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High BCAA Enteral Food Formulation Based on Local Food Elakati (Pumpkin Enteral, Red Beans, and Egg White) for Liver Cirrhosis Patients

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Abstract

Background: Liver cirrhosis is a chronic disease often accompanied by malnutrition due to an imbalance of amino acids, requiring nutritional interventions such as affordable, locally sourced enteral formulas high in Branched Chain Amino Acids (BCAA). **Objective:** To develop a high-BCAA enteral formula using pumpkin, red beans, and egg whites. **Methods:** This study used an experimental design. Nutritional content was assessed empirically; viscosity was measured with a viscometer, osmolality with an osmometer, flow rate using a nasogastric tube, organoleptic tests by 15 panelists, and food cost calculated through market surveys. Organoleptic data were analyzed using the Kruskal-Wallis and Mann-Whitney tests ($p<0.05$). **Results:** The formula had an energy density of 1.13 kcal/ml (F1) and 1.07 kcal/ml (F2), with nutrient content meeting the standards. Viscosity for F1 and F2 exceeded recommended levels; average flow rates were 0.08 and 0.18 cc/second, respectively. Osmolality of F1 met enteral nutrition recommendations and no sediment was found. Organoleptic tests showed significant differences between CEF, F1 and F2 in color ($p=0.001$), aroma ($p=0.008$), texture ($p=0.018$), and overall acceptance ($p=0.034$), but not in taste ($p=0.184$). **Conclusion:** ELAKATI F1 is recommended as a high-BCAA enteral formula due to its nutritional adequacy, sensory acceptability, and use of affordable local ingredients.

Keywords: Liver cirrhosis; Branched chain amino acids (BCAA); Enteral nutrition; Local food-based formula; Good health and well-being.

Introduction

Liver cirrhosis is a liver disease characterized by the formation of scar tissue (fibrosis) and nodules in the liver due to chronic injury, resulting in changes to the typical structure of the liver lobules[1]. Based on the Global Burden of Disease (GBD) study, liver cirrhosis showed an 8.1% increase in the number of deaths in 2019 compared to 2017, ranking 16th in years lived with disability[2]. Liver cirrhosis often causes malnutrition, with a prevalence varying between 5-92% in patients[3]. Malnutrition in patients with liver cirrhosis is often caused by decreased energy and protein intake, as well as impaired protein metabolism. Branched Chained Amino Acids (BCAA) levels decrease while aromatic amino acid levels increase. Unbalanced amino acid levels are thought to increase complications such as sarcopenia and encephalopathy[4]. BCAA consists of leucine, isoleucine, and valine, which are three of the nine essential amino acids needed in the body's protein synthesis[5].

According to the European Society for Clinical Nutrition and Metabolism (ESPEN), appropriate nutritional intervention includes a daily high-protein intake of 1.2–1.5 g/kg and 35–40 kcal/kg, which can improve nutritional status and clinical outcomes, even in cases of acute or chronic liver failure[3,6]. If oral intake is insufficient, enteral tube feeding may be considered to meet the patient's nutritional needs[7,8].

BCAAs have been shown to have various biological effects, such as promoting protein synthesis and hepatocyte proliferation, stimulating the immune system, improving insulin resistance, and inhibiting the proliferation of liver cancer cells and the formation of new blood vessels[9–11]. These effects suggest that BCAAs may be beneficial in the management of patients with chronic liver disease, with a minimum dose of 12 grams per day considered effective in improving liver disorders, especially in patients with liver cirrhosis[4]. Examples of food sources that contain high levels of BCAAs include beef, fish, grain products, tofu, tempeh, nuts, milk and eggs[11,12].

Current high BCAA enteral formulas still have limitations such as high cost, palatability, inconsistent evidence of efficacy, and potential gastrointestinal problems[13,14]. Access to appropriate and affordable enteral formulas remains a challenge, especially in areas with limited economic and resource constraints. Blended formulas can be an excellent choice for patients because they contain everyday food ingredients, have good physical and nutritional qualities, and are affordable[15].

Pumpkin is a local Indonesian food ingredient that contains beta-carotene, which is beneficial for growth, tissue maintenance, and as an antioxidant that can reduce the risk of cancer and liver disease[16]. Chicken egg white is a source of high-quality protein with a BCAA content of ± 2.5 grams per 100 grams[17]. Cooked red beans are also rich in protein and BCAAs, with approximately 1.9 grams per 100 grams[18]. Skim milk flour, with low fat and high protein content, serves as a texture enhancer, water binder, and nutritional value enhancer in various food products, especially those requiring a low fat content[19].

This study offers a solution through the development of a high BCAA enteral formula based on local foods, namely pumpkin, red beans, and egg whites, named ELAKATI. This formula is not only designed to meet the nutritional needs of patients with cirrhosis, but also to optimize the use of locally available and more affordable foods. Thus, the study aims to determine the effect of pumpkin and red bean formulations on the quality of enteral food, including macronutrients, total branched-chain amino acids (BCAA), viscosity, osmolality, flowability, sedimentation, and organoleptic properties. This study aims to fill the existing gap and make a significant contribution to the treatment of liver cirrhosis.

Materials and Methods

Research Design

The study employed an experimental research design. The process of manufacturing enteral formula and testing its viscosity, osmolality, flowability, sedimentation, and sensory properties was conducted at the Nutrition Laboratory of the Dietitian Profession Study Program at Muhammadiyah University of Surakarta in August 2024.

Sample

The experimental stages consist of formula making and sample testing. The materials used in this enteral formula modification are pumpkin, white chicken eggs, red beans, coconut oil, skim milk flour, maltodextrin, granulated sugar, and cinnamon.

Data Collection and Analysis

The observed variables include nutrient content test, viscosity test, flowability test, osmolality test, and organoleptic test. Nutrient content includes energy, protein, fat, and carbohydrates. The viscosity test was conducted using the Brookfield D-11+ PRO tool at a temperature of 26.5˚C. The flowability test used a 12 French NGT tube, with calculations based on the first drop and the last drop. The osmolality test used the Osmotech Advent Instrument tool. Sediment test by placing the measuring cup formula and leaving it for 6 hours at room temperature, with observations of the sedimented particles every 1 hour.

Organoleptic tests include hedonic quality assessments of color, aroma, taste, texture, and overall quality. Organoleptic tests were conducted on untrained panelists. The study included 15 panelists. Organoleptic testing consisted of color, aroma, taste, texture, and overall assessment using the Hedonic Scale Test. The assessment criteria used were 1 (immensely dislike), 2 (dislike), 3 (slightly dislike), 4 (so-so or neutral), 5 (slightly like), 6 (like), and 7 (very like). The higher the assessment score, the more the panelists liked the product.

Statistical analysis of the organoleptic test results using IBM SPSS Statistics 22, consisting of a normality test using Shapiro-Wilk. The organoleptic test has an abnormal data distribution, so the data is tested using Kruskal-Wallis, and the statistical significance of the real difference between treatments is evaluated using the Mann-Whitney test with significance ($p < 0.05$). The average value and standard deviation are presented.

The composition of the ingredients used is presented in Table 1. There are differences in the amount of use between pumpkin and red beans in the ELAKATI F1 and F2 Formulas. This study used protein sources from red beans, white chicken eggs, and skim milk flour. However, the treatment in this study consisted only of red beans with the ELAKATI F1 formulation at 33% and ELAKATI F2 at 20%. White chicken eggs and skim milk flour with a 100% formulation. The manufacture of ELAKATI enteral food uses a multi-stage blending method[20]. The procedure for making ELAKATI enteral food is illustrated in Figure 1.

Table 1. Enteral Formula Composition

Food Material	Weight (gram)	
	ELAKATI F1	ELAKATI F2
Pumpkin	100	120
White egg	43	43
Red bean	50	30
Cooking oil	25	25
Skimmed milk powder	70	70
Maltodextrin	70	70
Sugar	20	20
Cinnamon	5	5

Data source*: Primary data on food ingredients*

Ethical Consideration

This study has been submitted for approval from the Ethics Committee of the Faculty of Dentistry, Airlangga University, and is currently in the process of issuing an ethical certificate. All research procedures have been designed by applicable research ethics principles, including maintaining the confidentiality of respondent data and obtaining consent from participants before data collection.

Results

Every 1000 ml of ELAKATI F1 formula has a total energy of 1127 kcal with an energy density of 1.13 kcal/ml, protein of 42.1 g (14.9%), fat of 27.9 g (22.3%), and carbohydrate of 181 g (64.2%). The total BCAA in this formula is 8.8 g consisting of 3.9 g leucine, 2.3 g isoleucine, and 2.6 g valine. The nutritional content of ELAKATI F1 Formula is presented in Table 2. In 1000 ml of ELAKATI F2 formula, there is a total energy of 1067.7 kcal with an energy density of 1.07 kcal/ml, protein of 37.7 g (14.1%), fat of 27.8 g (23.4%), and carbohydrate of 170.7 g (64.0%). The total BCAA in this formula is 8 g consisting of 3.5 g leucine, 2.1 g isoleucine, and 2.4 g valine. The nutritional content of Formula ELAKATI F2 is presented in Table 2.

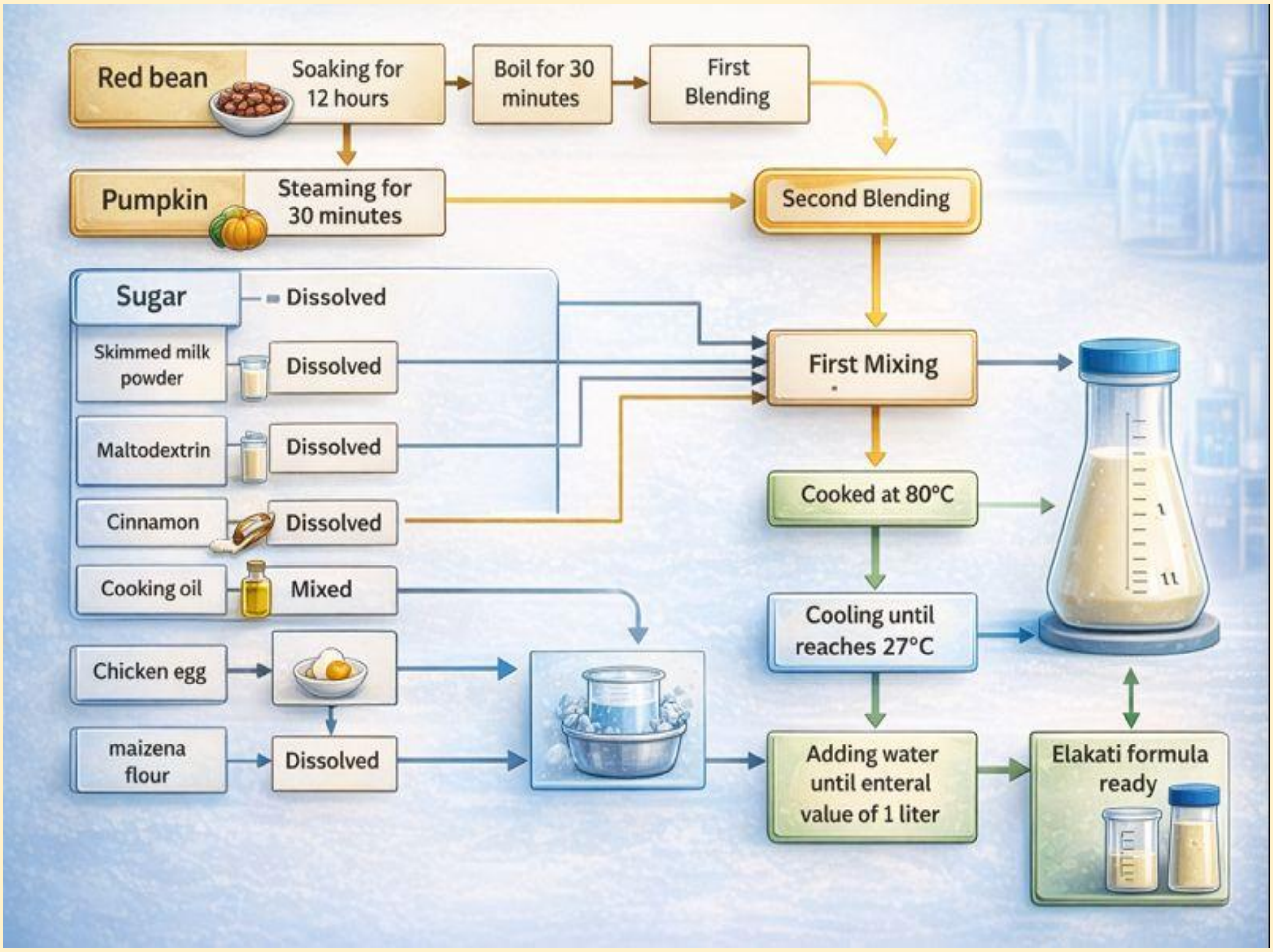

Figure 1. Flowchart for making the ELAKATI formula

Table 2. Results of Nutritional Content Tests and Enteral Formula Quality Tests

Formula	Nutritional Value					Osmolarity (mOsm/kg)	Flow Power (cc/s)	Sediment (cm)
	E (kcal)	P (gr)	F (gr)	CH (gr)	BCAA Total (gr)			
CEF	1140.0	36.0	45.2	147.2	12.48	429	1.85	0.4
ELAKATI F1	1127.0	42.1	27.9	181.0	8.8	490	0.08	0.0
ELAKATI F2	1067.7	37.7	27.8	170.7	8.0	583	0.18	0.0

Notes: E (Energi), P (Protein), F (Fat), CH (Carbohydrate), BCAA (Branched Chained Amino Acid), CEF (Commercial Enteral Formula), F1 (100 gr pumpkin, 50 gr red beans). And F2 (120 gr pumpkin, 30 gr red beans)
Dara source: Primary data analysis.

The enteral formula ELAKATI F1 exhibited osmolality characteristics of 490 mOsm/kg, with a flow rate of 0.08 cc/second and a sedimentation of 0.0 cm. At the same time, ELAKATI F2 had an osmolality of 583 mOsm/kg, a flow rate of 0.18 cc/second, and a sediment of 0.0 cm. The Comparative Commercial Formula (CEF) had a lower osmolality of 429 mOsm/kg, and a higher flow rate (1.85 cc/second) with a sediment of 0.4 cm.

Based on the viscosity test, as shown in Table 3, the ELAKATI F1 formula has a viscosity of 317.4 cP, while ELAKATI F2 is thinner, with a viscosity of 162.5 cP. These results indicate that the ELAKATI F1 formula has a higher viscosity and slower flow rate than the ELAKATI F2 formula.

Table 3. Enteral Formula Viscosity Test Results

Formula	Viscosity (Cp)
ELAKATI F1	317.4
ELAKATI F2	162.5

Organoleptic tests of the three formulas in Table 4. show that the CEF formula gets the highest overall score, both in terms of color (6.20 ± 0.77), aroma (5.93 ± 1.53), taste (5.40 ± 1.72), texture (5.93 ± 1.09), and overall (5.87 ± 1.30). However, the ELAKATI F1 formula gives relatively good organoleptic results, with an overall score of 5.07 ± 0.88, and is not significantly different from CEF in several attributes such as taste and texture. In contrast, ELAKATI F2 shows the lowest score in all organoleptic qualities, with an overall score of 5.07 ± 0.59. The Mann-Whitney statistical test indicates a significant difference ($p < 0.05$) between the formulas in all organoleptic attributes. Based on these results, the ELAKATI F1 formula is preferred over ELAKATI F2, as it exhibits physical and sensory quality characteristics that are similar to those of commercial enteral formulas.

Table 5. shows a comparison of food cost and nutritional content between ELAKATI Formula (F1 and F2) and commercial enteral formula (CEF). ELAKATI Formula F1 and F2 demonstrate superiority in terms of cost efficiency, with prices of Rp4,504,- and Rp4,331,- respectively.

Table 4. Mean Scores of Organoleptic Test Results

Formula	Average score ± SD				
	Color	Aroma	Taste	Texture	Overall
CEF	6.20 ± 0.77a	5.93 ± 1.53a	5.40 ± 1.72a	5.93 ± 1.09a	5.87 ± 1.30a
ELAKATI F1	5.13 ± 1.25b	4.73 ± 1.03a	4.87 ± 1.06a	5.20 ± 0.77a, b	5.07 ± 0.88a, b
ELAKATI F2	4.27 ± 1.22b,c	4.93 ± 1.16a	4.73 ± 0.96a	5.00 ± 0.74b	5.07 ± 0.59b
p Value	<0.01	<0.01	0.184	0.018	0.034

Description: a,b,c = similar letter notation means there is no real difference at the 5% Mann-Whitney test level. Data source: Primary data analysis

Table 5. Comparison of ELAKATI and Commercial Food Cost Formulas

Formula	Price (Rp)	E (kkal)	P (g)	F (g)	CH (g)	Leu	Isole	Valine	BCAA	Energy Density (Kkal/mL)
CEF	31.25	285	9	11.3	36.8				3.12	1.04
ELAKATI F1	4.504	281.8	10.5	7.0	45.3	1.0	0.6	0.7	2.2	1.13
ELAKATI F2	4.331	266.9	9.4	7.0	42.7	0.9	0.5	0.6	2.0	1.07

***Data source**: Primary data analysis*

Discussion

ELAKATI F1 enteral formula has a higher energy content than ELAKATI F2 but slightly lower than Commercial Enteral Formula (CEF). THE ELAKATI F2 formula has the lowest fat content compared to other formulas. The carbohydrates contained in ELAKATI F1 are the highest compared to other formulas. The highest protein content is found in the ELAKATI F1 formula. The BCAA content in ELAKATI F1 (8.8 g) and F2 (8.0 g) is still lower than CEF (12.48 g). This may be because plant-based formulas tend to have lower BCAA than commercial milk-based formulas[21,22].

The viscosity of the enteral formula significantly affects the smoothness of the formula entering the tube, the method of administration or feeding, and determines the size of the tube used. The higher the viscosity of the formula, the more difficult it will be to flow and increases the risk of blockage in the tube[23]. The optimum viscosity of blenderized enteral formula ranges from 3.5-10 cP[24]. Based on the viscosity values of the enteral formula in Table 2, it can be seen that ELAKATI F1 and F2 have not met the optimum viscosity of the blenderized enteral formula. ELAKATI F2 has a lower viscosity compared to ELAKATI F1. In this study, no viscosity test was carried out on the CEF formula.

Differences in the amount of red bean used can affect the viscosity of ELAKATI enteral formula. Red bean has a higher amylose content than other legume starches. The swelling characteristics and water absorption of starch are comparable among red bean varieties. The starch granules have a smooth surface and are round, elliptical, irregular, and oval in shape. The length and width of the starch granules vary significantly among cultivars. The sticking characteristics indicate that red bean starch has a high peak viscosity, making it an excellent thickener[25].

The flow rate test on CEF, ELAKATI F1, and ELAKATI F2 that has been carried out aims to determine the flow rate of the enteral formula. Based on the results of the enteral formula flow rate test in table 2, the results of the CEF flow rate are 1.85 cc/second, ELAKATI F1 is 0.08 cc/second and ELAKATI F2 is 0.18 cc/second. Flow rate refers to the speed and smoothness of the fluid flowing through the hosepipe. A thick formula can be an obstacle to flow in the hose pipe. Enteral formula flows best through a 10- to 14-French hose pipe.

Based on the results of the osmolality test in Table 1, the high BCAA enteral formula ELAKATI obtained results of 490 mOsm/kg in F1 and 583 mOsm/kg in F2. The recommended osmolality is around 300 - 450 mOsm/kg. The recommended enteral formula osmolality is <400 mOsm/kg[12,26]. The recommended osmolality for enteral feeding and Oral Nutrition Supplement (ONS) is between 300-500 mOsmol/kg (iso-osmolar). In this condition, the formula that is absorbed will be more optimal[27]. So ELAKATI F1 and CEF are in accordance with the osmolality recommendations for enteral food or ONS. High osmolality in enteral formula has the potential to cause dumping syndrome and diarrhea[28]. So the ELAKATI F2 formula has not met the recommended osmolality. Enteral formula administration requires attention to the risk of Refeeding Syndrome, especially in patients with malnutrition, so monitoring is needed to prevent metabolic complications[29].

Factors that influence osmolality include the content of dissolved substances such as disaccharides and monosaccharides, amino acids, proteins, medium-chain triglycerides, minerals, and electrolytes. Additionally, the amount of hydrolyzed substances also influences the osmolality value[30]. The use of more pumpkin can increase the osmolality value. High osmolality in blenderized food formulas is mainly caused by the use of sugar as a source of carbohydrates and high energy. Sugar is chosen because it is easily obtained, inexpensive, and meets calorie needs, as well as adding flavor. For ELAKATI F1, the results were 490 mOsm/kg, which is in accordance with the recommended osmolality for enteral formulas.

The addition of pumpkin can increase the osmolality value, as it contains starch. This is in line with research conducted by Fitria (2024) regarding the manufacture of ONS Niubi with the treatment of 3 formulations of tilapia fish flour and sweet potato flour which showed a tendency for increasing osmolality in the sweet potato flour formulation, the higher the osmolality value[12]. The cooking process can cause hydrolysis of the starch contained in sweet potato flour.

The results of the sediment test on CEF, ELAKATI F1, and ELAKATI F2, which have been carried out, can be seen in Table 2. Based on the results of the sediment test of the ELAKATI high BCAA enteral formula, after observing F1 and F2 for 6 hours, the ELAKATI enteral formula did not exhibit sediment, indicating that the ingredients used had completely dissolved in water. While commercial enteral formulas contain sediment, this is due to the formula being in powder form, which is difficult to dissolve in water, resulting in sediment formation within the formula.

The results of the hedonic taste test on the high BCAA enteral formula showed that CEF had the highest average preference among all formulas, with a score of 5.40 (slightly preferred). In contrast, ELAKATI F2 had the lowest average preference, which was 4.73 (somewhat like). ELAKATI has a slightly sweet taste characteristic, while CEF has a typical milky taste. In Table 3, it is evident that the taste parameter obtained a p-value of 0.184, indicating no significant difference in the formulas (ELAKATI F1, ELAKATI F2, and CEF) regarding the taste of high BCAA enteral.

The results of the organoleptic analysis of texture on CEF, ELAKATI F1, and ELAKATI F2 showed that CEF had the highest average preference, at 5.93 (like). In contrast, F2 had the lowest average preference, at 5.00 (somewhat like). ELAKATI F1 has a slightly thicker texture compared to ELAKATI F2, while CEF has a liquid texture. In Table 3, it can be seen that the texture parameter obtained a p-value of 0.018, indicating a difference in the formula (F1, F2, and CEF) for the high BCAA enteral texture. The results of the Mann-Whitney test showed that CEF had a significant difference with ELAKATI F1 and F2. There was no significant difference between ELAKATI F1 and F2.

The results of the overall organoleptic analysis of CEF, ELAKATI F1, and ELAKATI F2 showed that CEF had the highest average preference, with a score of 5.87 (like), while ELAKATI F1 and ELAKATI F2 had the same average preference, with a score of 5.07 (rather like). The panelists generally accepted neutral food in CEF, ELAKATI F1 and F2. Table 3 shows that the overall parameter obtained a p-value of 0.034, indicating a significant difference in the formula (F1, F2, and CEF) compared to the overall high BCAA enteral. The results of the Mann-Whitney test showed that CEF had a significant difference with ELAKATI F1 and F2. At the same time, there was no significant difference between ELAKATI F1 and F2.

Conclusion

BCAA in the ELAKATI F1 formula has met the nutritional value requirements with energy of 1127 kcal, protein 42.1 gr, fat 27.9 gr, carbohydrates 181 gr, leucine 3.9 gr, isoleucine 2.3 gr, valine 2.6 and BCAA 8.8 gr. This nutritional value meets the nutritional value requirements of enteral food for cirrhosis patients. The enteral viscosity of ELAKATI F1 is 317.4 cP, osmolality 490 mOsm/Kg, flow rate with an average F1 of 0.08 cc/second and there is no sediment in this formula. The organoleptic aspects of ELAKATI F1 have a color, aroma, taste, texture, and overall profile that are quite favorable. The estimated price per serving is IDR 4,500, making this formula a viable alternative to enteral food for patients with liver cirrhosis.

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Conflict of Interest Statement

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