Food Research 8 (2) : 443 - 452 (April 2024)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

Modification of the GLITEROS diabetes-specific hospital enteral formula based on jicama flour and tempeh flour with the addition of sunflower seed flour

[1]Wijayanti, L., [2]Muniroh, M., [3]Al-Baarri, A.N., [1,4]Fitranti, D.Y., [5]Mahati, E. and [1,4,*]Afifah, D.N.

[1]Department of Nutrition Science, Faculty of Medicine, Universitas Diponegoro, Semarang, Indonesia
[2]Department of Physiology, Faculty of Medicine, Universitas Diponegoro, Semarang, Indonesia
[3]Department of Food Technology, Faculty of Animal and Agricultural Sciences, Universitas Diponegoro, Semarang, Indonesia
[4]Center of Nutrition Research (CENURE), Universitas Diponegoro, Semarang, Indonesia
[5]Department of Pharmacology, Faculty of Medicine, Universitas Diponegoro, Semarang, Indonesia

Article history:
Received: 19 March 2022
Received in revised form: 10 May 2022
Accepted: 7 October 2022
Available Online: 26 April 2024

Keywords:
Enteral formula,
Diabetic mellitus,
Sunflower seed flour,
Tempeh flour,
Jicama flour

DOI:
https://doi.org/10.26656/fr.2017.8(2).150

Abstract

The diabetes-specific enteral formula is necessary to assist glycemic control for critically ill diabetic patients. The GLITEROS enteral formula is an innovative diabetes-specific hospital enteral formula made from local food, jicama flour and tempeh flour. However, the fat content in the GLITEROS enteral formula does not meet the fat requirements for a diabetes-specific enteral formula. Sunflower seeds are a good food source of monounsaturated fatty acids, specifically oleic acid which has antidiabetic effects. The addition of sunflower seeds to the GLITEROS enteral formula as a modification can optimize the lack of fat content. This study aimed to analyze the macronutrient content, dietary fiber, protein digestibility, and physical properties, including viscosity and osmolality of the modified GLITEROS enteral formula. This research was an experimental study with four formula groups, Formula A, B, C, and D, with different ratios of tempeh flour, jicama flour, and sunflower seed flour; (1:1:1), (1:1:2), (1:2:1), and (2:1:1). The variables of this study were energy density, calories, carbohydrates, fat, protein, dietary fiber, protein digestibility, viscosity, and osmolality were tested with three repetitions in duplicate. Data analysis used One-way ANOVA and the Kruskal-Wallis test. Formula B had the highest density of energy, energy, fat, and dietary fiber compared to the four formulas. Meanwhile, Formula C had the highest protein content and digestibility value compared to other formulas. The highest viscosity and osmolality values were in formula A. Formula C was the most qualified formula in terms of macronutrient content, dietary fiber, protein digestibility, and physical properties of diabetes-specific enteral formulas according to the requirements of the American Diabetes Association (ADA), Canadian Diabetes Association (CDA), American Society of Parenteral and Enteral Nutrition (ASPEN).

1. Introduction

Diabetes Mellitus (DM) is one of the fastest-growing chronic diseases with a prevalence increasing in an epidemic worldwide (Huhmann *et al.,* 2018; Sørensen, 2022). Intensive care (ICU) sometimes will be required for patients with diabetes mellitus who are in critical condition or DM that progresses to severe acute disease (Kar, 2015). It is known that diabetic patients admitted to the ICU are more susceptible to decreased glycemic control and complications due to pathophysiological responses to acute disease and impaired immune cell function. Appropriate nutritional support is needed to keep the patient's blood glucose levels in control, in addition to the significant increase in energy and protein requirements as well as their state of high inflammation, increased stress, and catabolism (Ojo *et al.*, 2019; Ojo *et al*, 2022).

Especially in diabetic patients with swallowing disorders or unconsciousness, both enteral and parenteral nutritional support are needed because of the patient's inability to receive food orally (Lewis *et al.*, 2016). In addition, to meet dietary needs, providing nutritional support for diabetic patients must also keep the patient's blood glucose levels under control. Enteral nutrition

*Corresponding author.
Email: *d.nurafifah.dna@fk.undip.ac.id*

eISSN: 2550-2166 / © 2024 The Authors.
Published by Rynnye Lyan Resources

support is recommended for patients with good gastrointestinal function than parenteral nutrition because it can help maintain intestinal barrier function and integrity and reduce infectious morbidity and length of hospital stay (Sadique *et al*., 2015; Lewis *et al*., 2016; Schörghuber and Fruhwald, 2018; Ma *et al*., 2021). However, standard enteral formulas tend to increase blood glucose levels due to their low-fat, low-fiber, and high-simple carbohydrate composition, which is quickly absorbed so it can worsen hyperglycemia in diabetic patients. Also, using the same standard enteral formula for days will raise the patient's blood glucose because it is low in fiber and high in sugar content. Therefore diabetes-specific enteral formulas are recommended (Elia, 2005; Mabrey *et al*., 2015; Huhmann *et al*., 2018; Wijayanti *et al*., 2020).

Unfortunately, the price of commercial diabetes-specific tends to be higher. This condition has driven the innovation of developing diabetes-specific hospital enteral formulas (HEF) in powder form using local food ingredients because the prices are more affordable than commercial formulas. One of the HEF that has been developed is the enteral formula "GLITEROS," which is made with tempeh flour and jicama flour (Sutikno *et al*., 2020; Wijayanti *et al*., 2020). Based on previous research, the GLITEROS enteral formula has met the requirements for enteral formulas for diabetic patients both in terms of physical properties and nutritional content and has a low glycemic index, which is 41.06. Therefore, it is suitable for glycemic control in critical patients with diabetes (Wijayanti *et al*., 2020). However, the GLITEROS enteral formula does not meet the requirements for a diabetes-specific enteral formula according to ASPEN in terms of fat content, which should be 20-35% (Sutikno *et al*., 2020).

Sunflower seeds are one of the foodstuffs that have an anti-diabetic effect through the mechanism of increasing insulin secretion by pancreatic beta cells, decreasing hepatic glucose production, and improving insulin resistance (Farid *et al.,* 2015; Cheenam and Leena, 2016). Sunflower seeds are a food source of fat-rich monounsaturated fatty acids (MUFA) in the form of linoleic acid (61.68%) and oleic acid (27%), which are recommended for diabetic patients because they can reduce the incidence of increased oxidative stress (Farid et al., 2015). Sunflower seeds are also rich in chlorogenic acid, which can control blood glucose levels by limiting the breakdown of glycogen in the liver (Anjum *et al*., 2012). Compared to sunflower seed oil, flour contains more fiber, which can also maintain blood glucose levels in diabetic patients (Rehman *et al*., 2021). This study aimed to analyze the macronutrient content, dietary fiber, protein digestibility, and viscosity of the modified GLITEROS enteral formula and determine the best formula suited to the enteral formula requirements based on ADA, CDA, and ASPEN.

2. Materials and methods

2.1 Study design

This research was an experimental study with four formula groups, Formula A, B, C, and D, with different ratios of tempeh flour (TF), jicama flour (JF), and sunflower seed flour (SSF). Formula A with the ratio of flour (1:1:1), formula B with the ratio (1:1:2), formula C with the ratio (1:2:1), and formula D with the ratio (2:1:1).

2.2 Composition of modified GLITEROS enteral formula

The ingredients used in this study were tempeh flour and jicama flour from "Hasil Bumiku", undried peeled sunflower seeds from "Granology", skimmed milk from "Indoprima", maltodextrin, sugar from "Gulaku", and soybean oil from "Happy". The composition of the formula can be seen in Table 1.

Table 1. Variations in the composition of the modified GLITEROS formula

Ingredients	Formula A	Formula B	Formula C	Formula D
Tempeh flour (g)	30	23	46	23
Jicama flour (g)	30	23	23	46
Sunflower seed flour (g)	30	46	23	23
Skim milk (g)	60	60	60	60
Soya oil (g)	7	7	7	7
Sugar (g)	12	12	12	12
Maltodextrin (g)	50	50	50	50
Total (g)	219	221	221	221

2.3 Enteral formula formulation

The formulation of the ingredients is carried out to compile the composition of each ingredient used to comply with the requirements of a diabetes-specific enteral formula. The main ingredients, such as sunflower seed flour, tempeh flour, and jicama flour, were first analyzed to determine the macronutrient content for combining ingredients. Meanwhile, the macro nutritional value of skim milk, refined sugar, maltodextrin, and soybean oil can be seen on the nutritional value label on each package.

The preparation of enteral formula ingredients and the calculation of nutritional values are carried out by inputting the nutritional value data of each ingredient into the Microsoft Office Excel program and then adding and subtracting ingredients predictively. The combination of formula ingredients (addition and subtraction) is carried out until the main ingredient combination meets the nutritional value requirements of a specific diabetes enteral formula. Energy density is obtained by calculating the total energy content divided by the volume per serving (Damayanthi *et al*., 2021). Energy and nutrient requirements are calculated based on the need for enteral formulas for diabetics, energy 15-25 kcal/kg body weight, carbohydrates 45%-60% of total energy, fat 20-35%, protein 1.3-1.7 g/kg BW, fiber 14 grams/L and sugar 5% of total energy. One formula recipe is required to dissolve up to 1000 ml of solute adjusted to the desired energy density of 1-1.2 kcal (Sutikno *et al*., 2020).

2.4 Preparation of formula

The oven-drying method changed “Granology” undried sunflower seeds to sunflower seed flour. The undried peeled sunflower seeds are oven-dried at 100°C for 30 mins (Tenyang *et al.,* 2021), then mashed in a food processor and sieved using a 100-mesh sieve. Tempeh flour and jicama flour from “Hasil Bumiku” were also sieved using a 100-mesh sieve. Powdered sugar was made by mashing it in a food processor and sieved using a 100-mesh sieve. The enteral formula was prepared by weighing the ingredients according to each ratio (Table 1). Dry ingredients such as tempeh flour, jicama flour, sunflower seed flour, skim milk, maltodextrin, and powdered sugar, were mixed manually for three mins. Next, soybean oil was added to the dry ingredients mixture and stirred for 2 mins. All stirred ingredients are then remixed using a mixer for 8 mins to be homogeneous. After the formula has been homogeneous, the powder formula is brewed using water with a temperature of 70°C to 200 mL for one formula recipe (Sutikno *et al*., 2020). Also, formula preparation is done by paying attention to hygiene and sanitation by using gloves and face masks in every preparation stage to keep food safe, which includes microbiology quality.

2.5 Analysis of macronutrient content, dietary fiber, protein digestibility, and physical properties

2.5.1 Macronutrients, dietary fiber, and protein digestibility analysis

Analysis of the nutritional content of the enteral formula includes the levels of fat, protein, and carbohydrates. Protein content was analyzed by the Kjeldahl method, fat content by the Soxhlet method, and carbohydrate content by the carbohydrate by a different calculation method. Energy content is obtained by calculating 4 kcal/g protein + 9 kcal/g fat + 4 kcal/g carbohydrates. Energy density was obtained from the calculation of the total energy content divided by the volume per serving size (Damayanthi *et al.,* 2021). The gravimetric method was used to analyze the fiber content of enteral formulas, while the digestibility analysis of enteral formula protein by everted gut sac method.

2.5.2 Viscosity and osmolarity analysis

The viscosity test was carried out using a Viscometer and the calculation of the osmolarity was carried out using the Commercial Enteral Formula viscosity approach. The commercial enteral formula viscosity approach was carried out by comparing the osmolality of the modified enteral GLITEROS enteral formula with the viscosity of the commercial enteral formula and multiplying by the osmolarity of the commercial enteral formula, as shown in the equation below. In this case, we use the “Ensure” commercial formula, which has a known osmolality of 375 mOsm/L (Nissa and Rahadiyanti, 2020).

$$\text{Osmolality of Formula Z} = \frac{\text{Viscosity of Formula Z} \times \text{Osm of commercial formula}}{\text{Osmolarity of commercial formula}}$$

3. Results and discussion

3.1 Macronutrients content

The results of the analysis of macronutrients and dietary fiber content can be seen in Table 2. The modified GLITEROS enteral formula has an energy density of 1.05 – 1.12 kcal/mL, whereas formulas D and B have the lowest and highest density averages compared to other formulas. The total energy content in 1000 mL of modified GLITEROS enteral formula ranges from 1056 – 1127 kcal. The average energy density in the modified GLITEROS enteral formula has met the requirements for the enteral formula, with a density of 1-1.2 kcal/mL (Sutikno *et al*., 2020). Excess energy during formula administration should be avoided because it can increase insulin requirements, leading to poor glycemic control in diabetic patients (Coulston, 2000; Sanz-Paris *et al*., 2017). The statistical test showed a significant difference between the four formula samples ($p = 0.000$), where formulas A and B had significant differences with group D ($p = 0.000$). The main components contributing to energy density are fats and carbohydrates (Damayanthi et al., 2021). Formula B had the highest density, and this is because formula B had the highest fat percentage among other formulas.

The carbohydrate content of the modified GLITEROS enteral formula was between 42.43 to 50.71%. The percentage of carbohydrates in formulas A, C, and D has met the recommendations of the Canadian Diabetes Association Clinical Practice Guidelines Expert Committee, which is in the range of 45-60%. Formula B has not met the recommendations because it only contains 42.43% carbohydrates (Sanz-Paris *et al*., 2017). Administration of low-carbohydrate enteral formulas still

https://doi.org/10.26656/fr.2017.8(2).150

Table 2. Content of macronutrients, dietary fiber and protein digestibility modified GLITEROS enteral formula in 1000 mL.

Nutrition content/1000 mL	Formula A	Formula B	Formula C	Formula D	p value
Energy density (kcal/mL)	1.08±0.34[a]	1.12±0.03[b]	1.09±0.01[ab]	1.05±0.02[a]	0.000*
Energy (kcal)	1088.80±34.1[a]	1127.30±31.63[b]	1090±15.82[ab]	1056.05±26.87[a]	0.000*
Carbohydrate (%)	45.97±1.83[a]	42.43±2.18[a]	45.97±1.1[a]	50.71±2.6[b]	0.000*
Protein (%)	17.50±018[a]	17.04±0.13[b]	18.45±0.33[c]	15.19±0.85[d]	0.000**
Fat (%)	26.64±1.55[a]	30.23±2.84[b]	26.20±1.22[a]	23.80±2.51[a]	0.000*
Dietary fiber (%)	29.81(11-8)[a]	30.20(30-29)[a]	25.26(26-23)[b]	24.47(24-23)[b]	0.003*
Protein digestibility (%)	42.85(41.75-42.96)[a]	41.38(41.09-41.79)[b]	46.92(46.83-48.07)[c]	42.89(41.87-44.32)[a]	0.000**
Water (%)	6.78±0.36	6.98±0.43	6.55±0.44	7.15±0.56	0.164
Ash (%)	3.09(3.03-3.17)[a]	3.26(3.13-3.51)[b]	2.78(2.34-3.41)[a]	3.17(2.95-3.26)[ab]	0.046**

Values are presented as mean±SD. Values with different superscripts within the same row are statistically significantly different ($p<0.05$).
*Test with One Way Anova and significant with Tukey.
**Test with Kruskal Wallis and significant with Mann Whitney.

in the standard range has improved glucose control by reducing mean glucose and significantly lowering insulin requirements compared with standard feeding in patients with diabetes (Huhmann *et al*., 2018). This improvement is associated with reduced insulin requirements due to the small number of carbohydrates given to the patient (Mesejo *et al*., 2015). The type of carbohydrates given should also be considered, where the types of carbohydrates recommended for diabetic patients are complex carbohydrates such as polysaccharides, oligosaccharides, corn syrup, maltodextrin, and starch (Coulston, 2000).

The carbohydrate sources of the modified GLITEROS enteral formula are jicama flour, maltodextrin, and refined sugar. Jicama is a source of carbohydrates with a low glycemic index (GI), whereas food ingredients with a low glycemic index can help diabetic patients control blood glucose (Wijayanti *et al*., 2020). This effect is because foods with a low GI will increase blood glucose levels more slowly than foods with higher GI (Rimbawan and Siagian, 2004; Lisa, 2013). Carbohydrates in jicama are inulin (13.4%) which is a fructooligosaccharide (soluble fiber) that is often also called natural insulin (Park and Han, 2015; González-Vázquez *et al*., 2022). Inulin can maintain blood glucose homeostasis by inhibiting gastric emptying, lowering blood glucose levels by stimulating glycogen synthesis and inhibiting gluconeogenesis, slowing glucose absorption in the blood, and increasing plasma insulin levels and insulin sensitivity (Park et al., 2016). Based on statistical tests showed that there was a significant difference between the four sample formulas ($p = 0.000$). Formulas B and D were groups that had a significant difference. Formula D has the highest carbohydrate content (50.71%), and Formula B has the lowest carbohydrate content (42.43%). It is affected by the high content of jicama flour which contains 85% of carbohydrates in 100 grams in formula D, and the lower content of jicama flour in formula B (Buckman *et al*., 2018). Maltodextrin and sugar did not affect the difference in carbohydrate content of formulas B and D because all formulas have equal amounts.

The protein content in the modified GLITEROS enteral formula is between 15.19 to 18.75%. The percentage of protein in the modified GLITEROS enteral formula has met the protein requirements of the diabetes-specific enteral formula (15 – 27% of the total calories) (Sanz-Paris *et al*., 2017). As a major source of nitrogen and amino acids, proteins act in keeping the body functioning properly as building blocks for body tissues and are in charge of making physiological enzymes important in regulating chemical and biological reactions (Qin *et al*., 2022). High protein enteral formulas are recommended for critical patients because they can prevent catabolism by providing protein synthetic materials (anabolism) and are also used for plasma reserves, resulting in better glycemic control and reduced insulin requirements compared to standard formulas (Patkova *et al*., 2017; Sanz-Paris *et al*., 2017). The protein sources in the modified GLITEROS enteral formula came from tempeh flour, sunflower flour, and skim milk. Tempeh is rich in soy protein (36.86%), which has a beneficial effect on diabetic patients. For instance, amino acids arginine and glycine have a beneficial effect on blood glucose control by increasing insulin and glucagon secretion from the pancreas (Haron and Raob, 2014; Huang *et al.*, 2018; Sutikno *et al*., 2020). The indirect mechanism is that soy protein affects insulin receptor gene expression and increases insulin receptor mRNA concentrations in liver and adipose tissue, which will increase insulin binding to receptors and allow insulin-mediated anabolic reactions, including glucose uptake into tissues, resulting in a decrease in extracellular blood glucose levels (Iritani *et al.*, 1997). In addition, tempeh flour also contains the amino acid leucine, which plays a role in increasing insulin secretion

https://doi.org/10.26656/fr.2017.8(2).150

from pancreatic cells by several mechanisms, such as providing metabolic materials, as an activator of the glutamate dehydrogenase (GDH) enzyme, inhibiting KATP cells, and stimulating gene transcription and synthesis protein in pancreatic cells (Yang *et al*., 2011).

Sunflower seeds are also a source of protein with a protein content of 20-40%, which is healthy for consumption by diabetic patients because of the sulfur and nitrogen content that helps provide a source of muscle cell formation and insulin production (González-Pérez, 2015; Rehman *et al*., 2021). Based on statistical tests showed that there was a significant difference between the four sample formulas (p = 0.000). Formula C had the highest protein content (18.45%). This is affected by the high content of tempeh flour and sunflower seed flour in Formula C as the source of protein in the modified GLITEROS enteral formula. Meanwhile, formula D is the lowest protein content formula (15.19%) due to the low composition of tempeh flour and sunflower seed flour in formula D. The higher tempeh flour and sunflower seed flour are added, the greater the percentage of protein in the modified GLITEROS formula.

Based on the fat analysis, the modified GLITEROS enteral formula contain fat between 23.80 to 30.23%, whereas formulas D and B have the lowest and highest fat percentages compared to other formulas. The percentage of fat in the modified GLITEROS enteral formula has qualified the fat requirements of diabetes-specific enteral formulas. The percentage of fat requirements is in the range of 20 – 35% of total calories, with <10% coming from saturated fatty acid and increasing the amount of monounsaturated fatty acid (MUFA) (Sanz-Paris *et al*., 2017). The high percentage of fat (especially MUFA) aims to reduce the percentage of carbohydrates. Studies have shown that acute consumption of a high-fat formula (38-50% of total caloric intake) compared to a high-carbohydrate formula results in a lower postprandial glycemic response. The high MUFA content also reduces blood glucose levels and variability and insulin requirements without worsening lipid control in the medium term; it even tends to improve (Sanz-Paris *et al*., 2017). Sources of fat in the modified GLITEROS enteral formula came from tempeh flour, sunflower seed flour, and soybean oil.

The statistical analysis showed a significant difference between the four sample formulas (p = 0.000), where formulas B and D were groups that had a significant difference (p = 0.000). The highest fat content is in Formula B (50.23%), while Formula D is the lowest fat content formula. Formula B contains sunflower seed flour twice as much as the other formulas, while in Formula D, the content of sunflower seed flour and tempeh flour is the lowest. This result shows that the fat content in the modified GLITEROS enteral formula is affected by the content of sunflower seed flour and tempeh flour. Soybean oil did not affect differences in fat content because the amount in all groups was the same. Sunflower seeds contain 41.46 g/mL MUFA, with the main components being 59-65% linoleic acid and 30-70% oleic acid (Imamura *et al*., 2016; Petraru *et al*., 2021). This ingredient is recommended by the American Diabetes Association in enteral formulas because it is involved in normalizing impaired glucose tolerance in humans and is good in increasing insulin sensitivity (Finucane *et al*., 2015; Sanz-Paris *et al*., 2017; Rehman *et al*., 2021). Meanwhile, tempeh flour contains 17.12% fat, with MUFA content in oleic acid and linoleic acid of 28.1% and 49.4% (Murata *et al*., 1967; Omosebi and Otunola, 2013).

3.2 Dietary fiber content

The modified GLITEROS enteral formula contained dietary fiber between 24.47 to 30.20%, and statistical tests showed a difference between the four formulas (p = 0.000). The fiber content in the four modified GLITEROS enteral formula has exceeded the fiber content requirement in the diabetes-specific enteral formula, which is 14 g/L. Dietary fiber is defined as stored polysaccharides found in plants that are not digested by the human gastrointestinal tract (Malone, 2005). Dietary fiber can weaken the interaction and mix of macronutrients with digestive enzymes, reducing intestinal permeability and endotoxemia, thereby delaying and reducing glucose absorption, making postprandial blood sugar levels stable, and reducing insulin requirements (Mao *et al*., 2021). However, the fiber content in enteral formulas that are too high can inhibit the absorption of other nutrients such as vitamins and minerals because fiber can absorb high enough water so that vitamins and minerals bind to fiber and are excreted through feces (Sutikno *et al*., 2020). The sources of fiber in this formula are yam flour and sunflower seed flour. Jicama contains 17.12% fiber. The fiber in yam is in inulin, which is higher in content than wheat and bananas. At the same time, sunflower seed flour contains 8.6 grams of fiber in 100 grams (Anjum *et al*., 2012; Sutikno *et al*., 2020).

3.3 Protein digestibility

Protein digestibility refers to the ability of a protein to be digested or hydrolyzed by protease enzymes as digestive enzymes into amino acids that are ready to be absorbed and used by the body (Sutikno *et al*., 2020). The higher the rate of protein digestibility, the easier it is for digestive enzymes to hydrolyze protein to be further absorbed by the body and used, and vice versa. The lower the protein digestibility rate, the less amino acids are absorbed by the body because it is difficult to hydrolyze by digestive enzymes (Manullang *et al.*, 2020). The protein digestibility of the GLITEROS enteral formula is based on the results of the everted gut sac test was in the range of 41.38 to 46.92%. Internal factors influence the level of protein digestibility, such as amino acid profile, the strength of amino acid and peptide bonds, the strength of protein folding or protein aggregation, and protein solubility. Meanwhile, external factors that affect protein digestibility include anti-nutritional factors such as tannins, phytic acid, and protease inhibitors (Joye, 2019). Tannins in soya will bind to protein and make protein difficult to digest by digestive enzymes (Gilani *et al.*, 2012; Çabuk *et al.*, 2018). Meanwhile, phytic acid can react with proteins to form complex compounds through ionic interactions. The speed of protein hydrolysis by proteolytic enzymes in the digestive system is hampered due to changes in protein configuration and decreases protein solubility (Setiawan *et al.*, 2016).

The statistical analysis showed a significant difference between the four modified GLITEROS enteral formulas (p = 0.000). Formula C has the highest digestibility of 46.92%, while Formula B has the lowest protein digestibility of 41.38%. Formula C has a high content of tempeh flour as a protein source. The fermentation process in tempeh helps increase the digestibility of soy protein by converting insoluble protein in soybeans into soluble protein, increasing levels of lysine, vitamins B and C, and reducing levels of anti-nutritional substances (Çabuk *et al.*, 2018; Syida *et al.*, 2018). Although soybeans contain phytic acid, the fermentation process in tempeh also reduces phytic acid levels in soybeans (Syida *et al.*, 2018). Also, the tannin content in soybeans has been reduced through efforts to make soybeans into tempeh. According to previous research, during the soaking and boiling process, the tannin content is reduced by 87-92%. This reduction is due to the diffusion process from inside the soybeans to the boiling and soaking water (Cabuk *et al.*, 2018). In addition to internal and external factors, carbohydrate and fiber content also affect protein digestibility. The fiber content in formula B is the highest, while formula C has the lowest fiber content. Carbohydrates and fibers that bind to protein molecules will inhibit the hydrolysis of proteins into amino acids and inhibit protease enzymes from penetrating and breaking peptide bonds, causing inefficient absorption of amino acids (Sutikno *et al.*, 2020). According to WHO, the standard protein digestibility for powdered milk is about 94%, but the protein digestibility standard for hospital enteral formulas has yet to find a suitable reference (Boyce *et al.,* 2012).

3.4 Physical properties

3.4.1 Viscosity

The results of the analysis of the viscosity of the modified GLITEROS enteral formula can be seen in Table 3. One of the things that must be considered in the manufacture of enteral formulas is viscosity. Viscosity shows the amount of flow given by the liquid to measure the speed of liquid passing through a glass tube. Based on the recommendations of ADA, CDA, and ASPEN, the enteral formula should have a viscosity of 1-50 cP, which can pass through a food pipe measuring 8-14 French (Sutikno *et al.*, 2020; Elvizahro *et al.*, 2021). Meanwhile, according to research conducted at Cipto Mangunkusumo Hospital, the viscosity of commercial diabetes-specific liquid foods is 7-13.5 cP (Elvizahro *et al.*, 2021).

The modified GLITEROS enteral formula has a viscosity between 13.09 to 13.94 cP, which has qualified the enteral formula viscosity requirements according to ADA, CDA, and ASPEN. The statistical tests showed no difference in viscosity between the four formulas ($p>0.005$). The viscosity of the enteral formula was affected by the energy density, the stirring time, and the time elapsed since preparation. The viscosity of the enteral formula is inversely proportional to the energy density. The higher the energy density of the enteral formula, the lower the viscosity. This is because formulas with lower density usually have a significant water content which will affect the viscosity of the formula. Furthermore, the duration of stirring the formula and the distance from brewing to serving also affect the viscosity. The more extended the stirring and the time elapsed since preparation, the higher the viscosity of the enteral formula. This is because the longer the time, the more water is absorbed by the enteral formula (Wakita *et al.*, 2012).

3.4.2 Osmolality

Table 3 shows the results of the osmolality test on the four modified GLITEROS enteral formulas. The

Table 3. Physical properties test results of modified GLITEROS enteral formula

Physical properties	Formula A	Formula B	Formula C	Formula D	p value
Viscosity (Cp)	13.94±0.64	13.70±1.08	13.03±0.46	13.09±0.99	0.173*
Osmolality (mOsm/kg water)	430.45±19.89	422.90±33.41	402.43±14.30	402.43±30.80	0.173*

*Test with One Way Anova and significant with Tukey.

modified GLITEROS enteral formula has an osmolarity of 402 - 430 mOsm/kg, which belongs to the iso-molar category. The osmolality value belongs to iso-molar if it is 300 – 500 mOsm/kg (Damayanthi *et al.*, 2021). Osmolality is essential to assess the diet's physiological acceptability and avoid complications (Damayanthi *et al*., 2021). There was no difference between the four enteral formulas based on statistical analysis. Osmolality is the osmotic power of a solution measured in milli-osmoles per kilogram of solvent (mOsm/kg) or the number of solute particles per kilogram of solvent. Osmolality is affected by the amount of hydrolyzed nutrients in food, such as mono and disaccharides, minerals and electrolytes, hydrolyzed protein, amino acids, and medium-chain triglycerides (Elvizahro *et al.*, 2021). The solids (g) of the four formulas were not much different, wherein 1 L of water, formula A contained 221 g of solids, and formulas B, C, and D contained 219 g of solids. The higher the calorie, sodium, and potassium content, the higher the osmolality of the enteral formula (Damayanthi *et al*., 2021).

4. Conclusion

The composition comparison of tempeh flour, jicama flour, and sunflower seed flour showed significant differences in macronutrient content and protein digestibility. Modifying the GLITEROS enteral formula with sunflower seeds can increase the fat content to meet the fat requirements for diabetes-specific enteral formulas. Formula C was the best formula compared to other formulas because of its macronutrient content, dietary fiber, protein digestibility, and physical properties that qualified the requirements for diabetes-specific enteral formulas according to ADA, CDA, and ASPEN.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

The modified GLITEROS enteral formula research is fully funded by the Non-Tax Revenue of the Faculty of Medicine, Universitas Diponegoro in 2021.

References

Anjum, F.M., Nadeem, M., Khan, M.I. and Hussain, S. (2012). Nutritional and therapeutic potential of sunflower seeds: A review. *British Food Journal*, 114(4), 544–552. https://doi.org/10.1108/00070701211219559

Buckman, E.S., Oduro, I., Plahar, W.A. and Tortoe, C. (2018). Determination of the chemical and functional properties of yam bean (*Pachyrhizus erosus (L.) Urban*) flour for food systems. *Food Science and Nutrition*, 6(2), 457–463. https://doi.org/10.1002/fsn3.574

Boyce, J.W., Bettoni, R. and Burlingame, B. (2012). Protein quality evaluation twenty years after the introduction of the protein digestibility corrected amino acid score method. *British Journal of Nutrition*, 108(1), 183-211. https://doi.org/10.1017/S0007114512002309

Çabuk, B., Nosworthy, M.G., Stone, A.K., Korber, D.R., Tanaka, T., House, J.D. and Nickerson, M.T. (2018). Effect of fermentation on the protein digestibility and levels of non-nutritive compounds of pea protein concentrate. *Food Technology and Biotechnology*, 56(2), 257–264. https://doi.org/10.17113/ftb.56.02.18.5450

Cheenam, B. and Leena, P. (2016). Effects of Sunflower Seeds on Fasting Blood Glucose in Diabetes Mellitus Type 2 Patients. *Journal of Chemical and Pharmaceutical Research*, 8(4), 1211–1217.

Coulston, A.M. (2000). Enteral nutrition in the patient with diabetes mellitus. *Current Opinion in Clinical Nutrition and Metabolic Care*, 3(1), 11–15. https://doi.org/10.1097/00075197-200001000-00003

Damayanthi, E., Rodlia, Putri, T.A. and Yuliana, F. (2021). Developing Enteral Feeding Formulas for Stroke Patients Using Lactose-Free Milk and Mung Bean as The Non-Dairy Protein Source. *Jurnal Gizi Pangan*, 16(28), 147–156.

Elia, M. (2005). Enteral Nutritional Support and Use of Diabetes-Specific Formulas for Patients with Diabetes. *American Diabetes Association*, 28(9), 2267–2279. https://doi.org/10.2337/diacare.28.9.2267

Elvizahro, L., Purwandari, A.D.A.N., Prastiwi, R.Y., Putri, S.E. and Majid, V.M. (2021). Formulations of edamame flour based enteral nutrition as an alternative liquid diet for stroke patients. *Academic Hospital Journal*, 3(1), 10–17.

Farid, H.E. A., El-Sayed, S.M. and Abozid, M.M. (2015). Pumpkin and sunflower seeds attenuate hyperglycemia and protect liver in alloxan-induced diabetic rats. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 6(5), 1269–1279.

Finucane, O.M., Lyons, C.L., Murphy, A.M., Reynolds, C.M., Klinger, R., Healy, N.P., Cooke, A.A., Coll, R.C., McAllan, L., Nilaweera, K.N., O'Reilly, M.E., Tierney, A.C., Morine, M.J., Alcala-Diaz J.F, Lopez-Miranda, L., O'Connor, D.P., O'Neill, L.A., McGillicuddy, F.C. and Roche, H.M. (2015). Monounsaturated fatty acid enriched high fat-diets impede adipose NLRP3 inflammasome mediated IL-1β secretion and insulin resistance despite obesity Orla. *American Diabetes Association*, 353, 2–29. https://doi.org/10.2337/db14-1098

Gilani, G.S., Xiao, C.W. and Cockell, K.A. (2012). Impact of antinutritional factors in food proteins on the digestibility of protein and the bioavailability of amino acids and on protein quality. *British Journal of Nutrition* (Suppl. 2), S315–S332. https://doi.org/10.1017/S0007114512002371

González-Pérez, S. (2015). Sunflower Proteins. In Sunflower: Chemistry, Production, Processing, and Utilization (pp. 331–393). https://doi.org/10.1016/B978-1-893997-94-3.50018-0

González-Vázquez, M., Calderón-Domínguez, G., Mora-Escobedo, R., Salgado-Cruz, M.P., Arreguín-Centeno, J.H. and Monterrubio-López, R. (2022). Polysaccharides of nutritional interest in jicama (*Pachyrhizus erosus*) during root development. *Food Science and Nutrition*, 10(4), 1146-1158. https://doi.org/10.1002/fsn3.2746

Huang, Y.C., Wu, B.H., Chu, Y.L., Chang, W.C. and Wu, M.C. (2018). Effects of tempeh fermentation with *Lactobacillus plantarum* and *Rhizopus oligosporus* on streptozotocin-induced type II diabetes mellitus in rats. *Nutrients*, 10(9), 1143. https://doi.org/10.3390/nu10091143

Huhmann, M.B., Yamamoto, S., Neutel, J.M., Cohen, S.S. and Ochoa Gautier, J.B. (2018). Very high-protein and low-carbohydrate enteral nutrition formula and plasma glucose control in adults with type 2 diabetes mellitus: a randomized crossover trial. *Nutrition and Diabetes*, 8, 45. https://doi.org/10.1038/s41387-018-0053-x

Imamura, F., Micha, R., Wu, J.H.Y., Otto, M.C.D.O., Otite, F.O., Abioye, A.I. and Mozaffarian, D. (2016). Effects of Saturated Fat, Polyunsaturated Fat, Monounsaturated Fat, and Carbohydrate on Glucose-Insulin Homeostasis: A Systematic Review and Meta-analysis of Randomised Controlled Feeding Trials. *PLoS Medicine*, 13(7), e1002087. https://doi.org/10.1371/journal.pmed.1002087

Iritani, N., Sugimoto, T., Fukuda, H., Komiya, M. and Ikeda, H. (1997). Dietary Soybean Protin Increases Insulin Receptor Gene Expression in Wistar Fatty Rats when Dietary Polyunsaturated Fatty Acid Level is Low. *The Journal of Nutrition,* 12(6), 1077–1083. https://doi.org/10.1093/jn/127.6.1077

Joye, I. (2019). Protein digestibility of cereal products. *Foods*, 8(6), 199. https://doi.org/10.3390/foods8060199

Kar, P. (2015). Management of critically ill patients with type 2 diabetes: The need for personalised therapy. *World Journal of Diabetes*, 6(5), 693-706. https://doi.org/10.4239/wjd.v6.i5.693

Lewis, S.R., Butler, A.R., Alderson, P. and Smith, A.F. (2016). Enteral versus parenteral nutrition for adults in the intensive care unit. *Cochrane Database of Systematic Reviews*, 7, CD012276. https://doi.org/10.1002/14651858.CD012276

Lisa, B. (2013). Glycemic Index Food Guide. Retrieved from Canadian Diabetes Association website: www.diabetes.ca/mealplanning

Ma, Y., Cheng, J., Liu, L., Chen, K., Fang, Y., Wang, G., Zhu, J. and Chen, L. (2021). Intermittent versus continuous enteral nutrition on feeding intolerance in critically ill adults: A meta-analysis of randomized controlled trials. *International Journal of Nursing Studies*, 113, 103783. https://doi.org/10.1016/j.ijnurstu.2020.103783

Mabrey, M.E., Barton, A.B., Corsino, L., Freeman, S.B., Ellen, D., Bell, E.L. and Setji, T.L. (2015). Managing hyperglicemia and diabetes in patient receiving enteral feedings: A health system approach. *Hospital Practice*, 43(2), 74–78. https://doi.org/10.1080/21548331.2015.1022493.

Malone, A. (2005). Enteral Formula Selection: Product Categories. *Practical Gastroenterology*, (28), 44–74.

Manullang, V.A., Rahadiyanti, A., Pratiwi, S.N., and Afifah, D.N. (2020). Glycemic Index, Starch, and Protein Digestibility in Tempeh Gembus Cookies. *Journal of Food Quality*, 2020, 5903109. https://doi.org/10.1155/2020/5903109

Mao, T., Huang, F., Zhu, X., Wei, D. and Chen, L. (2021). Effects of dietary fiber on glycemic control and insulin sensitivity in patients with type 2 diabetes: A systematic review and meta-analysis. *Journal of Functional Foods*, 82, 104500. https://doi.org/10.1016/j.jff.2021.104500

Mesejo, A., Montejo-González, J.C., Vaquerizo-Alonso, C., Lobo-Tamer, G., Zabarte-Martinez, M., Herrero-Meseguer, J.I., Acosta-Escribano, J., Blesa-Malpica, A. and Martinez-Lozano, F. (2015). Diabetes-specific enteral nutrition formula in hyperglycemic, mechanically ventilated, critically ill patients: A prospective, open-label, blind-randomized, multicenter study. *Critical Care*, 19, 390. https://doi.org/10.1186/s13054-015-1108-1

Murata, K., Hideo, I. and Miyamoto, T. (1967). Studies on the Nutritional Value of Tempeh. *Journal of Food Science*, 32(1), 580–586. https://doi.org/10.1111/j.1365-2621.1967.tb00837.x

Nissa, C. and Rahadiyanti, A. (2020). Buku Panduan Praktikum Formula Enteral Rumah Sakit. Semarang, Indoensia: Fakultas Kedoktern Universitas Diponegoro. [In Bahasa Indonesia].

Ojo, O., Weldon, S.M., Thompson, T., Crockett, R. and Wang, X.H. (2019). The effect of diabetes-specific enteral nutrition formula on cardiometabolic parameters in patients with type 2 diabetes: A systematic review and meta–analysis of randomised controlled trials. *Nutrients*, 11(8), 1905. https://doi.org/10.3390/nu11081905

Ojo, O., Ojo, O.O., Feng, Q., Boateng, J., Wang, X., Brooke, J. and Adegboye, A.R.A. (2022). The Effects of Enteral Nutrition in Critically Ill Patients with COVID-19: A Systematic Review and Meta-Analysis. *Nutrients*, 14(5), 1120-1132. https://doi.org/10.3390/nu14051120

Omosebi, M.O. and Otunola, E.T. (2013). Preliminary studies on tempeh flour produced from three different *Rhizopus* species. *International Journal of Biotechnology and Food Science*, 1(5), 90–96.

Sanz-Paris, A., Hernandez, J.A., Ballesteros-Pomar, M.D., Botella-Romero, F., León-Sanz, M., Martín-Palmero, A., Olmos, M.Á.M. and Olveira, G. (2017). Evidence-Based Recommendations and Expert Consensus on Enteral Nutrition in The Adult Patient with Diabetes Mellitus or Hyperglycemia. *Nutrition Journal*, 41, 58–67. https://doi.org/10.1016/j.nut.2017.02.014

Park, C.J. and Han, J. (2015). Hypoglycemic Effect of Jicama (*Pachyrhizus erosus*) Extract on Streptozotocin-Induced Diabetic Mice. *Journal of Clinical Biochemistry and Nutrition*, 20, 88–93. https://doi.org/10.3746/pnf.2015.20.2.88

Park, C.J., Lee, H.A. and Han, J.S. (2016). Jicama (*Pachyrhizus erosus*) extract increases insulin sensitivity and regulates hepatic glucose in C57BL/Ksj-db/db mice. *Journal of Clinical Biochemistry and Nutrition*, 58(1), 56–63. https://doi.org/10.3164/jcbn.15-59

Patkova, A., Joskova, V., Kovarik, M., Hronek, M., Havel, E., Kucharova, M. and Zadak, Z. (2017). Energy, protein, carbohydrate, and lipid intakes and their effects on morbidity and mortality in critically ill adult patients: A systematic review. *Advances in Nutrition*, 8(4), 624–634. https://doi.org/10.3945/an.117.015172

Petraru, A., Ursachi, F. and Amariei, S. (2021). Nutritional Characteristics Assessment of Sunflower Seeds, Oil and Cake. Perspective of Using Sunflower Oilcakes as a Functional Ingredient. *Plants*, 10(11), 12487. https://doi: 10.3390/plants10112487

Qin, P., Wang T. and Luo Y. (2022). A review on plant-based proteins from soybean: Health benefits and soy product development. *Journal of Agriculture and Food Research*, 7(1), 100265. https://doi.org/10.1016/j.jafr.2021.100265.

Haron, H. and Raob, N. (2014). Changes in Macronutrient, Total Phenolic and Anti-Nutrient Contents during Preparation of Tempeh. *Journal of Nutrition and Food Sciences*, 4(2), 265. https://doi.org/10.4172/2155-9600.1000265

Rehman, A., Saeed, A., Kanwal, R., Ahmad, S. and Changazi, S.H. (2021). Therapeutic Effect of Sunflower Seeds and Flax Seeds on Diabetes. *Cureus*, 13(8), 10–13. https://doi.org/10.7759/cureus.17256

Rimbawan and Siagian, A. (2004). Indeks Glikemik Pangan. Jakarta, Indonesia: Penebar Swadaya. [In Bahasa Indonesia].

Sadique, Z., Grieve, R., Harrison, D. and Rowan, K. (2015). Cost-Effectiveness Of Early Parenteral Versus Enteral Nutrition in Critically Ill Patients. *Value in Health*, 18(7), 25-32. https://doi.org/10.1016/j.jval.2015.09.1658

Sanz-Paris, A., Hernandez, J.A., Ballesteros-Pomar, M.D., Botella-Romero, F., Leon-Sanz, M., Martin-Palmero, A. and Olveira, G. (2017). Evidence-based recommendations and expert consensus on enteral nutrition in the adult patient with diabetes mellitus or hyperglycemia. *Nutrition*, 41, 58–67. https://doi.org/10.1016/j.nut.2017.02.014

Schörghuber, M. and Fruhwald, S. (2018). Effects of enteral nutrition on gastrointestinal function in patients who are critically ill. *The Lancet Gastroenterology and Hepatology*, 3(4), 281–287. https://doi.org/10.1016/S2468-1253(18)30036-0

Setiawan, B., Thamtam, S.K., Jati, I.R.A., Purwestri, R.C., Nohr, D. and Biesalski, H.K. (2016). The Influence of Traditional Stir-Frying with Oil on Acceptability, Antioxidant Activities, Nutrients, and The Phytic Acid Content of Fermented Soybean (Tempeh). *Nutrition and Food Science*, 46(2), 259–271. https://doi.org/10.1108/NFS-09-2015-0105

Sørensen, H.T. (2022). Prevention of diabetes mortality at ages younger than 25 years: access to medications and high-quality health care. *The Lancet Diabetes and Endocrinology*, 10(3), 151 – 152. https://doi.org/10.1016/S2213-8587(22)00009-2

Sutikno, V., Rahadiyanti, A., Fitranti, D.Y., Dieny, F.F., Afifah, D.N. and Nissa, C. (2020). GLITEROS enteral formula based on tempeh flour and jicama flour for patients with hyperglycemia. *Food Research*, 4(Suppl. 3), 38–45. https://doi.org/10.26656/fr.2017.4(S3).S17

Wan Saidatul Syida, W.K., Noriham, A., Normah, I. and

Mohd Yusuf, M. (2018). Changes in chemical composition and amino acid content of soy protein isolate (SPI) from tempeh. *International Food Research Journal*, 25(4), 1528–1533.

Tenyang, N., Ponka, R., Bernard, T., Fabrice, T.D. and Mecaire, W.H. (2021). Effect of boiling and oven roasting on some physicochemical properties of sunflower seeds produced in Far North, Cameroon. *Food Science and Nutrition*, 10(2), 402-411. https://doi.org/10.1002/fsn3.2637

Wakita, M., Masui, H., Ichimaru, S. and Amagai, T. (2012). Determinant factors of the viscosity of enteral formulas: Basic analysis of thickened enteral formulas. *Nutrition in Clinical Practice*, 27(1), 82–90. https://doi.org/10.1177/0884533611427146

Wijayanti, L., Nuryanto, Rahadiyanti, A., Fitranti, D., Dieny, F., Anjani, G. and Nissa, C. (2020). Analysis of glycemic index, glycemic load and acceptability of enteral formulas based on tempeh flour and jicama flour as innovations for hyperglycemic patients. *Food Research*, 4(Suppl. 3), 46–53. https://doi.org/10.26656/fr.2017.4(S3).S19

Yang, J., Chi, Y., Brant, B.R., Guan, Y. and Wolf, B.A. (2011). Leucine metabolism in regulation of insulin secretion from pancreatic beta cells, *Nutrition Reviews*, 68(5), 270–279. https://doi.org/10.1111/j.1753-4887.2010.00282.x.Leucine

