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Formulations of edamame flour based enteral nutrition as an alternative liquid diet for stroke patients

***Leiyla Elvizahro[1], Aprillia Dewi Arum Nur Purwandari[1], Riska Yunida Prastiwi[1], Syari Ernawati Putri[1], Vivi Meiliza Majid[1]**

[1]Universitas Gadjah Mada Academic Hospital
***Correspondency**: elvizahro@ugm.ac.id

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ABSTRACT

Background: *The liquid diet that has been given to stroke patients is a high-energy, high-protein and low-sodium enteral commercial formula. Commercial enteral formula has a relatively expensive price so we need a ready-made enteral product at a more affordable price. Hospitals can utilize potential ingredients to produce ready-to-use enteral formulas, one of which is edamame bean flour. Edamame is a source of protein, carbohydrates, fiber, amino acids, bioactive peptides, omega-3 fatty acids, and other micronutrients such as iron, folic acid, magnesium and phytochemical component.* ***Objective:*** *To formulate edamame flour-based enteral nutrition products that can be organoleptically acceptable, meet nutritional value, and meet the physical requirements of enteral nutrition for stroke patients.* ***Design:*** *Laboratory experimental research with a Completely Randomized Design with four research stage: 1) Making and testing the nutritional value of edamame flour, 2) Formulation of edamame flour-based enteral nutrition, 3) Testing of organoleptic quality, physical properties, and nutritional value and calculating the cost of enteral nutrition edamame flour based, 4) Determination of the selected formula.* ***Results:*** *Edamame flour produced in this study had the highest percentage of nutrient content in the form of protein (31.5%) and antioxidant activity of 69.75%. Based on the calculation of nutritional value, determined 3 formulas, namely formula A (comparison of edamame flour: skim milk 1: 4), formula B (2: 3), and formula C (1: 2). From the results of testing the nutritional value, physical properties, cost, and level of acceptance, formula A is determined as the chosen formula. Formula A has a protein content of 21.88%; energy content of 332.54 Kcal / 100 g; viscosity 8.6 cP; osmolality 436 mOsmol / Kg water; and most preferred panelists in terms of taste.* ***Conclusions:*** *Formula A with a ratio of edamame flour: skim milk 1: 4 has a nutritional value that is close to a commercial stroke formula and has the highest level of acceptance.*

KEY WORDS: *enteral formula, edamame flour, liquid diet, stroke*

1. Introduction

Lack of awareness and conditions of dysphagia that occur in stroke patients can reduce nutritional intake. Therefore, nutritional management of stroke patients plays an important role in preventing malnutrition[1]. Nutrition can be given via the enteral route if there is severe dysphagia or decreased/impaired consciousness. Study shows 20% of patients following a stroke may require enteral tube feeding during the acute phase, 8% will require long-term enteral tube feeding for more than six months[2]. For stroke patients, enteral nutrition must be able to meet energy and protein needs, energy content of at least 1 kcal / ml, osmolarity <400 mOsml[3]. The requirements for enteral formulas contain

balanced nutrition, namely 60-7-% carbohydrates, 15-20% protein, 20-30% fat, and easily absorbed[4]. Usually, the liquid diet that has been given to stroke patients is a commercial high-energy, low-fat, and low-sodium enteral formula.

Commercial enteral formulas that are sold in the market are relatively expensive, thus increasing the cost of treating stroke patients, especially for patients who are still on NGT until the time of discharge. Patient can also be given blenderised enteral formula, but a meta-analysis showed inconsistencies in the macronutrient and micronutrient values of the blenderised formula compared with the commercial formula[5].

Therefore patients need a ready-to-use enteral product at a more affordable price. Hospitals can utilize potential ingredients to produce ready-to-use enteral formulas. For example, a study in India produced Ready To Reconstitute Enteral Formula Feeds made from cereals, legumes, vegetables, and oil[6]. Another study in Semarang produced a modified enteral formula from palm oil, corn oil, skim milk, full cream milk, granulated sugar and maltodextrin[7].

The technology for drying food into ready-to-brew flour allows the use of local food ingredients as ingredients for enteral formulas. For example, a study in Yogyakarta found that starch arrowroot, fish cork, local tempeh and yellow pumpkin floured are potential to be formulated as enteral food to improve nutritional status among malnutrition patients[8].

UGM Food Technology Faculty has developed flour products from various local foods, one of which is edamame bean flour. The average edamame protein content is more than 40%, including all the important amino acids that other plant foods don't have. In edamame, the content of vitamins A, vitamin B, iron, and food fiber are high[9,10]. Edamame is a source of protein, carbohydrates, fiber, amino acids, bioactive peptides, omega-3 fatty acids, and other micronutrients such as iron, folic acid, magnesium and phytochemical components, namely isoflavones (0.1-0.3%), sterols (0.23-0.46%), and saponins (0.17-6.16%) which can reduce the risk of non-communicable diseases such as diabetes mellitus, hypertension, hypercholesterolemia, heart disease, and stroke[11]. Further research is needed to determine the formulation of edamame flour in order to qualify as enteral nutrition.

2. Materials and methods

The research conducted was a laboratory experimental study with a Completely Randomized Design (CRD). This research consists of four stages: 1) Preparation and testing of the nutritional value of edamame flour, 2) Formulation of edamame flour based enteral nutrition, 3) Testing of organoleptic quality, physical properties and nutritional value and calculation of the cost of enteral nutrition based edamame flour, 4) Determination of the selected formula.

Besides edamame flour, the ingredients used in this study included skim milk, maltodextrin, powdered sugar, and canola oil. Composition of ingredients in each formula was determined after the nutritional value of edamame flour was tested in the laboratory.

The nutritional values tested included moisture content, ash content, fiber content, fat content, protein content and carbohydrate content. The physical properties formulas which analyzed were viscosity and osmolality. Organoleptic quality was tested with the Hedonic Test using a minimum of 25 semi-trained panelists, namely panelists who already have knowledge of enteral nutrition products in general (nutritionists, nurses, and doctors). Organoleptic quality data were analyzed using the one way ANOVA statistical test and Duncan's advanced test.

Then, a production cost analysis was performed and compared with a commercial enteral formula for stroke patients. From the various test results and calculations, the chosen formula was determined.

This research has obtained Ethical Clearance from the Ethical Commission of FKKMK UGM.

3. Results

Edamame flour which was used as an ingredient in making formulas was processed from selected edamame beans which are easily available in supermarkets. Analysis of the nutritional content and antioxidant activity of edamame flour in this study was carried out in the laboratory of PT. Primary Chem-Mix with the results as in table 1 below.

Table 1. Results of Analysis of Nutritional Content and Antioxidant Activity of Edamame Flour

Content	Analysis Results		Average
	Deuteronomy 1	Deuteronomy 2	
Water content (%)	10,98	10,51	10,75
Ash content (%)	5,35	5,36	5,36
Protein content (%)	31,52	31,47	31,50
Fat content (%)	1,40	1,40	1,40
Food Fiber Content (%)	28,43	28,89	28,66
Carbohydrate content (%)	22,32	22,38	22,35
Antioxidant activity (%)	69,80	69,69	69,75

After obtaining the nutritional value of edamame flour, a formula is made based on the calculation of nutritional value. Edamame flour is mixed with skim milk, maltodextrin, powdered sugar, and canola oil. Besides edamame flour, the information on the nutritional value of other ingredients that will be used is obtained from food packaging and Nutrisurvey database.

Based on the calculations, three alternatives to the use of edamame flour were obtained with the ratio between edamame flour: skim milk of 1: 4, 1: 2, and 2: 3. The three formulas are named formula A (1: 4), formula B (1: 2), and formula C (2: 3). Composition calculation per 100 gram formula can be seen in Table 2.

The formula was prepared by a dry mixing method, where all the ingredients are dry-processed and mixed to obtain the desired powder formula. Testing of nutritional value and antioxidant activity were carried out in the laboratory of PT. Primary Chem-Mix with the results in Table 3.

Tabel 2. The Calculation of Composition per 100grams of Enteral Nutritional Formulas Based Edamame Flour

Materials	Formula A (1:4)	Formula B (1:2)	Formula C (2:3)	Commercial Stroke Formula
Edamame Flour (g)	15	25	30	-
Skimmed Milk Flour (g)	60	50	45	-
Maltodekstrin (g)	7	7	7	-
Sugar (g)	10	10	10	-
Canola Oil (g)	8	8	8	-
Energy (Kkal)	386,8	373,0	366,0	420
Protein (g)	22,7	22,9	23,0	22
Fat (g)	7,6	7,8	7,8	8
Carbohydrate (g)	53,9	50,5	48,8	64

Table 3. Testing Results of Nutritional Value and Antioxidant Activity of Enteral Formulas Based Edamame Flour

	Formula A (1:4)	Formula B (1:2)	Formula C (2:3)	Commercial Stroke Formula
Energy (Kkal/100 g)	332,54	323,61	326,49	420
Protein (%)	21,88	23,00	23,91	22
Fat (%)	10,58	11,30	12,39	8
Carbohydrate (%)	37,25	31,99	29,17	64
Food Fiber (%)	17,09	20,45	21,40	4
Water (%)	8,65	8,92	8,97	-
Ash (%)	4,57	4,35	4,17	-
Sodium (mg/100 g)	650,24	564,36	568,87	150
Potassium (mg/100 g)	370,41	319,80	391,81	1029
Antioxidants (%)	72,93	72,45	73,12	62,23

Note: The nutritional value of commercial stroke formulas is obtained from the nutritional information on the packaging.

In general, enteral formulas can be given to patients via the NGT tube or given orally. Therefore, organoleptic quality needs to be considered to determine the level of consumer acceptance of enteral formulas.

Organoleptic test for enteral formula based edamame flour was conducted at the UGM Academic Hospital with a panel of 30 people consisting of nutritionists, specialists, nurses, and pharmacists. The results of the organoleptic test were analyzed univariate and bivariate analysis. The data obtained is normally distributed so that it can be analyzed by One Way ANOVA. The results of the organoleptic quality analysis of the three formulas are shown in table 4 below. The number followed by the same letter in the same column shows no significant difference in the Duncan test at the 95% confidence level

Table 4. Results of Organoleptic Quality Analysis of Enteral Formulas Based Edamame Flour

Parameter		Mean	Category	p
Color	Formula A	$2,90^{b} \pm 0,66$	Like	0,001*
	Formula B	$2,83^{b} \pm 0,75$	Like	
	Formula C	$3,43^{a} \pm 0,73$	Like	
Flavor	Formula A	$2,97^{a} \pm 0,62$	Like	0,064
	Formula B	$2,60^{a} \pm 0,68$	Like	
	Formula C	$2,97^{a} \pm 0,77$	Like	
Consistency	Formula A	$2,83^{a} \pm 0,70$	Like	0,592
	Formula B	$2,90^{a} \pm 0,48$	Like	
	Formula C	$3,00^{a} \pm 0,70$	Like	
Parameter		Mean	Category	p
Taste	Formula A	$3,17^{a} \pm 0,66$	Like	0,000*
	Formula B	$2,27^{b} \pm 0,83$	Dislike	
	Formula C	$2,80^{a} \pm 0,89$	Like	

* Data shows significant differences ($p < 0.05$)

Table 5. Viscosity Test Results of Enteral Nutritional Formulas Based on Flour Edamame and Commercial Formula

	Viscosity (Cp)			Osmolity (mOsmol/kg water)
	Test 1	Test 2	Mean/Average	
Formula A	8,2	8,8	8,6	436
Formula B	9,8	8,7	9,25	469
Formula C	9,1	10,6	9,85	500
Commercial Formula	14,3	13,6	13,95	708

Table 6.Calculation Results for Enteral Formula Based Edamame Flour

Ingredient	Unit price/price per unit	Formula A		Formula B		Formula C	
		Weight per serving	Cost	Weight per serving	Cost	Weight per serving	Cost
Edamame Flour	25.000 per 150 g	15	Rp 2.500,00	25	Rp 4.166,67	30	Rp 5.000,00
Skim Milk	31.160 per 300 g	60	Rp 6.232,00	50	Rp 5.193,33	45	Rp 4.674,00
Maltodextrin	16.000 per kg	7	Rp 112,00	7	Rp 112,00	7	Rp 112,00
Powdered sugar	6.700 per 250 g	10	Rp 268,00	10	Rp 268,00	10	Rp 268,00
Canola Oil	38.555 per liter	8	Rp 280,40	8	Rp 280,40	8	Rp 280,40
Packaging	1.000 per pcs		Rp 1.000,00		Rp 1.000,00		Rp 1.000,00
Total			Rp 10.392,40		Rp 11.020,40		Rp 11.334,40

Important physical properties that need to be considered in making enteral formulas are viscosity and osmolality. The results of viscosity testing and osmolality calculations can be seen in table 4 above. The results of the viscosity test of the three enteral formulas meet the viscosity requirements of liquid food. This is in accordance with a research which states that the viscosity of commercial DM liquid food at Cipto Mangunkusumo Hospital ranges from 7–13.5 cP[12]. Other studies have reported the optimum viscosity of enteral (blenderized) formulas in the range of 3.5–10 cP [13].

One of the considerations for consumers in choosing enteral formulas is about the cost. For stroke patients who have NGT installed, enteral formula can be the only source of fulfilling nutritional needs so it is needed on a daily basis. Therefore, the researchers calculated the costs required to produce one serving of enteral formula based edamame flour. These costs are then compared to the prices for commercial stroke formulas.

The various test results and calculations above are summarized in Table 6 below for determining the selected formula. The criteria for determining the selected formula include formulas that meet nutritional value, physical characteristics requirements, have the lowest cost, and are most preferred organoleptically.

Table 6. Determination of Selected Formulas for Edamame flour based enteral nutrition

	Formula A (1:4)	Formula B (1:2)	Formula C (2:3)
The nutritional value which is close to the comparison formula	✓	✓	✓
Physical properties meet the requirements	✓	✓	✓
Lowest price	✓		
Most preferred color			✓
Most preferred aroma	✓	✓	✓
Most preferred thickness	✓	✓	✓
Most preferred taste	✓		
Score	6	4	5

From table 6 above, it can be concluded that formula A has the highest score so that it is determined as the chosen formula.

4. Discussion

Based on the previous study 2014, fresh edamame beans have water content of 70.8%, fat content of 3.9%, protein content of 11.39%, and carbohydrate content of 11.92%[14]. In edamame flour, it is possible to change nutritional value due to the processing of fresh edamame beans into flour. The water content and fat content of edamame flour produced in this study were lower than the fresh edamame beans. Meanwhile, the carbohydrate content and protein content of edamame flour were higher than fresh edamame beans. This is a result of the shrinkage of water content through the steaming and drying process of the edamame beans. The water content of edamame flour is 10.75% which is useful for extending its shelf life when compared to fresh edamame beans. The protein content of edamame flour is 31.50% which is considered as high so it can be used as a protein source in enteral formulas.

In the composition of the ingredients used, the nutritional value is calculated up to commercial stroke formula, namely 22 grams of protein, 8 grams of fat, and 64 grams of carbohydrates. The energy density that will be achieved is 1.2 Kcal / ml. The results of testing the nutritional value in the laboratory showed that the results were not much different from the calculations. The protein content of the three edamame formulas also adds to the protein content of the commercial stroke formula as a comparison. This is in accordance with the purpose of making enteral formula products based edamame flour, namely producing low fat and high protein product formulas.

The protein content in formula C was higher than formulas A and B. This could be because in formula C, edamame flour was more than formulas A and B. Based on the Standard Tables of Food Composition in Japan (2015), the protein content in raw edamame beans (green soybean) is 11.7 g.

The results of the nutritional value of fat from enteral formulas based edamame were still higher than commercial formulas. For formula A, the amount was 10.58%, formula B was 11.3%, and formula C was 12.39%. This is directly proportional to the raw edamame content which contains 6.2 grams of fat. The more edamame flour is given, the higher the fat will be. The fat in the edamame-based enteral formula is 10, 58%, 11.3%, and 12.39% of the total energy requirements and these values meet the requirements of a low fat and high protein diet for stroke patients because the fat content is still <30% of the total need. The highest carbohydrate content is formula A, 37.25%. However, it is still under the commercial formula which is 64%.

The antioxidant activity of edamame-based formulas is higher than commercial formulas. This can be caused by the content of isoflavones in edamame which is an antioxidant compound. In stroke patients, excess production of reactive oxygen species (ROS) and/or impaired metabolism resulting oxidative stress is a fundamental mechanism of cell damage following cerebral ischaemia[15]. By therefore, our bodies need the antioxidants that can help protect the body from free radical attack and reduce the negative impact[16].

The important physical properties that need to be considered in the preparation of enteral formulas are viscosity and osmolality. Viscosity is a method used to show how much power from the flow is given by a liquid. Viscosity can measure the speed of a liquid flowing through a glass tube, this is important because it affects the smooth entry of enteral food into the tube feeding tube. Enteral formulas should flow in an 8 - 14 French size food pipe. The viscosity of the formula was tested using a viscometer and written in Centripoise (cP).

Apart from viscosity, another physical property that needs to be considered is osmolality. Osmolality states the number of solute particles per kilogram of water. In this study, the osmolality of the commercial stroke formula as a comparison was known to be 708 mOsmol / kg of water. The osmolality of the enteral nutrition formula based edamame flour can be calculated by using a comparison.

The viscosity and osmolality of the enteral formula based edamame flour met the viscosity requirements of the enteral formula, it was 7–13.5 cP and osmolality of 350-720 mOsmol / Kg. Formula A has the lowest viscosity and osmolality compared to other formulas.

In general, enteral formulas can be given to patients via the NGT tube or given orally. Therefore, organoleptic quality needs to be considered to determine the level of consumer acceptance of enteral formulas. The quality of foodstuffs can be determined on several factors such as taste, texture, color and nutritional value[17]. Before other factors are considered, the color factor will come first visually and can sometimes greatly determine the quality of the food ingredient. The most preferred color formula is formula C. The color of formula C is preferred because it has lighter green color from edamame flour than the other formulas. The aroma of formula A and C are both the most preferred. The results of the organoleptic quality analysis showed that the treatment had a significant effect ($p < 0.05$) on the average level of preference for panelists in the color of the enteral formula.

Aroma is an odor caused by chemical stimulation that is smelled by olfactory nerves in the nasal cavity. Aroma is the most difficult sensory trait to classify and explain because of its many variations[18]. Based on the experiment, the aroma of formula A and C were stronger because each of these formulas has a dominant composition; formula A was dominant with skim milk aroma, while formula C was more dominant with edamame flour. The results of the organoleptic quality analysis showed that the treatment had no significant effect ($p > 0.05$) on the average level of preference for panelists in the aroma of enteral formula.

The most preferred viscosity formula was formula C. Formula C was preferred because it was thicker than formula A and B. The viscosity of formula C was because of edamame flour which was more abundant than skim milk flour. If edamame flour brewed, it was thicker than skim milk flour. The results of the organoleptic quality analysis showed that the treatment had no significant effect ($p > 0.05$) on the average preference level of the panelists on the viscosity of the enteral formula.

Taste is a product attribute that is measured using the sense of taste. The senses of taste are divided into four, namely sweet, salty, sour and bitter. The taste of food can be identified and distinguished by the taste buds found on the papilla in the form of an orange red stain on the tongue[17]. The most preferred flavor formula was formula A. Formula A had a tendency to taste skim milk and was not too unpleasant because the composition of edamame flour was less than formulas B and C. The results of the organoleptic quality analysis showed that the treatment had a significant effect ($p < 0.05$) on average of the level of preference for panelists on the taste of enteral formulas.

In determining the selected formula, organoleptic quality has a significant contribution because of the nutritional content, physical properties, and prices of the three formulas are not too different. Formula A is determined as the formula chosen with the advantage of being the most preferred by panelists in terms of taste. Based on its nutritional content, enteral formulas substituted for edamame flour can be used as an alternative to low-fat, high-protein enteral formulas for stroke patients to replace commercial enteral formulas. However, to determine the effectiveness of the enteral formula based edamame flour, it is necessary to conduct *In Vivo* trial research on experimental animals.

5. Conclusions

Based on the results of testing the nutritional value, physical characteristics, cost, and preference level, formula A with a ratio of edamame flour: skim milk 1: 4 was determined as the chosen formula. Formula A had a protein content of 21.88%; energy content of 332.54 Kcal / 100 g; viscosity 8,6 cP; osmolality 436 mOsmol / Kg of water; and most preferred by panelists in terms of the taste.

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Competing interests

Researchers do not have a conflict of interest in carrying out this research.

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