma W, 2019; Lawalata et al., 2018; Tan et al., 2019). Furthermore, the water-binding capacity of dietary fiber contributes to the formation of a more cohesive mass, which enhances the overall yield of the final product (Dewi et al., 2023).

Organoleptic Evaluation

Descriptively, a higher proportion of plantain flour tended to intensify the pleasant aroma of the flakes, although the difference was not significant. This observation is consistent with the findings of Carvalho and Conti-Silva (2018), who noted that incorporating bananas into composite flour products can enhance fruity notes and impart a characteristic natural sweetness (Carvalho & Conti-Silva, 2018). In formulations containing lower levels of plantain flour, the instant cereal beverage still exhibited a slightly bitter aftertaste attributed to the moringa leaves. In treatment T2, increasing the proportion of plantain flour resulted in a more pronounced banana flavor, which helped mask the residual bitterness of moringa, making this formulation more favorable among the panelists.

The bitter aftertaste commonly found in moringa-based products presents a challenge in food development. This sensory attribute is associated with phytochemical compounds, such as glucosinolates and phenolic constituents, which can produce lingering bitter or herbal sensations after consumption (Leone et al., 2016). In the present study, the reduced perception of moringa aftertaste in T2 was likely due to the natural sweetness and distinctive aroma of plantain flour, complemented by the savory contribution of soybean sprouts. Together, these components create a more balanced and acceptable flavor profile (Carvalho & Conti-Silva, 2018).

In terms of texture, the Kepilor flakes were crisp in their dry form. Upon rehydration, the product transformed into a ready-to-drink cereal beverage with a mildly sweet and savory taste and a viscosity comparable to that of commercially available instant cereals. These properties are related to the functional characteristics of plantain flour, which influence the product structure and texture. Khoozani et al. (2020) reported that the use of green banana flour can alter dough structure and produce a denser matrix, supporting the present finding that plantain flour incorporation contributes to the development of a crisp texture after drying or baking (Khoozani et al., 2020).

Beyond textural effects, increasing the proportion of plantain flour also influenced the product color. Previous studies have shown that substituting wheat flour with plantain flour may reduce brightness and intensify yellowish-brown hues due to natural pigment differences and non-enzymatic browning reactions (Bashmil et al., 2025). A similar trend was observed in this study, where higher plantain flour levels resulted in flakes with a deeper yellow-green appearance.

Overall, the organoleptic assessment indicated that the addition of plantain flour primarily affected the taste perception of Kepilor instant cereal, whereas the color, aroma, and viscosity remained relatively consistent across treatments. Given the limited published research on the combined use of plantain flour, soybean sprouts, and moringa leaves in instant cereal formulations, these findings provide a valuable reference for future product development and investigations.

Energy Value and Nutrition Composition

Incorporating tanduk (plantain) flour into the Kepilor cereal formulation increased the moisture, ash, and fiber levels in the final product. These changes were attributable to differences in the ingredient compositions among the treatments. Moringa leaf flour was included primarily to enrich the product with vitamins and minerals, and plantain flour was added to enhance dietary fiber and starch content.

The ash content reflects the total mineral concentration of a food product. In this formulation, the minerals were mainly derived from moringa leaf flour and soybean sprout flour. Moringa is recognized for its high levels of calcium, magnesium, and selenium, which are associated with reduced risk of diabetes-related complications. Calcium homeostasis is essential for proper insulin secretion and sensitivity, and disturbances in calcium balance may impair insulin release and contribute to vascular complications in individuals with diabetes. Magnesium functions as a cofactor in carbohydrate metabolism, particularly by facilitating glucose transport into cells. Insufficient magnesium intake can reduce cellular resistance to oxidative stress, thereby accelerating diabetic complications. Selenium supports the activity of glutathione peroxidase, an antioxidant enzyme that helps reduce reactive oxygen species (ROS) generated under hyperglycemic conditions (Dubey et al., 2020; Steinbrenner et al., 2022).

The carbohydrate content per 100 g of Kepilor instant cereal did not fully meet the recommended standards for diabetes-specific foods or the PKMK guidelines. Therefore, the suggested serving size consisted of 27 g of cereal powder mixed with 180 mL of water and supplemented with ¼ tsp (1.5 mL) of soybean oil, yielding approximately 200 mL per serving. Plantain flour serves as the primary carbohydrate source and contributes both dietary fiber and resistant starch to the formulations.

Resistant starch from plantain has been reported to exert glycemic control benefits. Evidence suggests that diets rich in resistant starch may lower fasting blood glucose levels, reduce insulin secretion, and improve insulin sensitivity. This effect is linked to its prebiotic function: resistant starch escapes digestion by amylase in the small intestine and undergoes fermentation by the colonic microbiota, producing short-chain fatty acids (SCFAs). One such SCFA, butyrate, stimulates L cells to release incretin hormones, particularly glucagon-like peptide-1 (GLP-1). GLP-1 plays a role in regulating fasting glucose levels, enhancing insulin secretion and gene expression, suppressing glucagon synthesis, and delaying gastric emptying (Priyadarshini et al., 2017; Zhang et al., 2015).

The protein in the instant cereal was derived from soybean sprout flour, skim milk, and eggs. Soybean sprouts were incorporated not only to increase protein levels but also because soy contains bioactive compounds and an amino acid profile that is suitable for individuals with type 2 diabetes. Soybeans are a plant-based protein source with a complete essential amino acid composition, containing approximately 30–40% protein with a profile comparable to the human essential amino acid requirements (Chatterjee et al., 2018). Although animal proteins also provide essential amino acids, they are often higher in saturated fat and cholesterol content. Soy protein contains no cholesterol and has relatively lower methionine and branched-chain amino acids (BCAAs) than animal proteins (Zuo et al., 2023). Excessive BCAA intake is associated with metabolic disturbances, including obesity, insulin resistance, cardiovascular disease, and type 2 diabetes (Neinast et al., 2019). Additionally, stigmasterol in soy has been linked to improved glucose metabolism and beta cell regeneration through enhanced GLUT4 translocation and improved insulin sensitivity (Bakrim et al., 2022). Soy isoflavones, functioning as phytoestrogens, interact with estrogen receptors in various tissues and exert modulatory effects on endogenous estrogen balance while also providing cardioprotective and antidiabetic antioxidant benefits (Im & Park, 2021; Zuo et al., 2023).

The fat content of the product originated from soybean oil and soybean sprout flour. Soybeans are rich in unsaturated fatty acids, particularly oleic and linoleic acids, and germination has been shown to increase palmitic, stearic, linoleic, and linolenic acid levels (Ghani et al., 2016). A higher linoleic acid intake has been associated with improved glycemic control and enhanced insulin sensitivity, potentially reducing the risk of type 2 diabetes (Belury et al., 2018).

Although the total dietary fiber content did not differ significantly among the treatments, fiber remains a critical component in the management of type 2 diabetes. It slows glucose absorption and attenuates postprandial glycemic responses. Plantain flour provides both fiber and resistant starch, which are fermented in the colon to produce short-chain fatty acids that support insulin sensitivity and glucose homeostasis (Vernaza & Chang, 2017; Zhang et al. 2019).

Statistical analysis showed that variations among the treatments (T1, T2, and T3) significantly affected the total energy and energy density ($p < 0.05$) but did not significantly alter the protein, fat, carbohydrate, or fiber content ($p > 0.05$). This indicates that formulation differences primarily influenced the energy per unit volume, likely due to variations in moisture and total solids rather than changes in macronutrient proportions. This finding aligns with the concept of dietary energy density, wherein foods with higher water content tend to exhibit lower energy density without substantial differences in macronutrient composition (Rolls, 2017).

The energy value of the cereal beverage ranged from 119 to 121 kcal per serving, which falls within the typical 100–200 kcal range recommended for snack portions in diabetes dietary interventions (Dimopoulou et al., 2024; Masutomi et al., 2023). Such energy standardization aims to prevent excessive caloric intake while maintaining stable postprandial glucose levels. Treatment T3 demonstrated the lowest total energy and energy density (approximately 0.60 kcal/mL), categorizing it as a low-energy-density food (<1.0 kcal/mL). Diets characterized by low energy density are consistently associated with reduced total energy intake and greater satiety, primarily because of the higher water and fiber content, which enhances gastric distension and modulates appetite-regulating hormones (Reynolds et al., 2019; Rolls, 2017). Contemporary evidence indicates that dietary patterns rich in low-energy-dense foods, such as vegetables, fruits, legumes, and whole grains, contribute to improved weight management and a lower body mass index, which are critical factors in reducing insulin resistance and preventing type 2 diabetes (Neuenschwander et al., 2019; Schwingshackl et al., 2017). Furthermore, prospective cohort studies have demonstrated that high-energy-density dietary patterns are associated with an increased risk of type 2 diabetes, whereas diets emphasizing fiber-rich, minimally processed foods exert protective effects on glucose metabolism and insulin sensitivity (Merino et al., 2019).

From a functional food development perspective, a cereal beverage with low energy density represents a promising snack alternative for individuals with diabetes, as it can promote satiety while delivering controlled energy intake and support overall dietary quality and glycemic management (Drewnowski et al., 2015).

In practical terms, this product may serve as a convenient ready-to-consume option that aligns with dietary recommendations for type 2 diabetes, particularly in improving portion control and facilitating adherence to low-glycemic and nutrient-dense dietary patterns. Additionally, the use of locally available ingredients enhances the potential accessibility and sustainability of broader community-based dietary interventions.

Conclusion

The formulation containing 30% plantain flour (T2) was identified as the best-performing treatment based on overall effectiveness, achieving the highest panelist acceptance and a balanced nutritional profile.

Soybean sprouts and moringa leaf flour (Kepilor) show potential for development as functional food products aligned with dietary principles for diabetes mellitus. The variation in the proportion of plantain flour influenced the sensory characteristics and energy-related properties, particularly taste and energy density, without significantly affecting the overall macronutrient composition.

The selected formulation (T2) exhibited favorable sensory acceptance, low energy density, and macronutrient distribution consistent with the standards for diabetes-oriented dietary products. These findings suggest that Kepilor instant cereal may serve as a potential snack or cereal beverage option within controlled dietary patterns.

However, this study was limited to sensory evaluation and nutrient composition analyses. Further research is required to evaluate the glycemic index, postprandial glycemic response, resistant starch content, product stability, and shelf life. In addition, clinical studies are necessary to confirm its effectiveness in individuals with diabetes mellitus.

Declaration of Conflict of Interest

The authors declare that this study was conducted in the absence of any financial or nonfinancial relationships that could be construed as potential conflicts of interest, wheter involving the authors or their affiliated institutions

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