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Development and evaluation of a blenderized enteral formula based on tempeh and pumpkin flour compared with a commercial enteral formula for a high-energy, high-protein (HEHP) diet: Nutritional, physical, and sensory characteristics for nutrition support in patients with cancer

Pengembangan dan evaluasi formula enteral blenderized berbasis tempe dan tepung labu dengan formula enteral komersial dalam Diet Tinggi Energi Tinggi Protein (TETP): Karakteristik nutrisi, fisik, dan sensorik untuk dukungan nutrisi pada pasien kanker

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Abstract

Natural food-based enteral formulas are gaining attention; however, their use in patients with cancer has not been widely reported. This study aimed to determine the nutritional, physical, and sensory characteristics of a blenderized enteral formula (EBF) based on local foods (tempeh flour and pumpkin flour) compared with a commercial enteral formula (CEF). This experimental study was conducted from September to December 2025 at the Faculty of Health Sciences and the Faculty of Agricultural Technology, Brawijaya University. Energy and protein content, viscosity, flow characteristics, and sensory acceptability of the EBFs and CEF were evaluated. Sensory acceptability was assessed by 32 untrained panelists. The costs of three EBF formulations (F1–F3) were compared with that of the commercial formula (F0). F1 had the highest energy density (1.21 kcal/mL) and protein content (5.75 ± 0.12%), as well as the lowest flow time (162.67 ± 2.08 s) and viscosity (127.67 ± 2.52 cP) among the EBFs. Sensory scores for F2 included color (5.59 ± 1.7), aroma (6.28 ± 1.3), texture (6.47 ± 1.4), and flavor (5.34 ± 1.9). F3 had the lowest cost. In conclusion, F1 was identified as the best EBF for an HEHP diet based on its nutritional and physical characteristics; however, further formulation improvement and testing in patients with cancer are required.

Keywords: Cancer patients, blenderized enteral formula, high-energy high-protein diet, tempeh flour, pumpkin flour

Abstrak

Formula enteral berbasis makanan alami semakin banyak diminati. Namun, aplikasinya untuk pasien kanker belum banyak dilaporkan. Penelitian ini bertujuan untuk mengetahui karakteristik nutrisi, fisik, dan sensory pada formula enteral blenderized (FEB) berbasis pangan lokal (tepung tempe dan tepung labu kuning) dan formula enteral komersial (FEK). Studi eksperimental ini dilakukan pada September-Desember 2025 di Fakultas Ilmu Kesehatan dan Teknologi Pertanian, Universitas Brawijaya. Kandungan energi-protein, viskositas, laju alir, dan penerimaan sensorik oleh 32 panelis tidak terlatih pada FEB dan FEK dianalisis. Biaya 3 formulasi FEB (F1-F3) dibandingkan dengan formula komersial (F0). Kandungan energi (1,21 kcal/mL) dan protein (5.75 ±

0.12%) tertinggi serta laju alir (162.67 ± 2.08 s) dan viskositas (127.67 ± 2.52 cP) terendah terdapat pada F1. Penerimaan sensori yang meliputi warna (5.59 ± 1.7), aroma (6.28 ± 1.3), tekstur (6.47 ± 1.4), dan rasa (5.34 ± 1.9) terbaik pada F2. Sedangkan biaya terendah pada F3. Kesimpulannya, F1 adalah FEB terbaik untuk diet HEHP karena menunjukkan karakteristik fisik dan nutrisi yang lebih baik dibandingkan dengan formula lain, meskipun masih memerlukan perbaikan formula dan pengujian lebih lanjut pada pasien kanker.

Kata Kunci: Formula enteral blenderized, pasien kanker, tepung labu, tepung tempe, tinggi energi tinggi protein

Introduction

Cancer is a major global public health threat, with nearly 20 million new cancer diagnoses and 9.7 million deaths worldwide; the number of new cases is projected to increase by 77% by 2050 (WHO, 2024). In Indonesia, breast, prostate, and lung cancers are among the most commonly reported cancers (Rusli et al., 2023). Malnutrition has been reported in 26%–80% of patients with cancer across different clinical conditions and is often associated with reduced intake (Hsu et al., 2026). Reduced intake may result from oral problems (e.g., difficulty swallowing and dry mouth) and gastrointestinal symptoms (e.g., nausea, vomiting, loss of appetite, and mucosal inflammation), which can further impair food intake and worsen malnutrition (Bargetzi et al., 2021; Tatsuta et al., 2025).

Dietary therapy is important for preventing and managing malnutrition in patients with cancer, and a high-energy, high-protein (HEHP) diet is one approach (Dingemans et al., 2023). For patients with severe malnutrition who consume 60% or less of their daily requirements, early enteral nutrition is recommended (Spurlock et al., 2022). Commercial enteral formulas are widely used because of their standardized nutritional composition and physical properties (Ojo et al., 2020). However, these products are relatively expensive and may increase inpatient costs. Some hospitals have developed blenderized enteral formulas; however, their shelf life may be limited by the use of liquid ingredients or a highwater content (Sutikno et al., 2020). Therefore, developing enteral formulas based on locally available flour-based foods may provide an opportunity for food innovation in health care.

Soybeans (*Glycine max* (L.) Merr.) are locally available legumes that are widely cultivated in Indonesia. Raw soybeans contain antinutritional compounds and have a firm texture. Fermentation into tempeh improves protein digestibility and may increase vitamin B12 content. Further processing into tempeh flour can also reduce antinutritional compounds (Drabo et al., 2023).

Pumpkin (*Cucurbita moschata* D.) is a carbohydrate-rich food with several nutritional benefits. It contains vitamins, minerals, dietary fiber (including pectin), and antioxidant compounds such as β-carotene. Processing pumpkin into flour may improve digestibility, concentrate nutrients, and extend shelf life. Among several pumpkin varieties, parang pumpkin flour is characterized by a relatively high carbohydrate and fat content and provides some protein. Pumpkin flour provides 333.64 kcal/100 g, compared with 51 kcal/100 g in raw pumpkin (Bekele & Emire, 2023; Mardiah et al., 2020). These characteristics suggest that tempeh flour and parang pumpkin flour may serve as potential local food ingredients to help meet the increased energy needs of patients with cancer while providing readily digestible nutrients.

Previous studies have demonstrated the potential of local flours in blenderized enteral formulas. A formula containing tempeh flour and jicama flour (50:50) had physical properties and energy and protein contents that met the needs of patients with hyperglycemia, whereas a formula containing pumpkin flour and egg white (80:20) showed favorable physical properties, protein content, and acceptability for patients with chronic kidney disease (Putri & Yenny, 2024; Sutikno et al., 2020). These studies support the development of local flour-based enteral products; however, neither provided a detailed comparison of the blenderized formula with a commercial enteral formula.

This study aimed to determine the nutritional, physical, and sensory characteristics of a blenderized enteral formula (EBF) based on local foods (tempeh flour and pumpkin flour) compared with a commercial enteral formula (CEF). The findings are expected to inform the development of enteral nutrition options for patients with cancer who require a high-energy, high-protein diet.

Methods

This study was conducted from September to December 2025 at the Faculty of Health Sciences and the Faculty of Agricultural Technology, Brawijaya University. A completely randomized design (CRD) was used, with three replications and randomized assignment of formulations to samples. Three tempeh flour-to-pumpkin flour ratios were evaluated: F1 (60:40), F2 (50:50), and F3 (40:60); a commercial enteral formula served as the control (F0) (Table 1). All samples were evaluated for energy density, protein content, flow characteristics, viscosity, and sensory acceptability.

The sensory preference test included 32 untrained panelists who provided informed consent before participation. The study received ethical approval from the Health Research Ethics Committee, Faculty of Health Sciences, Brawijaya University (No. 90/UN10.F17.10.4/TU/2025).

Table 1. Composition of blenderized enteral formulations based on tempeh flour and pumpkin flour

Ingredients (g)	F1 (60:40)	F2 (50:50)	F3 (40:60)
Tempeh flour	72	60	48
Pumpkin flour	48	60	72
Skim milk	50	50	50
Soybean oil	15	15	15
Maltodextrin	50	50	50
Granulated sugar	15	15	15
Egg white powder	20	20	20

The ingredients used for the blenderized enteral formulas were FERGLIN Tempe Powder (tempeh flour; CV Kriya Mandiri Restu), parang pumpkin flour, Indoprima skim milk, Happy soybean oil, food-grade maltodextrin (DE 10–12), Gulaku granulated sugar, and Breggfast egg white powder. Equipment included a scale, blender, measuring cup, spoon, stove, funnel, 100-mesh sieve, and strainer.

Each formula was prepared in three replicates. To reduce sediment, the tempeh flour and pumpkin flour were passed through a 100-mesh sieve. The dry ingredients (tempeh flour, pumpkin flour, skim milk, maltodextrin, granulated sugar, and egg white powder) were mixed for 3 min. Soybean oil was then added, and the mixture was stirred for 2 min. Mineral water was added to a final volume of 1,000 mL, and the mixture was blended for 8 min. The homogenized formula was then filtered to remove lumps. The commercial enteral formula was prepared by dissolving the powder in warm water to a final volume of 250 mL. All ingredients were weighed in grams. The volume of water was converted from milliliters to grams using a measuring cup (1,000 mL = 967 g).

Energy Density

Energy density was estimated using NutriSurvey 2007 software based on the ingredient composition of each enteral formula. This method was selected as a rapid approach for estimating energy content from the formulation. Each ingredient was entered in grams using the Indonesian food database when available; brand-specific ingredients not included in the database were entered manually. After all ingredients were entered, the software-generated energy and nutrient values were recorded. Energy density (kcal/mL) was calculated by dividing the estimated energy content of the formula (kcal) by the final volume (1,000 mL).

Protein Content

Protein analysis was performed only on the blenderized enteral formulas. The commercial formula used as the control was not analyzed because its nutritional composition had been standardized. A minimum sample volume of 10 mL was required, and no special temperature treatment was applied; samples were analyzed at room temperature (16–25°C). Testing was conducted at the Food Safety and Quality Testing Laboratory, Faculty of Agricultural Technology, Brawijaya University.

Protein content was analyzed using the Kjeldahl method based on the Association of Official Analytical Chemists (AOAC) 1995 method. This method estimates protein content from the nitrogen content of the sample through three steps: digestion, distillation, and titration. Protein content was then calculated using the following equation (Pratiwi et al., 2021):

$$\text{Protein content (\%)} = \frac{V \times 0.014 \times 6.25 \times 100}{W}$$

Note:
V = volume of HCl used for titration (mL)
0.014 = the nitrogen-to-ammonia conversion factor
6.25 = the nitrogen-to-protein conversion factor
W = the sample weight (g)

Flow Rate

The flow characteristics of the enteral formulas were evaluated to determine their ability to pass through a nasogastric tube (NGT). This test was selected because it is simple and rapid. Testing was conducted in the Dietetics and Culinary Laboratory, Department of Nutrition, Faculty of Health Sciences, Brawijaya University. The equipment included a 120-mL syringe, a basin, and a 14-Fr tube. This tube size was selected to minimize the risk of blockage (Bischoff et al., 2022). Each of the four samples was tested in triplicate to obtain the mean flow time.

First, a syringe with the plunger removed was connected to a 14-Fr nasogastric tube. The tube was positioned at a height of approximately 125 cm and bent near the syringe tip. A 100-mL sample was used. Flow time was measured from the start of formula passage through the tube until dripping ceased. The recorded time (s) was then used with the sample volume (100 mL) to determine the flow rate (mL/s).

Viscosity

Viscosity was measured to characterize the physical properties of the enteral products and their suitability for tube administration. Samples were tested at the Food Safety and Quality Testing Laboratory, Faculty of Agricultural Technology, Brawijaya University. A viscometer equipped with a spindle suitable for low-viscosity liquids (typically No. 1 or No. 2) was used, and results were reported in centipoise (cP). A minimum sample volume of 100 mL was used to ensure full immersion of the spindle. Samples were measured at room temperature (16–25°C) without additional temperature treatment.

Preference Levels

A sensory preference test using a 9-point hedonic scale was conducted to assess panelists' acceptability of the color, aroma, texture, and flavor of the blenderized enteral formulas based on tempeh flour and pumpkin flour, with the commercial enteral formula as the control (F0). Thirty-two untrained panelists, all university students, received four samples (F0–F3), which were presented individually and labeled with different three-digit codes. University students were selected as untrained panelists to provide an initial assessment of product acceptability during the early stage of formula development because the formulas had not yet undergone food safety and microbiological testing, and patients with cancer may experience disease- or treatment-related changes in sensory perception. Each 16-mL sample was served in a 35-mL food-grade thin-wall cup. Testing was conducted in a dedicated sensory evaluation chamber at the Dietetics Laboratory, Universitas Brawijaya, with controlled temperature and lighting. Before the evaluation and between samples, participants rinsed their mouths with mineral water. The 9-point hedonic scale was based on SNI 01-2346:2006, ranging from 1 (dislike very much) to 9 (like very much).

Statistical Analysis

Normality was assessed using the Shapiro–Wilk test. Normally distributed data were analyzed using one-way analysis of variance (ANOVA), whereas nonnormally distributed data were analyzed using the Kruskal–Wallis test, with a 95% confidence level. When significant differences were identified, Tukey's honestly significant difference (HSD) test was used for post hoc comparisons following one-way ANOVA, and the Mann–Whitney U test was used following the Kruskal–Wallis test.

Best Formulation

The optimal formulation was selected using the multiple-attribute decision-making (MADM) method proposed by Zeleny (1982). This method was used because evaluation of enteral formulas involves multiple nutritional and physical parameters that must be considered simultaneously to identify the most balanced formulation. The MADM approach enables objective comparison among formulations based on energy density, protein content, flow rate, and viscosity. Sensory preference was additionally evaluated using the De Garmo effectiveness index method, with subjective weighting of each attribute. All analyses were performed using Microsoft Excel 2013.

In the Zeleny method, ideal values were defined for each parameter, with higher values considered optimal for protein content and energy density and lower values considered optimal for flow rate and viscosity. Equal weights were assigned to all parameters, and distance measures (L_1, L_2, and $L\infty$) were calculated to assess each formulation's deviation from the ideal solution. The formulation with the lowest distance value was selected as optimal.

Sensory preference was analyzed using the De Garmo method, a weighted decision-making approach that integrates multiple sensory attributes into a single composite score. Attribute weights were determined from panelists' priority ratings. An effectiveness value (NE) was calculated for each formulation, and the total productivity score (NP) was derived as an overall preference index. The formulation with the highest NP was considered to have the greatest overall sensory acceptability.

Result and Discussion

Energy Density

Energy density decreased sequentially from F1 (1.21 kcal/mL) to F2 (1.19 kcal/mL), F3 (1.17 kcal/mL), and the commercial control formula, F0 (0.96 kcal/mL). According to the DAA Nutrition Support Interest Group, enteral formulas with an energy density of 1.0–1.2 kcal/mL are recommended for patients requiring high-energy, high-protein (HEHP) nutritional support (DAA, 2018). Based on this criterion, all blenderized enteral formulations evaluated in this study had energy densities within or close to the recommended range, suggesting their potential suitability for HEHP feeding.

Energy density can be influenced by macronutrient composition, particularly fat, which provides more energy per gram than protein or carbohydrate (Bazshahi et al., 2021). Tempeh flour and pumpkin flour are energy- and nutrient-dense ingredients that may help achieve the target energy density for patients with cancer. In patients receiving enteral nutrition, an energy density of 1 kcal/mL can contribute approximately 184–200 kcal/day and may help reduce the risk of muscle mass loss (Ichikawa et al., 2025). However, in practice, patients may not consume 100% of the prescribed volume because of feeding intolerance, including diarrhea, vomiting, and abdominal distension (Gabrielli & Steemburgo, 2024). Therefore, a higher energy density may improve daily energy intake while reducing the required feeding volume and potentially help limit muscle mass loss in patients with cancer.

Protein Content and Physical Characteristics of Enteral Formula

The protein content, flow time, and viscosity of the enteral formulas were evaluated to characterize their nutritional and physical properties. Protein content and flow time data were normally distributed and homogeneous; therefore, differences among formulations were analyzed using one-way ANOVA, which showed significant differences in protein content and flow time ($p < 0.01$).

Viscosity data were not normally distributed and were therefore analyzed using the Kruskal–Wallis test, which also showed significant differences among formulations ($p < 0.05$). Post hoc analysis using the Mann–Whitney U test identified significant differences between the blenderized enteral formulas and the control formula.

Table 2. Results of statistical analyses of protein content and physical characteristics of the enteral formulas

Formula	F0	F1	F2	F3	p value
Protein (%)	5.20 ± 0.00^{b}	5.75 ± 0.12^{a}	5.25 ± 0.10^{b}	4.90 ± 0.07^{c}	< 0.01
Flow time (s)	81.40 ± 3.70^{a}	162.67 ± 2.08^{b}	177.87 ± 2.42^{c}	215.97 ± 1.53^{d}	< 0.01
Viscosity (cP)	18.00 ± 0.00^{a}	127.67 ± 2.52^{b}	314.00 ± 5.57^{b}	371.33 ± 8.08^{b}	0.02

Values are presented as mean ± standard deviation. Different superscript letters within the same row indicate significant differences ($p < 0.05$). Analyzed using one-way ANOVA, Analyzed using the Kruskal–Wallis test followed by Mann–Whitney U post hoc tests.

Protein Content

The protein content of the three blenderized enteral formulas decreased from F1 (5.75 ± 0.12 g) to F2 (5.25 ± 0.10 g) and F3 (4.90 ± 0.07 g). This pattern reflected the ratio of the main ingredients, particularly tempeh flour as the principal protein source. The protein content of tempeh flour (46.82 g/100 g) is substantially higher than that of pumpkin flour (11.56 g/100 g) (Mardiah et al., 2020). Thus, the progressive decrease in protein content from F1 to F3 corresponded with the decreasing proportion of tempeh flour. Soybeans, the primary ingredient in tempeh, are affordable and nutritionally dense after processing. Heating and fermentation may also improve protein digestibility, supporting the use of soybeans as a nutritious local food source (Accardo et al., 2025).

Protein supports tissue maintenance and repair. Enteral feeding providing 5 g protein/100 mL seven times per day may help achieve the ESPEN-recommended protein intake of 1.3 g/kg/day (Badpeyma et al., 2025). Plant-based protein intake has been associated with lower breast cancer risk and mortality compared with animal protein intake (Pan et al., 2020). These findings support the potential nutritional value of tempeh flour. Adequate protein intake may also reduce excessive protein catabolism and the risk of complications such as sarcopenia and cachexia (Dingemans et al., 2023). In this study, F1 provided the highest protein content among the blenderized formulations.

Flow Rate

Flow characteristics were evaluated using flow time (s), with shorter times indicating faster flow. The formulations ranked from fastest to slowest as F0 (81.40 ± 3.70 s), F1 (162.67 ± 2.08 s), F2 (177.87 ± 2.42 s), and F3 (215.97 ± 1.53 s). Longer flow times indicate a thicker formula consistency and may reflect differences in ingredient composition. In particular, F3 contained the highest proportion of pumpkin flour and had the longest flow time.

Flow time can also be expressed as flow rate (mL/s). The significant difference in flow time ($p < 0.05$) indicated different flow characteristics among the formulas. The calculated flow rates were F0, 1.23 mL/s; F1, 0.61 mL/s; F2, 0.56 mL/s; and F3, 0.46 mL/s. The reported acceptable range for enteral feeding through a nasogastric tube is 0.40–1.67 mL/s (Ilminawati et al., 2024). Rates below this range may increase the risk of tube clogging, whereas excessively rapid feeding may increase the risk of diarrhea. Therefore, all commercial and blenderized formulas had flow rates within the reported acceptable range.

Viscosity

Viscosity is an important physical property of enteral nutrition because it influences flow through the feeding tube and ease of administration (Sutikno et al., 2020). In this study, viscosity increased progressively from F1 to F3 and was higher in all blenderized formulas than in F0. The increase in viscosity with higher proportions of pumpkin flour may be related to starch gelatinization and the water-binding capacity of dietary fiber, both of which influence the rheological behavior of enteral formulas. Pumpkin flour contains starch and soluble fiber that absorb water during reconstitution and heating, causing starch granules to swell and form a viscous gel network.

In addition, hydrogen bonding between polysaccharides and water molecules may increase resistance to flow. From a rheological perspective, increasing the total solids content and hydrocolloid-like components increases internal friction within the liquid system and, consequently, viscosity. These mechanisms may explain why formulas with higher proportions of pumpkin flour had a thicker consistency and slower flow. The viscosity of liquid enteral formulas can be influenced by temperature, macronutrient composition, total solids concentration, and the properties of the solid components. In this study, higher pumpkin flour content was associated with greater viscosity, likely because of its starch and dietary fiber content. During reconstitution and heating, starch granules absorb water, swell, and form a gel matrix, while dietary fiber increases water binding through hydrogen bonding, resulting in a thicker formula (Fauzi & Sholeha, 2023; Khan et al., 2019).

Descriptively, all blenderized formulas had higher median viscosity values than the commercial formula. The median viscosity of F0 (18 cP) was within the recommended range for enteral formulas (1–50 cP). In contrast, F1, F2, and F3 had substantially higher viscosity values, ranging from 128 to 370 cP, and exceeded the recommended range. These findings suggest that the high viscosity of the blenderized formulas may create challenges during administration through feeding tubes, particularly by increasing the risk of tube clogging and reducing flow efficiency. The high viscosity was likely related to the starch and dietary fiber content of pumpkin flour, which increases water absorption and gel formation. Further formulation optimization is therefore needed to improve the physical characteristics of the formulas before clinical application.

Preference Levels

Preference scores for sensory attributes, including color, aroma, texture, and flavor, were evaluated using untrained panelists to assess the preliminary acceptability of the enteral formulations (Table 3). These results represent an initial preference assessment during the early stage of formula development.

Color

Color preference differed significantly among formulations ($p < 0.05$). The control formula (F0) had the highest color score (7.07 ± 1.4; "like"), whereas the blenderized formulas had lower scores ranging from 5.31 ± 1.5 to 5.78 ± 1.5 (neutral to slightly like). Post hoc analysis showed significant differences between F0 and all blenderized formulas ($p < 0.001$), whereas no significant differences were observed among the blenderized formulas ($p > 0.05$).

Table 3. Sensory preference scores for the blenderized and commercial enteral formulations

Attributes	Groups				p value
	F0	F1	F2	F3	
Color	7.07 ± 1.4^{b}	5.31 ± 1.5^{a}	5.59 ± 1.7^{a}	5.78 ± 1.5^{a}	< 0.001
Aroma	8.13 ± 0.9^{b}	5.91 ± 1.8^{a}	6.28 ± 1.3^{a}	6.16 ± 1.5^{a}	< 0.001
Texture	7.59 ± 1.2^{b}	6.47 ± 1.3^{a}	6.47 ± 1.4^{a}	6.38 ± 1.6^{a}	0.001
Flavor	8.13 ± 0.9^{b}	5.47 ± 2.0^{a}	5.34 ± 1.9^{a}	5.25 ± 1.6^{a}	< 0.001

Values are presented as mean ± standard deviation. Different superscript letters within the same row indicate significant differences ($p < 0.05$). Analyzed using the Kruskal–Wallis test followed by Mann–Whitney U post hoc tests.

Among the blenderized formulations, F3 was descriptively closest to F0 in color preference and tended to score higher than F1. Visually, all blenderized formulas had a yellow hue, with F1 appearing lighter than F3. These differences were influenced by the proportions of the ingredients. Skim milk, maltodextrin, and egg white powder contributed relatively similar light colors, whereas the two primary ingredients, tempeh flour and pumpkin flour, differed more visibly. Tempeh flour was pale yellow, while pumpkin flour had a deeper brownish-yellow hue. Therefore, the higher proportion of pumpkin flour in F3 likely contributed to its more intense color compared with F1. The yellow-orange color of pumpkin is attributed to carotenoid pigments, particularly β-carotene, which naturally contribute to the color of *Cucurbita moschata*. Color intensity may also be influenced by fermentation duration (Sari et al., 2025).

Aroma

Aroma preference differed significantly among formulations ($p < 0.05$). The commercial control (F0) had the highest score (8.13 ± 0.9; "like very much"), whereas the blenderized formulas had lower scores ranging from 5.91 ± 1.8 to 6.28 ± 1.3 (neutral to slightly like). Post hoc analysis showed significant differences between F0 and all blenderized formulas ($p < 0.001$), with no significant differences among the blenderized formulations ($p > 0.05$).

Among the blenderized formulas, F2 was descriptively closest to F0 in aroma preference. Because no flavoring agents were added, the perceived aroma was derived primarily from tempeh flour and pumpkin flour, while the other ingredients were standardized. Legume-based ingredients such as tempeh may produce characteristic "beany" off-odors associated with volatile compounds formed through lipid oxidation, which may explain the lower scores relative to the flavored commercial formula (Yang et al., 2023). Pumpkin may also contribute volatile compounds that influence aroma, although their intensity can vary with the raw material and processing conditions (Zhang et al., 2025).

Because no significant differences were observed among F1–F3, one potential approach to improving aroma acceptability is the addition of aromatic ingredients such as cinnamon, which provides sweet, slightly spicy, and warming sensory notes (Putri & Yenny, 2024). Alternatively, cinnamon could be cooked with the tempeh flour or pumpkin flour, although this approach would require additional processing steps.

Texture

Texture preference differed significantly among formulations ($p < 0.05$). The commercial control (F0) received the highest score (7.59 ± 1.2; "like"), whereas the blenderized formulas had slightly lower scores (6.38 ± 1.6 to 6.47 ± 1.4; "slightly like"). Post hoc analysis showed significant differences between F0 and all blenderized formulas ($p = 0.001$), with no significant differences among the blenderized formulations. Within the blenderized formulas, F1 and F2 had the highest texture scores and were descriptively closest to F0.

The higher viscosity of the blenderized formulas compared with the commercial control may explain these differences because pumpkin flour contains starch that absorbs water and increases thickness through granule swelling (Huang et al., 2024). Although panelists noted a slight powdery mouthfeel and residual flour aftertaste, sieving the flours to obtain finer particles may have improved texture uniformity. Despite the higher viscosity, texture acceptability remained relatively stable across the blenderized formulations, consistent with previous findings that formulation-related differences can be statistically significant without markedly affecting perceived thickness preference (Puspita et al., 2022).

Flavor

Flavor preference differed significantly among formulations ($p < 0.05$). The commercial control (F0) had the highest score (8.13 ± 0.9; "like very much"), whereas the blenderized formulas had lower scores and remained within the neutral range (5.25 ± 1.6 to 5.47 ± 2.0). Post hoc analysis showed significant differences between F0 and all blenderized formulas ($p < 0.001$), with no significant differences among the blenderized formulations. F3 had the lowest flavor acceptability score among the blenderized formulas.

Given the similar sweetness levels, flavor preference was likely influenced by the ratio of tempeh flour to pumpkin flour. In this study, F2 (50:50) was selected as the preferred blenderized formulation based on the overall De Garmo sensory evaluation. This suggests that a balanced proportion may reduce the dominance of the characteristic flavor of either ingredient. Although the selected ratio differed, a previous study of a pumpkin- and soybean-tempeh-based enteral formula also found that ingredient proportions were associated with hedonic quality and selection of the preferred formulation (Mardani et al., 2025).

Some panelists perceived bitterness and a powdery mouthfeel, which may have reduced perceived sweetness. Although the statistical analysis showed no significant differences among the blenderized formulas, further flavor improvement appears warranted. Potential approaches include adding cinnamon, as described above, or incorporating carrot flour. Carrot flour has been used in enteral formulations and may contribute to color, aroma, and flavor (Nur'faizah et al., 2025).

Food Cost

The average cost of the blenderized enteral formulas (F1, F2, and F3) was approximately Rp33,763, whereas the commercial formula cost approximately Rp122,800 for the same volume (1,000 mL) (Table 4). Thus, the blenderized enteral formulas cost approximately one-quarter as much as the commercial formula.

Table 4. Food cost of the enteral formulas

Ingredients (g)	Ratio			Cost (Rp)			
	F1	F2	F3	F0	F1	F2	F3
Tempeh flour	72	60	48	-	14.400	12.000	9.600
Pumpkin flour	48	60	2		7.200	9.000	10.800
Skim milk	50	50	50		389	389	389
Soybean oil	15	15	15		698	698	698
Maltodextrin	50	50	50		3.750	3.750	3.750
Sugar	15	15	15		327	327	327
Egg white powder	20	20	20		7.600	7.600	7.600
Total (Rp per 1,000 mL)				122.800	34.363	33.763	33.163

F1 (60:40); F2 (50:50); F3 (40:60)
F0: The ingredient composition of the commercial formula (F0) was not disclosed; therefore, only the total cost per 1,000 mL is presented.

The differences in cost among the blenderized formulas were small because the ingredient proportions varied only modestly. In addition, most ingredients were locally sourced and relatively affordable. The more expensive ingredients, such as maltodextrin and egg white powder, accounted for less than 50% of the total food cost.

Based on the food cost analysis, the use of local ingredients such as tempeh flour and pumpkin flour may contribute to a lower-cost blenderized enteral formula compared with the commercial formula. This cost advantage may be relevant when developing alternative enteral formulas, particularly in settings where affordability is an important consideration (Regina et al., 2021). However, the present cost analysis should be interpreted within the context of formulation development and does not demonstrate clinical effectiveness or safety in patients with cancer.

Best Formulation

Sensory preference was evaluated using the De Garmo method, with attribute weights based on panelist priorities: flavor (0.4), texture (0.3), color (0.2), and aroma (0.1). F2 obtained the highest composite score among the blenderized formulas. The NP and NE values for F2 were 0.09 and 0.44, respectively, followed by F1 and F3. However, the commercial control (F0) had the highest overall score, with NP and NE values of 1.00 and 4.00, respectively. These results indicate that F2 was the blenderized formulation with the highest overall sensory preference score, although its NP value remained substantially lower than that of F0.

This result may be related to the balanced proportions of pumpkin flour and tempeh flour in F2, which may have reduced the dominance of the distinctive sensory characteristics of either ingredient. Tempeh-based ingredients may contribute a beany aroma and slightly bitter flavor, whereas pumpkin flour may contribute characteristic color, aroma, and flavor. Dominance of either ingredient could therefore affect overall preference. Further improvement using natural flavoring ingredients such as cinnamon may be considered; however, the concentration should be carefully controlled because excessive addition may reduce acceptability (Putri & Yenny, 2024). Carrot flour may also be considered because its carotenoid content can contribute to color, aroma, and flavor (Nur'faizah et al., 2025).

Based on nutrient content (energy density and protein content) and physical characteristics (flow rate and viscosity), the optimal formulation was determined using the Zeleny method. The commercial formula (F0) had the lowest total distance value (0.23), indicating the closest proximity to the ideal solution and ranking as the best formulation overall. Among the blenderized formulas, F1 had the smallest distance from the ideal solution (0.30), followed by F3 (0.32) and F2 (0.34).

Viscosity was the physical parameter of the blenderized enteral formulas that did not meet the recommended range. Factors that may influence viscosity include dietary fiber and sugar concentration. The recommended dietary fiber content in enteral formulas is 10–15 g/L. Dietary fiber, particularly soluble fiber, is known to increase viscosity relative to insoluble fiber (Anggraeni et al., 2023; Khusanaini et al., 2023).

Several limitations should be considered when interpreting the findings. This study used commercially available tempeh flour and pumpkin flour selected according to predetermined inclusion criteria; however, the flours required additional preparation before formulation. These preparation steps may have altered the characteristics of the raw materials and influenced the nutritional, physical, and sensory properties of the final blenderized enteral formulas.

In addition, the study did not evaluate several important physical and clinically relevant parameters, including osmolarity, shelf life, compatibility with enteral feeding tubes under actual administration conditions, and viscosity stability during storage and administration. Energy density was estimated using software and may therefore differ from the measured nutrient composition of the final product. Flow testing also did not further evaluate the relatively large variability observed in several measurements. For sensory evaluation, no descriptive sensory analysis was conducted to characterize the specific color, aroma, flavor, and texture attributes of each formula before the preference test because the evaluation focused on hedonic preference in accordance with the primary objective of assessing formula acceptability.

Conclusion

The local food-based blenderized enteral formulas containing tempeh flour and pumpkin flour differed from the commercial enteral formula in their nutritional, physical, and sensory characteristics. Among the blenderized formulas, F1 had the highest energy density and protein content and the highest calculated flow rate, while F3 had the lowest cost. In the sensory evaluation, F2 achieved the highest overall composite preference score among the blenderized formulations. However, the commercial enteral formula received higher sensory preference scores than all blenderized formulas. Based on the Zeleny analysis of nutritional and physical characteristics, F1 was identified as the best blenderized enteral formula among the tested formulations.

These findings indicate that tempeh flour and pumpkin flour have potential as local ingredients for high-energy, high-protein blenderized enteral formulas. Further formulation development is recommended to improve acceptability, particularly aroma and flavor, while maintaining nutritional and physical characteristics. Future studies should consider optimizing the proportions of tempeh flour and pumpkin flour and evaluating natural flavoring ingredients such as cinnamon or carrot flour to improve sensory properties. Food safety and microbiological testing, osmolarity analysis, shelf-life evaluation, and sensory evaluation in the target population should also be conducted before further evaluation in patients with cancer who require enteral nutrition.

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