Jurnal Gizi dan Dietetik Indonesia
(Indonesian Journal of Nutrition and Dietetics)
Vol 14, Issue 3, 2026: 199-209

Available online at: https://ejournal.almaata.ac.id/index.php/IJND
p-ISSN 2303-3045 e-ISSN 2503-183X
DOI: https://dx.doi.org/10.21927/ijnd.2026.14(3).199-209

The development of low-glycemic, antioxidant-rich moringa–beetroot enteral nutrition for diabetic and stroke patients

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ABSTRAK

Latar Belakang: *Pasien dengan stroke dan diabetes melitus (DM) berisiko mengalami disfagia dan rentan terhadap malnutrisi. Oleh karena itu, formula enteral dipilih sebagai bentuk terapi nutrisi dan diformulasikan secara khusus agar memiliki indeks glikemik rendah serta kaya akan antioksidan.*

Tujuan: *Penelitian ini bertujuan untuk mengetahui komposisi proksimat, kapasitas antioksidan, viskositas, total nilai kalori, dan indeks glikemik dari formula enteral yang disubstitusi dengan bit dan kelor.*

Metode: *Penelitian ini menggunakan rancangan acak lengkap yang terdiri dari tiga kelompok perlakuan dan satu kelompok kontrol. Kelompok kontrol menerima Formula Rumah Sakit (FRS), sedangkan kelompok perlakuan terdiri dari Formula Modifikasi dengan tambahan bit (FRS-B) dan bubuk kelor (FRS-M). Uji total kalori dilakukan dengan kalorimetri bom, analisis makronutrien dengan uji proksimat, viskositas dengan viskometer rotari, daya alir menggunakan selang NGT 16 Fr, analisis kapasitas antioksidan dengan uji DPPH, dan indeks glikemik dengan respons glukosa darah. Data dianalisis menggunakan uji t independen, uji t berpasangan, uji Mann-Whitney, dan uji Wilcoxon.*

Hasil: *FRS-B memenuhi prinsip diet stroke-DM dengan kandungan karbohidrat rendah, lemak rendah, dan protein tinggi, meskipun masih perlu peningkatan kadar protein. Viskositasnya memenuhi standar National Dysphagia Diet. Aktivitas antioksidan FRS secara signifikan lebih tinggi dibandingkan dengan formula enteral FRS-B. Indeks glikemik formula FRS-B tergolong tinggi, namun beban glikemiknya rendah. Kandungan energi FRS lebih besar (0.9 kkal/ml) dibandingkan FRS-B (0.7 kkal/ml).*

Kesimpulan: *Secara keseluruhan, formula enteral FRS-B menunjukkan potensi sebagai terapi nutrisi bagi pasien stroke-DM karena memenuhi kebutuhan diet pada pasien dengan disfagia dan menawarkan manfaat antioksidan. Namun, diperlukan perbaikan pada kandungan protein dan indeks glikemik untuk mengoptimalkan aplikasinya secara klinis.*

KATA KUNCI*:* *bit; diabetes mellitus; kelor; nutrisi enteral; stroke*

ABSTRACT

Background: *Patients with stroke and diabetes mellitus (DM) are at risk of developing dysphagia and are therefore susceptible to malnutrition. Consequently, enteral formulas are selected as a form of nutritional therapy and are specifically formulated to have a low glycemic index and be rich in antioxidants.*

Objectives*: This study aimed to determine the proximate composition, antioxidant capacity, viscosity, total caloric value, and the glycemic index of the tested enteral nutrition.*

Methods: *This study employed a completely randomized design, featuring three treatment groups and one control group. The control group received the Hospital Formula (FRS-C), while the treatment groups included a Modified Formula with added beetroot (FRS-B) and moringa powder (FRS-M). Total calorie test using bomb calorimetry, macronutrient analysis with proximate test, viscosity with rotary viscometer, flow power on 16 Fr NGT tube, antioxidant capacity analysis with DPPH test, and glycemic index with blood glucose response. Data were analyzed using an independent T-test, a paired sample T-test, Mann-Whitney, and Wilcoxon.*

Results: *FRS-B meets the principles of stroke-DM diet with low carbohydrate, low fat, and high protein, although it needs to increase protein. Its viscosity meets the National Dysphagia Diet standards. The antioxidant activity of FRS is significantly higher than FRS-B enteral formula. The FRS-B glycemic index formula is high, but the glycemic load is low. The energy content of FRS is greater (0.9 kcal/ml) than the FRS-B (0.7 kcal/ml).*

Conclusions: *To summarize, the FRS-B enteral formula demonstrates potential as a nutritional therapy for stroke-DM patients, as it meets dietary requirements for dysphagia and offers antioxidant benefits, although improvements in protein content and glycemic index are necessary to optimize its clinical applicability..*

KEYWORDS***:*** *beetroot; diabetes mellitus; enteral nutrition; moringa; stroke*

Article info: Received April 20, 2025; 1st revision May 23, 2025; 2nd revision June 20, 2025; 3rd revision July 18, 2025; 4rd revision September 22, 2025; accepted November 25, 2025; available online May 29, 2026; published May 29, 2026.

INTRODUCTION

Diabetes mellitus (DM) is a chronic disease indicated by persistently increased blood glucose or hyperglycemia (1). Hyperglycemia decreases nitric oxide (NO) and promotes the formation of atherogenic low-density lipoprotein (LDL), leading to reduced cerebral circulation and increased endothelial dysfunction, consequently increasing the risk of ischemic stroke (2). Diabetes often coexists with other cardiometabolic risk factors that independently double the risk of stroke compared to those without diabetes, even after adjusting for age (2). Moreover, diabetic patients tend to experience poorer outcomes following a stroke and face a higher risk of recurrence (3). Despite this, no major clinical trials have focused specifically on stroke dietary management strategies in diabetic individuals, highlighting a critical gap in care. Glycemic control through diet management is a key factor in preventing disease progression of both diabetes and stroke (4). Consuming low glycemic index food is known to be effective in glycemic control and improving metabolic biomarkers (5). Damage caused by oxidative stress and inflammation can be reduced by consuming food rich in antioxidants such as polyphenols (6). Red beetroot (Beta vulgaris L.) contains inorganic nitrate and polyphenols that support NO production, especially under hypoxic conditions like ischemic stroke (7). Nitrate is reduced to nitrite and NO, improving blood flow and reducing platelet aggregation. Polyphenols further enhance this effect through anti-inflammatory actions, making beetroot a potential dietary aid in stroke management (8).

Similarly, Moringa (Moringa oleifera) contains flavonoids, polyphenols, and isothiocyanates that exhibit strong antioxidant effects (9). Preclinical studies using ethanolic Moringa extracts have shown neuroprotective activity against ischemic stroke in animal models, reducing infarct volume and oxidative stress markers while increasing antioxidant enzymes like SOD and CAT. While clinical studies are still lacking, evidence suggests that Moringa has promising therapeutic value in reducing stroke-induced oxidative damage and inflammation (10).

Enteral nutrition (EN) is an alternative nutritional therapy for patients with a functional digestive system who cannot meet their nutritional needs orally due to dysphagia, commonly found in stroke (11). EN are usually made according to the food recipe standard (FRS) used in hospitals, with further modifications according to patients' specific nutritional requirements. The EN formula specifically for treating hyperglycemia is mainly made of peptides with added antioxidant compounds, resulting in a formula that is low in carbohydrate, high in monounsaturated fatty acids and fiber, as well as possessing anti-inflammatory effects (12).

Incorporating Moringa and red beetroot into the EN formula may enhance its benefits, as they both contain polyphenols and antioxidants that regulate blood glucose, reduce inflammation, and support vascular health. Although early initiation of EN is beneficial, interruptions, depending on their underlying causes, can delay the time needed to reach nutritional targets (13). Therefore, this study aims to develop an enteral nutrition formula for diabetic stroke patients to maintain blood glucose levels, reduce inflammation, prevent hospital malnutrition, shorten the length of stay, and improve overall outcomes.

MATERIALS AND METHODS

Design, location, and time

This study used a completely randomized design (CRD) with 3 formulas: hospital control formula (FRS), modified enteral formula with added beetroot powder (FRS-M), and modified enteral formula with added beetroot powder (FRS-B). Organoleptic scale was used to decide on the most preferred formula by panelists (14), resulting in FRS-B as the most liked and later used for glycemic index testing (15). This research received approval from the Health Research Ethics Commission of the Faculty of Nursing and Health Science, number 202/KE/2024/Bioethics Commission. The study was carried out at the Dietetic Laboratory, Food Technology Laboratory, and Biochemistry Laboratory at Universitas Muhammadiyah Semarang for the formula development, viscosity measurement, and blood glucose examinations, respectively, while the nutritional proximate test was done at the TPHP Public Service Testing Laboratory, Gadjah Mada University, Yogyakarta, Indonesia.

Moringa and Beetroot Powder Preparation

Moringa powder was prepared according to Rathore et al. (2022). Moringa oleifera leaves were collected and thoroughly washed, then blanched and cooled before being dried in a food dehydrator at 50°C until fully dried (16). Beetroot powder was prepared according to Mitrevski et al. (2023). Beetroot was cleaned, peeled, and sliced into thin pieces approximately 1 mm thick, then arranged in a single layer and dehydrated at 50°C until fully dried (17). Both dried materials were then ground into fine powder and stored in an airtight sealed container.

Specific Enteral Nutrition Formulations

Formulas were designed by modifying the food recipe standard (FRS) for hospital enteral formulas and calculating the estimated nutritional value using Nutrisurvey 2007 to provide approximately 1800 calories. The formula composition is shown in **Table 1**. Oat milk was prepared by blending rolled oats with ice water (1:4 w/v) for 30 seconds and filtering through a clean cloth to obtain non-slimy milk (15). Multigrain milk was produced by soaking nuts in water for 4–6 h, steaming for 45 min over medium heat, blending with water (1:10), filtering, and then boiling over low heat (18). Dates, steamed carrots, steamed egg whites, oranges, and water were blended and strained. Beetroot and moringa powder were each dissolved in 10 mL of water and filtered. Finally, all components were combined according to the composition listed in **Table 1.**

Calorie Testing

The energy content analysis stage used a bomb calorimeter test (Thermo Scientific Nicolet iS10 FT-IR Spectrometer) by adding 1 gram of the sample into the vessel, then adding 1 ml of distilled water, and maintaining oxygen flow at 30 atm/bar. Water heated to 25-30 degrees Celsius was flowed into the tool, and the water temperature increase would be the result of the energy content (19).

Table 1. Composition of control and modified enteral formula

Ingredients	Weight	Formula		
		FRS	**FRS-M**	**FRS-B**
Rolled oat	90 g	-	+	+
Multigrain mix	100 g	-	+	+
Dates	30 g	-	+	+
Skim Milk	150 g	+	+	+
Full cream milk	120 g	+	-	-
Whey protein milk	30 g	-	+	+
Egg whites	150 g	+	+	+
Orange	100 g	+	+	+
Carrot	100 g	+	+	+
MCT	15 mL	-	+	+
Inulin	10 g	-	+	+
Sugar	5 g	+	+	+
Xanthan gum (0,05%)	0.4 g	-	+	+
Vanilla powder	5 g	-	+	+
Soy lecithin	1.95 g	-	+	+
Beetroot powder (1%)	7.8 g	-	-	+
Moringa powder (1%)	7.8 g	-	+	-
Water	1800 mL	+	+	+

Macronutrient Analysis

Proximate analysis was conducted to determine macronutrient composition, employing standard AOAC methods: protein content by Kjeldahl (AOAC 2005), fat via Soxhlet extraction (AOAC 920.39), moisture using thermogravimetry (AOAC 925.10), ash through drying (AOAC 923.03), crude fiber by acid and alkali digestion (AOAC 962.09), and carbohydrate calculated by difference (20).

Viscosity & Flow Rate Measurement

Viscosity was measured using the NDJ-5 digital viscometer (Vevor, Shanghai, China) following the manufacturer's instructions. Measurements were conducted at room temperature (16–24°C). Results were the average of several test repetitions and were expressed in cP (centipoise) units. The formula flow rate was assessed using the International Dysphagia Diet Standardization Initiative (IDDSI) Syringe Flow Test. This procedure was repeated three times, and the average volume was used to determine the IDDSI thickness level (21).

Antioxidant Activity Analysis

The DPPH assay was used to evaluate the antioxidant capacity of the enteral nutrition samples. Absorbance was measured at 517 nm using a spectrophotometer. The antioxidant activity was determined by the reduction in DPPH solution absorbance (22).

Glycemic Index Analysis

Glycemic index analysis involved a total of 19 physically healthy adults aged 18–30 years, non-smokers, with no family history of diabetes mellitus, BMI of 18.5–22.9 kg/m², neither pregnant nor breastfeeding, not taking medications that could affect blood glucose levels, had normal fasting blood glucose levels (70–100 mg/dL), and had filled out an informed consent form. Participants were randomly assigned to one of two sequences: receiving the Control Intervention (FRS) followed by the Treatment Intervention (FRS-B), or vice versa, with a one-week washout period in between sequences. For each treatment, blood glucose was checked five times: pre-intervention (fasting blood glucose after 8 hours of fasting), then post-intervention at 15th, 30th, 60th, 90th, and 120th minute. Based on TKPI 2017, portions of glucose and cereal products provided were 50 g of total carbohydrates.

The glucose response data for each subject were entered into a curve with the x-axis showing time and the y-axis for blood glucose levels, then the area under the control intervention curve and the treatment intervention were compared to obtain the glycemic index value. The formula for calculating the area of a curve using the IAUC method is:

$$L = \frac{\Delta 15t}{2} + \Delta 30t + \frac{\Delta 30t}{2} + \Delta 60t + \frac{\Delta 30t - \Delta 60t}{2} + \Delta 90t + \frac{\Delta 60t - \Delta 90t}{2} + \Delta 120t + \frac{\Delta 90t - \Delta 120t}{2} \quad [1]$$

$$\text{Glycemic index} = \frac{area\ under\ the\ treatment\ blood\ glucose\ curve}{area\ under\ the\ control\ blood\ glucose\ curve} \times 100\% \quad [2]$$

$$Glycemic\ load = \frac{AUC}{100} \times available\ carbohydrate\ per\ serving \quad [3]$$

After the curve value is obtained, the glycemic index value is calculated using this equation (23) [2]. Other than glycemic index, glycemic load was also calculated with the following equation (24) [3].

Data Analysis

Normality was assessed using the Shapiro–Wilk test. Normally distributed data were analyzed with an independent t-test, and non-normal data with the Mann–Whitney U test. Glycemic index blood glucose responses were evaluated using a paired t-test or Wilcoxon signed-rank test ($p < 0.05$). Analyses were conducted at a 95% confidence level using GraphPad Prism version 10 (GraphPad Software, San Diego, CA, USA).

RESULTS AND DISCUSSIONS

Calorie Content

Nutrisurvey 2007 was used for the initial estimation of energy content, showing a slight difference between FRS and specific enteral formulas (**Table 2**). In contrast, bomb calorimeter analysis revealed that FRS had higher energy (**Table 2**). However, neither FRS (0.918 kcal/mL) nor the specific formulas fulfilled (0.747 kcal/mL) the energy requirements of a standard enteral formula (±1.0 – 1.2 kcal/mL). Nevertheless, both formulas may still be administered to patients every 3 to 6 hours for 20 to 60 minutes each. Enteral formulas should be given no more than 250 mL per feeding to prevent stomach retention and regurgitation. Providing approximately 1800 to 2000 mL of the formula would adequately fulfill adult patients' daily energy needs without risks of overfeeding (25).

The significant discrepancy between the estimated and measured values may be attributed to the effects of food processing methods, such as boiling, frying, steaming, and grilling. These processes can cause macronutrient degradation or loss (26), consequently leading to a reduced actual energy content compared to estimations based on food composition databases. This highlights the importance of direct laboratory analysis for accurate nutritional assessment, especially for processed food products (27).

Table 2. Energy content of enteral formulas

Sample	Total Calorie by Nutrisurvey 2007 (kcal)	Calories/100 g by Bomb Calorimeter
FRS	1.812.1	918.08±24.46
FRS-B	1.843.3	747.56±9.84

Nutritional Content

Nutritional content analyzed in this can be seen in **Table 3**. The nutritional content was then compared to dietary requirements for diabetic patients as per PERKENI guidelines and AsDI recommendations for stroke patients (**Table 3**). Carbohydrate content was lower in FRS-B than in FRS due to the addition of ingredients with high complex carbohydrates like rolled oats. Rolled oats have a low glycemic index (43.4-64.6) and contain high fiber (60% insoluble fiber and 40% soluble fiber) (28,29). Inulin is a group of complex carbohydrates with low-calorie content (25-35% energy), recommended for glycemic control of DM patients. FRS-B used less sugar than FRS, resulting in different carbohydrate content. **Table 3** showed that the overall carbohydrate levels of FRS-B are lower than PERKENI recommendations, but still within the minimum requirement of 130 g/day. Consuming 1800 ml of FRS-B provides 149.526 g of carbohydrate (>130 g).

No significant difference was observed between FRS and FRS-B in terms of protein content, but FRS-B appears slightly higher, possibly due to the addition of whey protein milk. Whey protein is well-known as a superior protein source because of its digestibility, bioavailability, and near-complete amino acids (30). Moreover, whey protein is rich in branched-chain essential amino acids (BCAA), which play an important role in blood glucose homeostasis (31). As seen in **Table 3**, the protein content of FRS-B complies with recommendations for stroke patients according to PERSAGI and AsDI. However, it might need to be enhanced as stroke patients have higher protein needs. A stroke attack triggers hypermetabolic and inflammatory responses, which induce protein breakdown and muscle catabolism (32). Insufficient protein intake among stroke patients leads to higher risks of malnutrition, muscle wasting, and poor functional outcomes. Clinical guidelines recommend increased protein intake for stroke patients, typically 1.2 to 1.5 g/kg/day (33). FRS-B contained whey protein milk, which is rich in BCAA, including leucine, that can modulate inflammation and aid recovery. Studies showed that protein supplementation during rehabilitation can enhance muscle function and improve overall recovery in post-stroke patients (34). For fat content, FRS-B is lower than FRS, as it was indeed designed to have lower fat to support the treatment of Stroke-DM patients. In this research, medium-chain triglyceride (MCT) from coconut oil was used as the main fat source in FRS-B. MCTs are rapidly absorbed and metabolized, providing a quick energy source without requiring bile salts for digestion, which is useful for patients with increased energy demands, such as stroke patients with compromised gastrointestinal function (35).

In diabetic patients, MCTs have been shown to improve insulin-mediated glucose metabolism, suggesting a role in better glycemic control (36,37). Consuming enteral formulas enriched with MCTs has led to improved nutritional status markers like albumin levels, which are crucial for recovery in stroke patients (36). Incorporating MCTs into enteral formulas may offer metabolic advantages for stroke and diabetic patients, aiding in energy intake and glycemic control (38).

Table 3. Nutritional composition and comparison with recommendations of stroke-DM specific enteral formula

Nutrient	Composition (%, Mean±SD)		Nutritional Value		% of Intake	Recommendation
	FRS	FRS-B	1800 ml	2000 ml		
Carbohydrate	11.05±0.15	8.31±0.29*	149.53 g	166.14 g	44.45%	45-65%*
Protein	2.04±0.05	2.37±0.26**	42.71 g	47.46 g	12.70%	10-20%**
Fat	2.68±0.10	1.76±0.26*	31.68 g	35.2 g	21.19%	20-25%*
Energy	-	-	1345.61 kcal	1495.12 kcal	-	1100-1500 kcal**
Water	83.84±0.22	87.11±0.10*	-	-	-	-
Ash	0.38±0.01	0.45±0.02*	-	-	-	-
Crude Fiber	0.02±0.02	-	-	-	-	-

Asterisk notation indicates statistical significance: $p < 0.05$ (*), $p < 0.01$ (**), [a] Recommendation for DM (PERKENI, 2021), [b] Recommendation for Stroke (PERSAGI and ASDI, 2019).

Viscosity and Flow Rate

Clinical guidelines emphasize that enteral formulas should have a viscosity that allows unimpeded flow through standard feeding tubes without compromising patient safety or nutritional adequacy (39). Highly viscous formulas may increase the risk of tube clogging, delay gastric emptying, and compromise nutrient delivery (40). Conversely, formulas that are too dilute may potentially cause gastroesophageal reflux and aspiration, particularly in neurologically impaired patients (41). Proper viscosity also contributes to formula stability and homogeneity (12). Results showed that the viscosity of FRS-B (**Table 4**) was compatible with the NGT bore size and suitable for applications in hospital settings. FRS-B showed higher viscosity than FRS, though both met the 1–50 cP thin-liquid standard of the National Dysphagia Diet (NDD) (40). Viscosity is greatly influenced by fiber (42), and FRS-B was made from rolled oats and beetroot that contribute to its fiber content. Rolled oats are rich in β-glucan, while beetroot contains pectin (43,44); both are fibers with medium to high viscosity that contribute to increased consistency. Maintaining viscosity within this specified range is critical, as deviations can adversely affect bolus flow and swallowing mechanics, potentially increasing aspiration risk (45). These results proved that both FRS and FRS-B are suitable for therapeutic use in dysphagia management while allowing for variation in texture based on formulation adjustments. **Table 4** showed that FRS had a faster flow rate than FRS-B, consistent with the viscosity test.

The addition of xanthan gum, oat, and multigrain mix to the formula might influence the viscosity and flow rate of FRS-B. Xanthan gum was used as a thickening agent to replace starch-based thickeners (e.g., modified corn and potato) for clinical treatment of dysphagia due to its better texture, cohesiveness, stability against temperature, and resistance to salivary α-amylase (46). Oats contain β-glucan with hydrocolloid properties that can prevent separation by forming a gel and stabilizing oat milk, thus reducing the risk of creaming (47). Furthermore, the main starch component of the multigrain oats contributes to improving the texture and mouthfeel of the formula (48).

Table 4. Viscosity, flow rate, and antioxidant activity of enteral nutrition formulas at room temperature

Enteral Formula	**Viscosity (cP)**	***p-value***	***Flow Rate***		***Antioxidant Activity (%)***	***p-value***
			Time (second)	**Flow rate (cc/second)**		
FRS	1.56±0.24	0.001*	7	7.14	23.43**±**0.13	0.010*
FRS-B	3.19±0.22		12	4.16	22.17**±**0.13	

** asterisk notation indicates statistical significance*

Antioxidant Activity

Antioxidant activity (**Table 4**) was slightly lower in FRS-B compared to FRS, most likely due to phytochemical changes in the ingredients during processing that involved altered temperature, pH, oxygen levels, and water content (49,50). The multigrain beans used as the ingredient in FRS-B were steamed before being added to the formula. Steaming could reduce antioxidant levels by 30-40% due to thermal degradation (51). Beetroot was also susceptible to phytochemical changes, since high temperature (>100°C) and changes in water activity reportedly decreased betalain concentration (52,53).

Glycemic Index

Blood glucose concentrations (mg/dL) were measured at 0, 15, 30, 60, 90, and 120 minutes after ingestion of test foods containing 50 g of available carbohydrates. Values are expressed as mean ± SD. For the control (sucrose), blood glucose levels were 85.69 ± 5.67, 127.81 ± 19.39, 139.69 ± 14.76, 118.69 ± 22.75, 97.55 ± 13.57, and 86.50 ± 7.72 mg/dL at 0, 15, 30, 60, 90, and 120 minutes, respectively. For the intervention (FRS-B), values were 91.13 ± 7.79, 120.19 ± 12.07*, 129.31 ± 20.92*, 103.06 ± 21.27**, 99.31 ± 9.20, and 93.25 ± 9.30* mg/dL at the corresponding time points. Statistical comparisons between groups at each time point were performed using an independent t-test. *p < 0.05, **p <0.01.

Glycemic index measures how fast carbohydrate-containing foods raise blood glucose, where low glycemic index foods are recommended for better glycemic control because they are digested slowly with gradual glucose release. The glycemic index of FRS-B was 93,70 which is considered high (**Figure 1**). This is due to its liquid form, which facilitates the digestion and absorption of monosaccharides and disaccharides (54). When a large amount of rapidly soluble and absorbed carbohydrates is introduced into the digestive tract, blood glucose increases rapidly (55). Fiber and protein are important to counter these effects. Fiber increases the viscosity of the digesta, enhancing satiety and slowing glucose absorption rate, leading to a lower overall glycemic index. Soluble fiber in beetroot, like pectin, has been shown to hinder the activity of amylase and consequently lowering glucose absorption (55). Similarly, protein reduces glycemic index by delaying gastric emptying and influencing glucose absorption, although its effect may not be as pronounced. Other factors that impact glycemic index include monosaccharide type, starch structure, and amylose to amylopectin ratio (56).

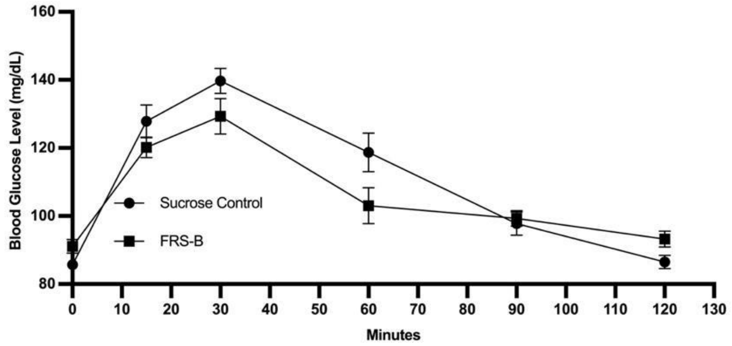

Figure 1. Blood glucose response following consumption of FRS-B and sucrose over 120 minutes.

Other than glycemic index, another important aspect to consider in the treatment of diabetic patients is glycemic load (GL) (25). GL are generally categorized into three types: low (<10), medium (11-19), and high (>20) (57). The results showed that FRS-B has a low glycemic load (5.27). Low GL implies prolonged gastric emptying rate as the entry of chyme into the intestines is delayed, leading to slower glucose absorption in the duodenum and jejunum. Accordingly, pancreatic insulin secretion is suppressed, and blood glucose spikes are prevented (24).

CONCLUSION AND RECOMMENDATION

Enteral formula FRS-B met dietary and viscosity standards for stroke-DM patients but failed to meet caloric requirements. It showed a low glycemic load, indicating potential glycemic control benefits. Further formulation is needed to increase protein, energy, and antioxidant activity, as well as to improve nutrient bioavailability and overall functional properties.

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