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Development of "EKA-DM" Enteral Nutrition Formula Based on Edamame and Cinnamon for Type 2 Diabetes Mellitus

Pengembangan Formula Enteral "EKA-DM" Berbasis Edamame dan Kayu Manis untuk Diabetes Melitus Tipe 2

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Abstract: *The prevalence of Type 2 Diabetes Mellitus (T2DM) in Indonesia tends to increase. One approach to managing diabetes in hospitals is administering specialized formulas. This study aimed to develop an enteral nutrition formula based on edamame flour and cinnamon powder for T2DM. The composition of the formula was determined using a trial-and-error design by adjusting the weights of the components to achieve nutritional content that meets dietary requirements. The resulting formula was then evaluated regarding viscosity, osmolarity, nasogastric tube (NGT) flowability, hedonic quality, and Color Difference Ratio. Data analysis was conducted using univariate and bivariate approaches. As much as 1,000 mL of the developed "EKA-DM" enteral nutrition formula provides 1,013.59 kcal of energy, with an energy density of 1.01 kcal/mL, 43.51 grams of protein, 52.79 grams of fat, 103.24 grams of carbohydrates, and 35.94 grams of dietary fiber. The viscosity and osmolarity of the formula were 10.00 mPa's and 380 mOsm/L, respectively. Hedonic testing showed a significant difference in the taste of the formula (p=0.045). The best formula, according to the panelists, was F3, with a ratio of edamame flour to cinnamon powder of 65:35. The utilization of edamame flour and cinnamon powder as functional local food ingredients presents a promising alternative for enteral nutrition formulas for T2DM patients. It is suitable for further development as it meets nutritional composition standards, has appropriate viscosity and osmolarity, flows well through NGTs, and has attained positive organoleptic test results. Future studies are recommended to assess the formula's glycemic index and shelf life.*

Key word: edamame, cinnamon, enteral nutrition formula, type 2 diabetes mellitus, dietary fiber

1. INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a metabolic disease characterized by chronically elevated blood sugar levels (hyperglycemia). This condition occurs due to disturbances in the body, whether they be in the form of damage or deficiency in the pancreas's ability to produce insulin, resistance to the action of the insulin hormone, or a combination of these two factors (1). This type of diabetes is the most commonly experienced by people worldwide. It is closely related to living habits, including unhealthy eating patterns, irregular physical activity, and a lifestyle that tends to be inactive, which can increase the risk of developing T2DM (2).

According to World Health Organization (WHO) data, people living with diabetes increased from 200 million in 1990 to 830 million in 2022. In Indonesia, the Basic Health Research (RISKESDAS) in 2018 revealed a diabetes mellitus prevalence rate of 10.9% (3). Meanwhile, based on the results of blood sugar level measurements, the 2023 Indonesian Health Survey (SKI) showed an 11.7% increase in the prevalence of diabetes mellitus in the population aged ≥15 years (4).

Fiber plays an important role in helping control blood glucose levels, especially by prolonging feelings of fullness. One mechanism by which fiber helps manage diabetes is by reducing the efficiency of absorption of simple carbohydrates. Soluble fiber works by binding excess glucose, which is then excreted from the body with the help of soluble fiber (5). Diet management can be done by increasing the consumption of fruits, vegetables, and other natural foods such as edamame and cinnamon.

Edamame is a dish of soybeans that are picked or harvested when they are still young and green in color, where 100 grams of edamame has 121 kcal of energy, 11.9 grams of protein, 5.2 grams of fat, 8.91 grams of carbohydrates, and 5.2 grams of dietary fiber (6). Edamame is an excellent source of dietary fiber, which plays an important role in the management of type 2 diabetes because it can slow down the absorption of glucose in the intestine. Research has shown that fiber can reduce the risk of cardiovascular complications in diabetes sufferers by lowering LDL cholesterol levels. The vegetable protein content in edamame also provides energy without causing a drastic increase in blood sugar levels, making it a healthy snack choice. This combination of fiber and protein in edamame is ideal for supporting the management of T2DM (7). Edamame has a low glycemic index value (≤55), so it can maintain stable blood sugar levels in people with diabetes mellitus; the glycemic index values of fresh, frozen, fried, and floured edamame are 18, 43, 36 and 53, respectively (8). Edamame is rich in isoflavones, fiber, and vegetable protein, which help control blood sugar levels, increase insulin sensitivity, and lower LDL cholesterol. Its antioxidant content also plays a role in reducing inflammation and the risk of cardiovascular disease and in supporting weight management (9).

Meanwhile, cinnamon is a spice obtained from the inner bark of a *Cinnamomum* tree, which is famous for its distinctive aroma and spicy sweet taste. As much as 100 grams of cinnamon contains 247 kcal of energy, 3.99 grams of protein, 1.24 grams of fat, 80.6 grams of carbohydrates, and 53.1 grams of total dietary fiber (10). In traditional medicine and modern research, cinnamon is known to have antioxidant, anti-inflammatory, and anti-diabetic effects. Research has shown that cinnamon can help control blood sugar levels, improve insulin sensitivity, and reduce the risk of metabolic complications (11). In an experimental study, giving cinnamon powder to people with T2DM in an intervention group for seven days showed a significant reduction in fasting blood glucose levels, from an initial average of 278 mg/dL to around 124 mg/dL. This reduction was caused by cinnamon's ability to increase insulin activity and reduce insulin resistance in peripheral tissues (12). Cinnamon has a lower glycemic index value compared to edamame, which is around 5 (13).

Diabetes mellitus patients in hospitals do not only consist of outpatients, but also inpatients who require therapeutic support with appropriate management to meet nutritional needs and prevent complications. In hospitals, feeding patients can be done through three main methods—orally, enterally, or parenterally—depending on the patients' condition. Enteral feeding, in particular, can be done via various routes, such as direct administration via the mouth or jejunum, or using a gastric tube or nasogastric tube (NGT) (14). Enteral nutrition formulas are of two main types, commercial and non-commercial. Commercial formulas are ready-to-eat products formulated according to international standards, such as the recommendations of the American Diabetes Association (ADA) or the European Society for Parenteral and Enteral Nutrition (ESPEN). In contrast, non-commercial formulas (blenderized diets) are made from local ingredients, such as sorghum flour, soybeans, green beans, skim milk, and olive oil. These latter formulas allow adjustments according to patient needs but require precise measurement of nutritional content and hygienic processing to maintain quality (15).

Research regarding the development of edamame-flour-based enteral nutrition formulas has been carried out to provide nutritional alternatives for diabetes mellitus patients. For instance, Elvizahro et al. (2021) developed an enteral nutrition formula consisting of edamame flour and skim milk in a ratio of 1:4. Every 100 grams of this formula contains 332.54 kcal of energy, 21.88% protein, 10.58% fat, 37.25% carbohydrates, and 17.09% dietary fiber, with a viscosity of 8.6 cP and osmolality of 436 mOsmol/kg water. The organoleptic test results showed that this formula was most liked by the panelists in terms of taste (16). Research regarding the development of enteral nutrition formulas based on cinnamon powder has also been carried out for the same purpose. For example, Kurniawati et al. (2022) in their study administered 1 gram of cinnamon powder per day for seven days to 30 elderly people with type 2 diabetes mellitus. The results showed significant reductions in fasting blood glucose levels in the intervention group, with a *p*-value = 0.001 (17). From these research instances it can be concluded that the use of edamame flour and cinnamon powder can reduce blood glucose levels in diabetes mellitus sufferers.

Based on observations for approximately six months, the enteral nutrition formulas used in hospitals have several weaknesses: they have low acceptability, especially in terms of aroma and low protein and fiber content (i.e., 7 grams and 3.84 grams per serving, respectively). Additionally, there has been a lack of research regarding alternative choices using local ingredients for commercial enteral nutrition formulas for diabetes mellitus sufferers. Edamame is known to be rich in nutrients and has the potential to be developed as a basic ingredient for enteral nutrition formulas. It can increase the protein and fiber content in enteral nutrition products, which is beneficial for people with diabetes and other non-communicable diseases. However, specific research on its use for enteral nutrition product diversivication has been limited. Therefore, researchers have been taking interest in researching and studying enteral formulas based on local food ingredients, particularly edamame flour coupled with cinnamon powder, as an innovative enteral nutritional support or liquid food supplement for DM sufferers. These formulas are on par with the formulas used for DM sufferes in hospitals in terms of high dietary fiber content and low glycemic index. Thus, it is hoped that they can help control blood sugar levels, increase insulin sensitivity, and reduce the risk of metabolic complications.

2. METHODS

Research Design, Time, and Place

This research employed an experimental research design to develop a new food product. The product was formulated by substituting some of the ingredients of basic recipes used in hospitals using a trial-and-error approach to produce nutritional value in accordance with the standard enteral nutrition formula for diabetes mellitus patients. The ingredients used in question were edamame flour and cinnamon powder. Different treatments were applied in the experiments based on the ratios of edamame flour to cinnamon powder used, namely F1 (55:50), F2 (60:40), F3 (65:35), and F4 (70:30).

The composition of the enteral nutrition formula for each treatment was selected based on initial calculations of nutrients that had been adjusted to hospital standards and energy density requirements, as well as on preliminary research. As a result, different formulations were possible depending on the calculated nutritional content of the formula. For example, in F1 (55:50), the proportion of both ingredients does not 100% because if the proportion were 100%, it would not achieve an energy density of 1 kcal/ml, which is the required nutritional standard for enteral nutrition formulas (1 kcal per 1 ml of liquid) (18).

The materials used were purchased from online shops, including edamame flour (Hasil Bumiku) as a substitute for the soya formula used in hospitals, cinnamon powder (Yutakachi) as a substitute for inulin used in hospitals, skimmed milk powder (Lactona Skim Low Fat), coconut oil (Ikan Dorang), canola oil (Tropicana Slim), granulated sugar (Happy Sweet), and maltodextrin (Lihua Starch Malto Dextrin).

Table 1. Composition of Hospital and EKA-DM Enteral Nutrition Formulas (g/1000 ml)

Material	Formulas				
	Hospital	**F1**	**F2**	**F3**	**F4**
Edamame flour	-	55	60	65	70
Cinnamon powder	-	50	40	35	30
Soya formula	70	-	-	-	-
Skim milk powder	80	50	50	50	50
Coconut oil	25	30	30	30	30
Canola oil	10	10	10	10	10
Sugar	15	20	20	20	20
Maltodextrin	10	10	10	10	10
Inulin	10	-	-	-	-
Total	**220**	**225**	**220**	**220**	**220**
Serving Weight (g)	**44**	**45**	**44**	**44**	**44**

The tools used in this research included a food processor (Philips Cucina HR7633, China), filter, plastic basin, plastic plate, aluminum pan, gas stove, mercury thermometer (GEA Alcohol Thermometer -10 to 150), porcelain cup, teflon pan, spatula, spoon, digital food scale, measuring cup, NGT (TERUMO, size Fr.16 125 cm), syringe catheter tip spuit or sonde (HEXA CARE, 50 cc), digital rotary viscometer (NDJ-8s), stopwatch, cup, digital camera (SONY ILCE-6400), and mini studio box made from white cardboard with a black backdrop. The stages of product creation are illustrated in **Figure 1**.

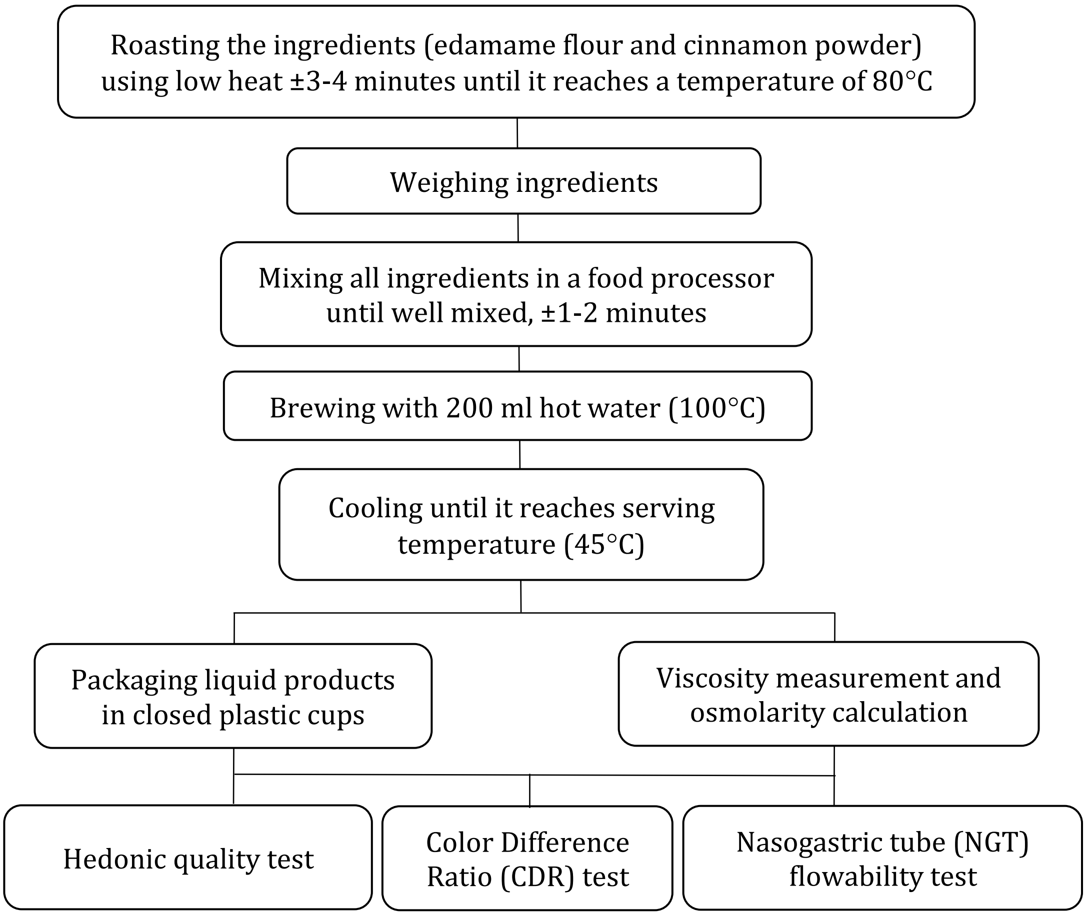

Figure 1. Research Process Flow Diagram

The research was carried out from November 2024 to January 2025 at the Food Ingredient and Processing Science Laboratory of Malang Ministry of Health Polytechnic. Ethical clearance was obtained from the Research Ethics Commission of Yatsi Madani University Tangerang on December 17, 2024 (Number 326/LPPM-UYM/XII/2024).

Data Collection

The developed formula (EKA-DM) was assessed based on nutritional content (energy, protein, carbohydrates, fat, and dietary fiber), viscosity and osmolarity, ability to flow in an Fr.16 NGT, organoleptic quality, and product color. Energy and nutrient content data were obtained from the Indonesian Food Composition Table (TKPI) (19) and United States Department of Agriculture (USDA) database (20), and then analyzed by comparing the calculation results of selected formula samples against the standard needs of the targets (i.e., diabetes mellitus patients) (21).

Data on the flowability of the enteral nutrition formulas were subjectively observed and obtained based on the research by Ekawati et al. (2024) with some modifications. Tests were carried out using a 125-cm-long Fr.16 TERUMO NGT and 50-cc HEXA CARE catheter tip syringe (sonde) when the enteral nutrition formulas were still warm or at a temperature of 45°C. For each enteral nutrition formula, 50 mL of the formula was

flowed through an NGT using the gravity feeding method to the last bit, and the flow time was calculated using a stopwatch (21)
Data on the hedonic quality of the enteral nutrition formulas were obtained involving 20 moderately trained panelists and then analyzed descriptively according to Ekawati et al. (2024) (21). The inclusion criteria for the moderately trained panelists were that they were Nutrition Department students at Malang Ministry of Health Polytechnic who had taken the Food Ingredient Science or Food Technology Science or Acceptability Test course, willing to be panelists, in good health, not under the influence of alcohol or drugs, and not allergic to any of the main ingredients of the enteral nutrition formulas. Meanwhile, the exclusion criteria were that they had disorders such as impaired sense of smell and diseases related to decreased immune function and body metabolism. The panelists were presented with four different formulas. Before commencing the tests, the researcher explained to the panelists the aims and procedures of the research being conducted. After showing an understanding and willingness to be involved in the research, the panelists were asked to sign an informed consent form. Next, the panelists were invited to do a hedonic test on organoleptic parameters for ± five minutes, prior to which they were given one minute to neutralize their tongue using mineral water. Assessment was carried out using a questionnaire with items on color, flavor, taste, texture, and aftertaste parameters. The questionnaire was adapted from Linangsari et al*.* (2022) on a seven-point scale, from 1 (strongly dislike), 2 (dislike), 3 (slightly dislike), 4 (neutral), 5 (slightly like), 6 (like), to 7 (strongly like) (22).

In addition, descriptive analysis was conducted to determine the best treatment according to Ekawati et al. (2024) involving 10 trained panelists (21) using de Garmo's Effectiveness Index (1984) as explained in Linangsari et al. (2022). This method was carried out by measuring several variables that influenced the quality of the enteral nutrition formulas, such as energy content, nutrient content, and organoleptic quality. The inclusion criteria for the trained panelists were that they were Nutrition Department lecturers at Malang Ministry of Health Polytechnic who were experts in the field of food. The panelists were asked to rank and assign value to variables that they considered to have influenced the quality of the formulas, where they were allowed to assign the same value to different variables that they considered to have an equally important influence on the quality of the formulas. The best treatment was one which had the highest productivity value (PV), which was obtained by dividing the effectiveness value (EV) by the variable weight (VW). Meanwhile, EV was the treatment value for each variable minus the lowest value divided by the best value minus the lowest value (22).

Viscosity data of the enteral nutrition formulas were collected using an NDJ-8s digital rotary viscometer and No. 2 spindle rotor at a speed of 60 rpm. Measurement was carried out twice for each sample at room temperature. Viscosity value readings were taken after the rotor reached stability, or after 20 seconds. The results are reported in Pa's and °C. Meanwhile, osmolarity was calculated based on the viscosity results with the standard osmolarity formula (23).

Enteral nutrition formula color testing was carried out using the Color Difference Ratio (CDR) method as used in Winarti's research (2024) (24) (24), where product images were taken using a digital camera (SONY ILCE-6400, Sony Corp, Japan) at a resolution of 350 × 350 dpi 24 bit with a 16-mm f/4 ISO 100 camera lens. Image captures of the enteral nutrition formulas were taken in a closed laboratory room using a mini studio box with 1-tube-type electric light on the front of the top side of the box. Images were taken from above at a distance of 10 cm. The color profile of the enteral nutrition formulas was determined based on the image histogram. The RGB (red, green, blue) channels of the images being analyzed were first separated. Then, for each channel, the maximum possible area obtained from the images (region of interest/ROI) was determined with a round shape according to the product container. Image processing for color analysis was performed with ImageJ software version 1.54g (25).

Data Analysis

The research data were analyzed using univariate and bivariate analyses. Univariate analysis was carried out to obtain a descriptive picture of the characteristics of each variable, whereas bivariate analysis was carried out to determine differences between treatments (26). Initial data testing on organoleptic data was carried out using a normality test (Shapiro-Wilk test) to determine the level of spread or distribution of the data. The organoleptic data showed that the data were not normally distributed ($p<0.05$). In consequence, the Kruskal-Wallis test was carried out to determine differences between groups using JASP statistical software version 0.19.2.0 (27). Another program used in data processing is ImageJ version 1.54g (25) for color tests or CDR assessment.

3. RESULTS

Energy and Nutrient Content of Enteral Nutrition Formula

From analysis it was found that the protein, fat, and dietary fiber values of the developed enteral nutrient formulas EKA-DM (F1, F2, F3, and F4) based on Indonesian Food Composition Table (TKPI) and USDA database calculations were higher than those of the standard hospital formula for diabetes mellitus patients, while the energy and carbohydrate content were slightly lower but still meeting the ±10% standard. The energy and nutrient content of the enteral nutrition formulas based on edamame flour and cinnamon powder (EKA-DM) can be seen in detail in **Table 2**.

Table 2. Energy and Nutrient Content of Hospital and EKA-DM Enteral Nutrition Formulas (1000 ml)

Parameter	Unit	Nutritional Content of Formulas				
		Hospital	F1*	F2*	F3*	F3*
Energy	kcal	1210.8	1006.19	1003.72	1013.59	1023.47
Energy density	kcal/ml	1.2	1	1	1.01	1.02
Protein	g	37.2	40.37	41.84	43.51	45.18
Fat	g	48	51.11	51.92	52.79	53.66
Carbohydrate	g	138	112.15	105.68	103.24	100.79
Dietary fiber	g	19.2	41.24	37.26	35.94	34.62

*Level of formula development with the proportion of edamame flour:cinnamon powder F1 (55:50), F2 (60:40), F3 (65:35), and F4 (70:30)

Flowability of the Enteral Nutrition Formulas through an NGT

The enteral nutrition formulas were subjected to flow tests using an NGT to ensure smooth flow through the tube, prevent blockages, and minimize the risk of complications. The results of the formula flow tests can be seen in **Table 3**.

Table 3. Flowability of the EKA-DM Enteral Nutrition Formulas through an NGT in 50 ml of Volume and 45°C of Temperature

Parameter	EKA-DM Enteral Nutrition Formulas			
	F1*	F2*	F3*	F4*
Description (flow)	Flow	Flow	Flow	Flow
Time (seconds)	10	5	5	10

*Level of formula development with the proportion of edamame flour:cinnamon powder F1 (55:50), F2 (60:40), F3 (65:35), and F4 (70:30)

Table 3 shows that all formulas could flow smoothly. Based on the time parameter, F2 and F3 were found to have a higher flow rate (five seconds) compared to F1 and F4 (10 seconds).

Viscosity and Osmolarity of the Enteral Nutrition Formulas

The viscosity of the EKA-DM, hospital, and commercial enteral nutrition formulas was tested using a viscometer. In addition, the osmolarity of the formulas was also measured. The results of the viscosity and osmolarity tests are shown in **Table 4**.

Table 4. Viscosity and Osmolarity of the EKA-DM, Hospital and Commercial Enteral Nutrition Formulas

Parameter	EKA-DM				Hospital	Commercial
	F1	F2	F3	F4		
Readable viscosity (second)	00:29	00:29	00:29	00:29	00:29	00:29
Temperature (°C)	30	30	30	30	30	30
Viscosity (mPa's)	8.00	9.00	10.00	9.50	5.00	9.00
Osmolarity (mOsm/L)	304	342	380	361	190	342

Table 4 shows that the viscosity and osmolarity values for F2 were the same as those of the comparator commercial formula. In contrast, the hospital formula had a lower value than those of the EKA-DM and comparator commercial formulas.

Hedonic Quality of the Enteral Nutrition Formulas

The EKA-DM enteral nutrition formulas were subjected to organoleptic or hedonic tests to determine their acceptability and level of preference, which involved 20 slightly trained panelists. The results of the organoleptic or hedonic tests of the formulas are shown in **Table 5**.

Table 5. Hedonic Quality of the EKA-DM Enteral Nutrition Formulas

Parameter	Average (Mean ± SD)				*p*
	F1	F2	F3	F4	
Color	5.150 ± 1.387^a	5.200 ± 1.152^a	5.300 ± 0.923^a	5.000 ± 1.376^a	0.890
Flavor	4.050 ± 1.572^a	3.750 ± 1.333^a	4.050 ± 1.317^a	4.100 ± 1.210^a	0.843
Taste	4.500 ± 1.670^a	4.900 ± 1.252^b	5.500 ± 1.000^b	5.400 ± 0.883^b	0.045*
Texture	5.150 ± 1.182^a	4.900 ± 1.252^a	5.500 ± 1.000^a	5.400 ± 0.883^a	0.309
Aftertaste	4.350 ± 1.496^a	3.650 ± 1.461^a	4.450 ± 1.317^a	4.000 ± 1.451^a	0.284

*There are significant differences (p<0.05)
Note: Different notations in the same line indicate statistical differences at p<0.05
(a = not significantly different and b = significantly different)

Table 5 shows that the hedonic quality in terms of color, aroma, taste, texture, and aftertaste parameters of F1, F2, and F4 was lower than that of F3. The organoleptic or hedonic test results for the formulas are presented in the following diagram.

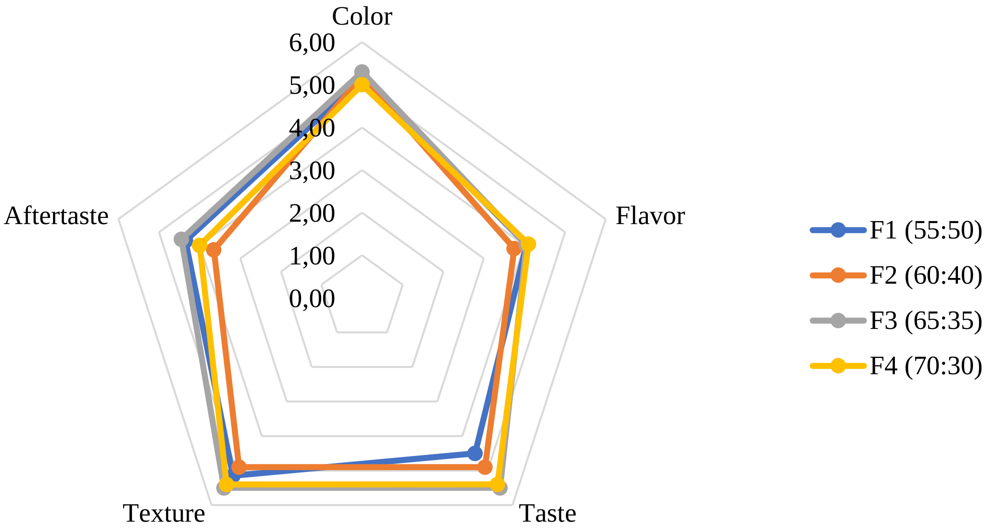

Figure 2. The EKA-DM Enteral Nutrition Formulas Hedonic Quality Diagram

Color Difference Ratio (CDR) of the Enteral Nutrition Formulas

Digital images of the enteral nutrition formulas were taken using a digital camera and mini studio box to determine the Color Difference Ratio (CDR). The results of the Color Difference Ratio (CDR) calculations are shown in **Figure 3** and **Table 6**.

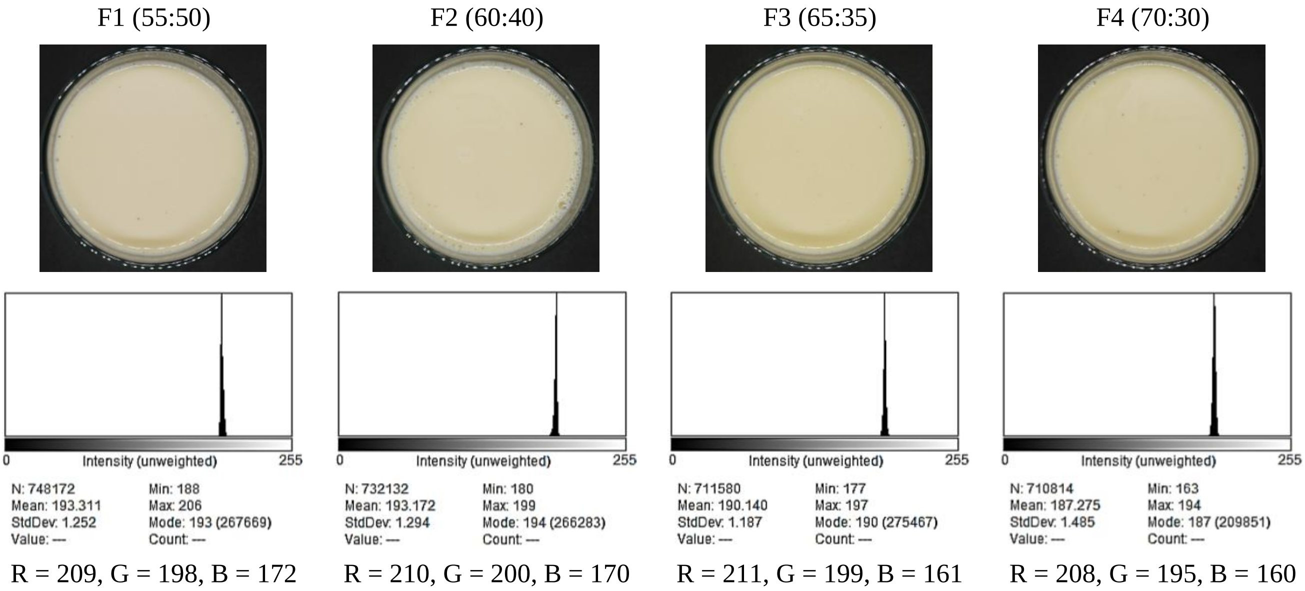

Figure 3. Color Comparison Histogram of the EKA-DM Enteral Nutrition Formulas

Figure 3 shows a histogram with varying color intensities; as the graph approaches the value 0, the color intensity grows darker. It can be observed that there is a decrease in RGB color intensity from F1 to F4, with the use of more edamame flour being able to provide a darker color or greater color intensity.

Table 6. Color Difference Ratio (CDR) of the EKA-DM Enteral Nutrition Formulas

Formulas	R	G	B
F1	209.397±1.017	198.347±1.053	172.826±2.110
F2	210.038±1.262	200.023±1.190	168.972±1.907
F3	210.637±1.269	199.181±1.181	160.790±2.045
F4	206.769±1.555	195.445±1.287	159.631±2.150

Note: The CDR value is the average and standard deviation of four measurements.

The CDR values of F2 and F3, as shown in **Table 6**, indicate that the use of more edamame flour and less cinnamon powder causes the color of the enteral nutrition formulas to be slightly darker and lower in the RGB color intensity.

Nutrient Content of Selected Formula

The selected formula was the best treatment that was assessed using De Garmo's method (1984). The analysis results of the best treatment are shown in **Table 7**.

Table 7. Best Treatment Level for EKA-DM Enteral Nutrition Formulas

Parameter	Ranking	Value Weight	Treatment							
			F1 (55:50)		F2 (60:40)		F3 (65:35)		F4 (70:30)	
			EV	PV	EV	PV	EV	PV	EV	PV
Color	3	0.2	0.50	0.10	0.67	0.13	1.00	0.20	0.00	0.00
Flavor	4	0.1	1.00	0.10	0.00	0.00	1.00	0.10	1.17	0.12
Taste	2	0.3	0.88	0.26	0.00	0.00	1.00	0.30	0.41	0.12
Texture	1	0.4	0.42	0.17	0.00	0.00	1.00	0.40	0.83	0.33
Total		**1**	**2.80**	**0.63**	**0.67**	**0.13**	**4.00**	**1.00**	**2.41**	**0.57**

As shown in **Table 7**, F3, with a ratio of edamame flour to cinnamon powder of 65:35, had the highest productivity value (PV) of 1.00 and was selected as the best treatment. Its nutritional content (energy, protein, fat, carbohydrates, water, and dietary fiber) was then calculated based on food databases and compared with the standard hospital formula. The results for 100 grams of the selected formula are provided in **Table 8**. According to this table, F3 had higher protein, fat, and dietary fiber values than the standard hospital formula.

Table 8. Comparison of Nutrient Content Between EKA-DM and Hospital Standard Enteral Nutrition Formulas

Parameter	Selected Modified Formula (F3) (100 g)	Hospital Standard Formula (100 g)
Energy (kcal)	460.72	550.36
Protein (g)	19.78	16.91
Fat (g)	23.99	21.82
Carbohydrate (g)	46.93	62.73
Dietary Fiber (g)	16.34	8.73
Water (ml)	5.74	-

4. DISCUSSION

Nutrient Content of Selected Formula

The selected enteral nutrition formula based on hedonic quality was F3, which had a ratio of edamame flour to cinnamon powder of 65:35. Its nutritional content met the standards, and its viscosity and osmolarity met the requirements for a blenderized enteral formula.

The nutrient content was calculated to determine the final volume of the enteral nutrient formula to obtain an energy density of 1 kcal/mL, where energy density refers to the amount of energy stored per unit weight of material (28). According to **Table 2**, the energy densities of F1, F2, F3, and F4 were 1 kcal/mL, 1 kcal/mL, 1.01 kcal/mL, and 1.02 kcal/mL, respectively, which met the nutritional content requirements for enteral nutrition formulas (1 kcal in 1 mL of fluid) (29).

The developed EKA-DM enteral nutrition formula had higher protein, fat, and fiber values and lower energy and carbohydrate content compared to those of the standard hospital formula due to the modification (substitution) of ingredients with edamame flour and cinnamon powder, which are high enough in fiber to meet the nutritional needs of people with type 2 diabetes mellitus (T2DM). Based on the Dietary Guidelines for Americans, consuming 25–38 grams of fiber per day is recommended to prevent type 2 diabetes mellitus (T2DM) and promote general health (30). Efforts to control other non-communicable diseases, such as cardiovascular disease and colorectal cancer, can be done with a high-fiber diet, which helps reduce cholesterol levels and improve digestive tract health. Consuming fiber from vegetables, fruits, and whole grains has been shown to play a role in reducing the risk of chronic inflammation and obesity, which are major risk factors for non-communicable diseases (31).

Edamame flour has great potential in managing diabetes mellitus because of its high content of dietary fiber, oligosaccharides, and other bioactive compounds. The dietary fiber in edamame flour helps slow glucose absorption, thereby preventing spikes in blood sugar levels. In addition, oligosaccharides that it contains can function as prebiotics that support gut health, indirectly affecting the body's glucose metabolism. Research has shown that processing such as removing the fat and protein in edamame flour can increase the fiber content of edamame flour and strengthen its hypoglycemic effect, with blood glucose levels reduced by more than 50% in trials using animal models (32). Apart from that, edamame also contains essential amino acids, making it a source of high-quality vegetable protein (33).

The bioactive components in cinnamon, such as polyphenols and cinnamaldehyde, increase insulin sensitivity and reduce insulin resistance in body tissues. Research has shown that consuming cinnamon can improve the mechanism of glucose transport into cells by increasing GLUT-4 protein activity in the muscle and adipose. Cinnamon also helps reduce inflammation and oxidative stress, which often cause complications in T2DM. Thus, cinnamon powder is used as additional therapy to control blood glucose levels in T2DM sufferers (34). In an experimental study, giving cinnamon powder to people with type 2 diabetes mellitus in an intervention group for seven days showed a significant reduction in fasting blood glucose levels, from an initial average of 278 mg/dL to around 124 mg/dL. This decrease was caused by cinnamon's ability to increase insulin activity and reduce insulin resistance in peripheral tissues (12).

The lower carbohydrate content in the EKA-DM enteral nutrition formula can affect the blood glucose absorption response, where the lower the carbohydrates available in food the lower the glycemic index value (35). One of the risk factors that can increase the possibility of developing T2DM is a diet high in calorie, especially from simple carbohydrates, but low in fiber. Consuming large amounts of carbohydrates increases glucose levels and in turn the risk of diabetes. In addition, energy intake that exceeds the body's needs can cause a spike in blood glucose levels, which is directly related to high energy consumption (36).

The limitation of using nutritional database calculations to determine nutritional value is that there may arise differences in nutritional composition or deviations in nutritional value due to variations in raw materials, processing methods, and storage conditions that cannot be detected without laboratory analysis. In addition, nutritional databases often contain average values that may not reflect the specific content of a product, which can lead to inaccuracies in nutrient estimates. Without laboratory testing, factors such as nutrient interactions, bioavailability, and chemical changes during processing cannot be accurately analyzed.

Viscosity and Osmolarity of the Enteral Nutrition Formulas

Viscosity is one of the main characteristics that must be considered in developing an enteral nutrition formula because it has an important role in ensuring the smooth delivery of nutrition through a feeding tube, such as the enteral feeding tube. The viscosity level of the formula greatly influences how the formula can pass through the tube without resistance. If the viscosity is too high, it may become difficult for the formula to flow through the tube, thus increasing the risk of blockage in the tube and resulting in hampered formula administration. Conversely, if the viscosity is too low, the formula may flow too quickly or not provide adequate texture, which can cause side effects such as diarrhea or vomiting in the patient. It can also slow down the process of providing a diet that should run regularly. Changes in viscosity in enteral nutrition formulas do not just happen, but are influenced by various factors. Some of these include the temperature of the formula when served, the duration and speed of stirring during preparation, the fiber content in the formula, the concentration of the solution used, and the time spent in the preparation process until the formula is ready to be administered. Managing these factors is crucial to ensure that the enteral nutrition formula has the optimal viscosity for the patient's needs (37).

In this study, flow tests were carried out using an NGT of size 16, which is the size for adults. The standard viscosity values commonly used in blenderized enteral nutrition formulas based on research range from 3.5 to 10 mPa’s (or centipoise, cP) (38). The results of this study show that the EKA-DM enteral nutrition formula met the standard viscosity value for a blenderized enteral nutrition formula. As for osmolarity, the formula met the recommended osmolarity standard for an enteral nutrition formula, namely <400 mOsm/L (39).

Hedonic Quality and Color Difference Ratio (CDR) of the Enteral Nutrition Formulas

Organoleptic or sensory testing is an evaluation method that uses humans as the main tool to assess a product’s quality. This assessment covers various quality aspects, such

as color, flavor, taste, texture, and aftertaste. In addition, this testing may include other relevant factors to determine the overall quality of the product (40).
The color of the EKA-DM enteral nutrition formulas had a value somewhere between 5.000 and 5.300, which means that the average panelist slightly liked it. The color of the enteral nutrition formulas was yellowish white (pale yellow), which was due to the influence of the skim milk and edamame flour used. The reflection of fat globules, calcium caseinate, and colloidal phosphate in the formulas produced the white color of milk. Meanwhile, the yellowish color came from the soybean ingredient, indicating the presence of isoflavone compounds. Flavones derive their name from the word "flavus", which means yellow in Latin, because these compounds have a yellow base color (41). Ekawati et al. (2024) state that adding flour derived from soybeans significantly affects the organoleptic response to color attributes in enteral nutrition formulas, which become increasingly yellow (21).

The flavor of the EKA-DM enteral nutrition formulas had an average value within the range from 3.750 to 5.300, which means that the average panelist was neutral to slightly pleased about it. The flavor of the enteral nutrition formulas was a typical cinnamon flavor and was slightly unpleasant. The distinctive flavor of cinnamon comes from main compounds such as cinnamaldehyde, eugenol, and coumarin, which give it a strong, sweet, warm flavor (42). Meanwhile, the pleasant flavor comes from the lipoxygenase enzyme activity found in edamame or soybeans. Lipoxygenase enzyme is a natural enzyme found in edamame (41).

The taste of the EKA-DM enteral nutrition formulas was within the average range from 4.500 to 5.500, which means that the average panelist was neutral to slightly pleased with it. The taste of the enteral nutrition formulas was sweet, which grew weaker with each treatment. This is in line with research (43) which employed increasing ratios of cinnamon powder with each treatment, where the instant powder drink produced had a stronger sweet taste. The dominant sweet taste came from a compound in cinnamon named cinnamaldehyde (42).

The texture of the EKA-DM enteral nutrition formulas fell within the average range from 4.900 to 5.500, which means that the average panelist slightly liked it. The enteral nutrition formulas were generally of a liquid-like texture and could flow through an NGT smoothly, which was expected of enteral nutrition formulas. Texture is related to the feeling or sensation felt when a product comes into contact with the taste buds in the mouth. Apart from that, it is also related to the viscosity of the product. Texture is considered as important as other parameters because it can influence the taste of the product (44).

Finally, the aftertaste of the EKA-DM enteral nutrition formulas was in the mean range from 3.650 to 4.450, which means that the average panelist was neutral about it. The aftertaste of the enteral nutrition formulas was bitter, which grew weaker with each treatment. This was also in line with research (43), which showed increasing ratios of cinnamon powder with each treatment, where the instant powder drink had an increasingly bitter aftertaste with each treatment. Cinnamon contains polyphenol compounds in essential oils, which can give a bitter aftertaste (45).

The difference in color intensity of a product or formula is determined using the Color Difference Ratio (CDR) method. The imaging results of different enteral nutrition formulas, each contained in a plastic cup as much as 200 mL in volume, were compared based on the mode values. ImageJ software, which was used in data processing for color analysis, was initially run to read a black image to determine whether it had a good reading capability. Increases in the intensity of the brownish yellow color of the EKA-DM enteral nutrition formulas could be clearly observed through digital analysis of the enteral nutrition formula images. The X axis of the color histogram (**Figure 3**) shows the RGB (red, green, blue) color intensity scale, starting from the highest 0 to the lowest 255, the Y axis shows the number of pixels, and the peak in the histogram is the mode which represents the color that appears most in the observed area (ROI). The histogram was interpreted in two distinct manners. If the histogram moved further to the left, approaching 0, it means that the enteral nutrition formulas grew darker. On the other hand, if it moved further to the right, approaching 255, it is interpreted that the enteral nutrition formulas grew brighter (21). As the histogram in this study tended to approach 0, it means that the enteral nutrition formulas were more of a darker color intensity. This could also be observed in the decreasing trend of RGB color intensity from F1 to F4 with increasing edamame flour amounts used, which resulted in a darker color or higher color intensity.

5. CONCLUSION

According to the panelists, the enteral nutrition formula with a ratio of edamame flour to cinnamon powder of 65:35, F3, was the best formula because it had nutritional content that met the standards. Based on food database calculations, the formula contained higher levels of protein, fat, and fiber and lower energy and carbohydrate content than the standard hospital formula. The hedonic quality assessment of taste parameters also demonstrated significant differences. The EKA-DM enteral nutrition formula was declared suitable for development in further research because its nutritional composition (high protein and dietary fiber content), viscosity, and osmolarity met the standards, and it was able to flow through an NGT smoothly. In addition, the organoleptic test results were positive. Further development and research regarding the shelf life and other nutritional content, as is indicated by the glycemic index, of the EKA-DM enteral nutrition formula is expected.

CONFLICT OF INTEREST

The authors declare that there were no conflicts of interest in this study.

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