



Development and Characterization of a Dayak Onion-Based Enteral Formula Prototype

Miftahul Jannah¹, Nur Rahman¹, Endang Widajati¹

¹Poltekkes Kemenkes Malang, Indonesia

✉ miftahulj627@gmail.com*

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Abstract

Dayak onion, traditionally recognized for its ethnomedicinal properties, contains bioactive flavonoids with potential applications in functional nutrition, yet its incorporation into enteral formulas has not been systematically explored; therefore, this study aimed to develop and characterize a milk-based enteral formula prototype containing Dayak onion bulb extract powder through a laboratory-based product-development design that assessed proximate composition, calculated energy, apparent viscosity, flavonoid-related characteristics, and preliminary sensory acceptability, with results showing nutritional values of 383.83 kcal, 72.31 g carbohydrate, 6.57 g protein, 2.60 g fat, 9.61% moisture, and 2.07% ash, corresponding to an energy density of 1.47 kcal/mL, while viscosity analysis indicated 8 mPa·s under standardized conditions, qualitative flavonoid screening was positive, and TLC-densitometric quantification yielded 4.4403 mg quercetin equivalents/g with R_f values of 0.75–0.76 comparable to the quercetin reference, and sensory evaluation by 21 semi-trained panelists demonstrated high acceptability for color (94.3%), aroma (90.5%), taste (94.3%), and texture (86.7%), thereby providing an initial multidomain characterization of the prototype and establishing a formulation-level basis for further optimization, although clinical nutritional adequacy, antioxidant or anticancer efficacy, and suitability for tube feeding remain unverified, necessitating future analytical validation, stability testing, safety assessment, and controlled clinical nutrition studies before patient application can be considered.

INTRODUCTION

Cancer remains a major global health burden. In 2022, nearly 20 million new cancer cases and 9.7 million cancer-related deaths were estimated worldwide. In Indonesia, the Global Cancer Observatory reported 408,661 new cases and 242,988 deaths, with an age-standardized incidence rate of 136.9 per 100,000 population. The continuing burden of cancer underscores the importance of not only effective oncological treatment but also supportive interventions that help maintain nutritional status throughout the course of disease and treatment (Bray et al., 2024; Ervik et al., 2026).

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Nutritional deterioration is particularly important in oncology because reduced food intake, metabolic alterations, treatment-related symptoms, and systemic inflammation can contribute to malnutrition and loss of body mass (Arends, 2024; Klek et al., 2025; McGovern et al., 2022). Malnutrition, in turn, has been consistently associated with adverse clinical outcomes. A systematic review and meta-analysis of patients with cancer found that malnutrition, defined according to the Global Leadership Initiative on Malnutrition criteria, was associated with poorer overall survival and a higher risk of postoperative complications. However, the certainty of the underlying evidence was limited (Matsui et al., 2023). These findings support the importance of early nutritional assessment and appropriately targeted nutrition support as part of comprehensive cancer care.

Current ESPEN guidance recommends nutritional intervention when patients with cancer are malnourished or at risk of malnutrition, beginning with dietary counseling and oral nutritional supplements when oral feeding remains feasible. When oral intake remains inadequate, and the gastrointestinal tract is functional, enteral nutrition is preferred over parenteral nutrition whenever clinically appropriate (Muscaritoli et al., 2021). Consequently, developing enteral products for nutrition support requires attention not only to nutrient composition but also to properties that affect preparation and administration. Nutritional composition determines a formula's potential contribution to dietary requirements, whereas physicochemical properties such as viscosity influence flow characteristics and handling during enteral feeding. Ingredient composition, concentration, temperature, and preparation procedures can affect these characteristics (Boullata et al., 2017; Wakita et al., 2012).

One botanical ingredient of potential interest for food-product development is Dayak onion, *Eleutherine bulbosa* (Mill.) Urb., a bulbous member of the Iridaceae that has a history of traditional use in Southeast Asia, particularly among communities in Kalimantan. Phytochemical studies have identified several groups of bioactive constituents in *E. bulbosa* bulbs, including phenolic and flavonoid derivatives, naphthalene derivatives, anthraquinones, and naphthoquinones (Arbain et al., 2022; Kamarudin et al., 2021). Quantitative characterization of bulbs collected from different locations in Kalimantan has further shown measurable total flavonoid content expressed as quercetin equivalents, indicating that the botanical material is a source of flavonoid-related phytochemicals that can be analytically characterized in food-development studies (Muthia et al., 2021).

Experimental studies have also highlighted the biological activity of *E. bulbosa*. Recent in vitro investigations have reported cytotoxic and antiproliferative responses of *E. bulbosa* extracts or isolated constituents in several cancer-cell models (Kamarudin et al., 2021, 2022). For example, an *E. bulbosa* extract was associated with apoptosis induction and cell-cycle alterations in T47D breast cancer cells, while other studies reported antiproliferative effects against A549 lung cancer cells and cytotoxic activity of isolated isoeleutherol against several human cancer cell lines (Kurniawan et al., 2026; Milliana et al., 2023; Zakaria et al., 2023). These observations remain preclinical, however, and cannot be extrapolated to the therapeutic efficacy of an *E. bulbosa*-containing food product or enteral formula in patients. Accordingly, the present study considers the botanical ingredient as a phytochemical-containing component of a nutrition-oriented formulation rather than an established anticancer treatment.

The potential incorporation of *Eleutherine* species into food matrices has received some attention. Previous applications have included fermented

food products, yogurt-related systems, and salad dressings, where researchers have investigated the botanical material primarily for functional, antioxidant, antimicrobial, or food-quality characteristics (Kamarudin et al., 2021). Nevertheless, these applications differ substantially from enteral nutrition products, for which nutritional composition and flow-related physical properties must be considered alongside botanical constituents and product acceptability. Published evidence integrating *E. bulbosa* into an enteral-formula matrix and concurrently characterizing nutritional composition, viscosity, phytochemical markers, and sensory acceptability therefore remains limited.

This limitation defines the principal research gap this study addresses. Existing *E. bulbosa* research has focused primarily on phytochemical characterization and preclinical pharmacological activity, while food-related studies have generally examined other product matrices (Kamarudin et al., 2021; Panyachariwat et al., 2024). Conversely, enteral-nutrition research emphasizes nutritional adequacy, physicochemical behavior, and safe administration but has rarely addressed *E. bulbosa* as a botanical ingredient. The novelty of the present work therefore lies not in demonstrating anticancer efficacy, but in integrating *E. bulbosa* bulb extract powder into a milk-based enteral-formula prototype and examining multiple formulation-level attributes within the same product-development framework: proximate composition and calculated energy, reconstituted viscosity, flavonoid-related phytochemical content, and preliminary sensory acceptability. Accordingly, this study aimed to develop and characterize a milk-based enteral formula prototype containing *E. bulbosa* bulb extract powder. The investigation addressed four research questions:

- RQ1. What are the proximate composition, calculated energy value, and energy-density characteristics of the developed *E. bulbosa*-containing enteral formula prototype?
- RQ2. What is the apparent viscosity of the reconstituted prototype under the specified measurement conditions?
- RQ3. What flavonoid-related content and TLC-densitometric characteristics are detected in the *E. bulbosa* ingredient relative to the quercetin reference under the analytical conditions used?
- RQ4. What are the preliminary hedonic responses to the color, aroma, taste, and texture of the reconstituted prototype among the 21 semi-trained panelists?

By integrating these nutritional, physicochemical, phytochemical, and sensory domains, the study provides an initial formulation-level characterization of an *E. bulbosa*-containing enteral prototype. Its contribution is therefore methodological and translational at the product-development level: it establishes a reproducible basis for evaluating the feasibility of incorporating Dayak onion into an enteral nutrition matrix while clearly defining the evidence required before clinical application. The findings are intended to support subsequent studies involving independent production batches, analytical validation, microbiological and storage stability, osmolality, tube-delivery compatibility, safety, and ultimately patient-based nutritional evaluation rather than to establish anticancer efficacy or therapeutic benefit.

METHODS

Study design and setting

This laboratory-based product-development and descriptive characterization study was conducted in December 2024. Preparation of the

Eleutherine bulbosa-containing formula, viscosity measurement, and sensory evaluation were conducted at the Food Science Laboratory, Poltekkes Kemenkes Malang, Indonesia. Proximate analyses were performed at the Nutrition Laboratory, Universitas Airlangga, Surabaya, whereas phytochemical analysis was conducted at Materia Medica Batu, East Java, Indonesia.

The study included preparing *E. bulbosa* extract powder, formulating and reconstituting the powdered enteral prototype, and characterizing its nutritional composition, viscosity, flavonoid-related phytochemical characteristics, and sensory acceptability. Figure 1 summarizes the overall experimental workflow.

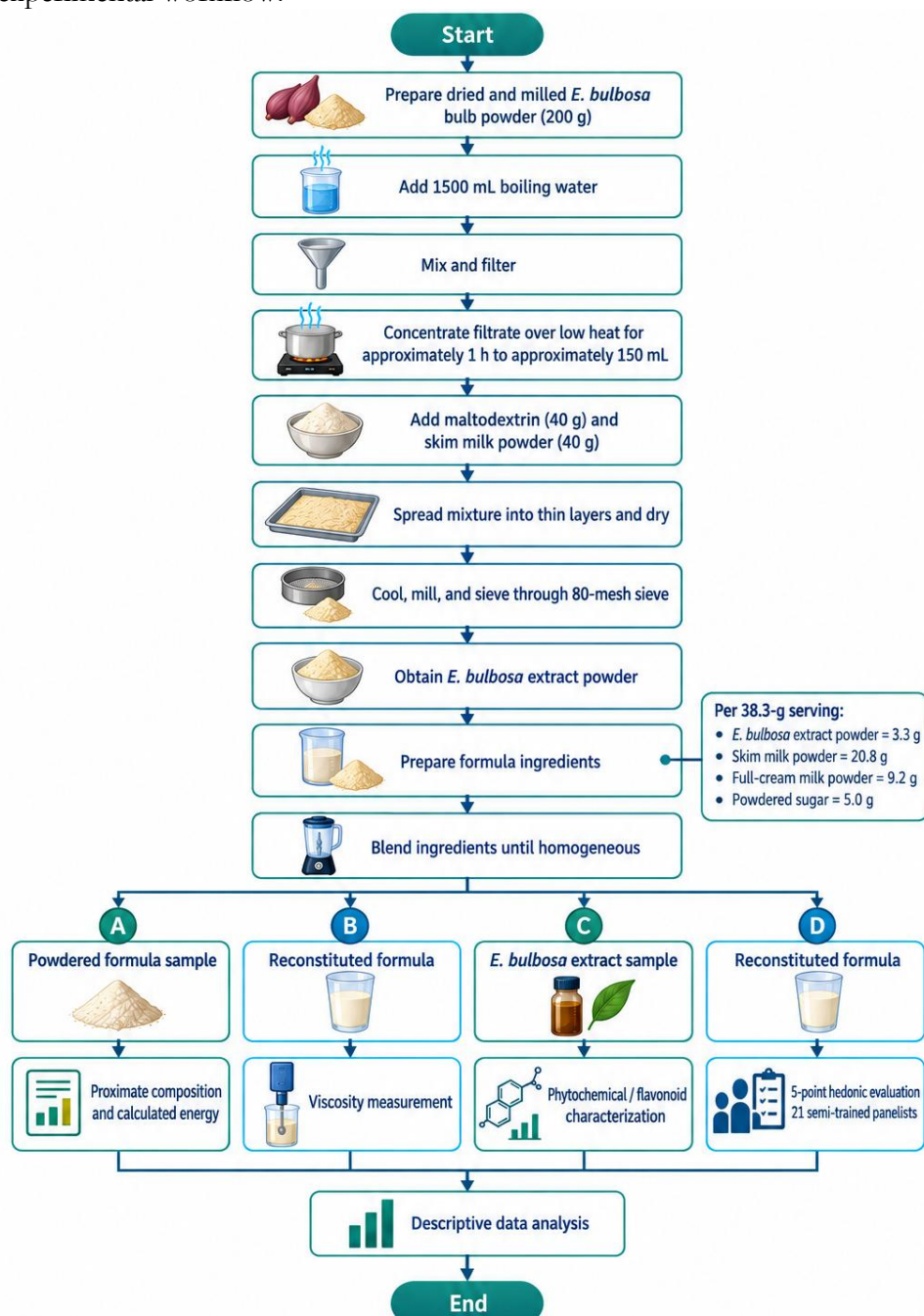


Fig 1. Development and characterization workflow of the *Eleutherine bulbosa*-containing enteral formula prototype

Preparation of *Eleutherine bulbosa* extract powder

Dried and milled *E. bulbosa* bulbs (200 g) were extracted with 1500 mL of boiling water. The mixture was stirred and filtered, and the filtrate was

concentrated over low heat for approximately 1 h until its volume was reduced to approximately 150 mL. Maltodextrin (40 g) and skim milk powder (40 g) were subsequently incorporated and mixed until homogeneous.

The resulting mixture was distributed into thin layers and dried. After cooling to room temperature, the dried material was milled into powder and passed through an 80-mesh sieve. The resulting *E. bulbosa* extract powder was stored for subsequent incorporation into the enteral-formula prototype. Previous food-product development studies have also reported using maltodextrin as a carrier or stabilizing component in powdered Dayak-onion products (Rosda & Rosida, 2024; Engkizar et al., 2026; Eriyanti et al., 2020; Muhlasin et al., 2026; Sari et al., 2025).

Enteral formula preparation and reconstitution

Table 1 presents the formulation used for one serving. One serving contained 3.3 g of *E. bulbosa* extract powder, 20.8 g of skim milk powder, 9.2 g of full-cream milk powder, and 5.0 g of powdered sugar, providing a total dry weight of 38.3 g.

Table 1. Composition of the *Eleutherine bulbosa*-containing enteral formula prototype per serving

Ingredient	Amount (g serving ⁻¹)	Proportion of dry formula (%)
<i>E. bulbosa</i> extract powder	3.3	8.62
Skim milk powder	20.8	54.31
Full-cream milk powder	9.2	24.02
Powdered sugar	5	13.05
Total	38.3	100

We weighed the ingredients and mixed them until visually homogeneous, and packaged one 38.3-g portion as a single serving. For reconstitution, we mixed one serving with 150 mL of boiling water, stirred until no visible lumps remained, and filtered it before further evaluation.

Proximate composition and calculated energy

Proximate composition of the powdered enteral formula was analyzed at the Nutrition Laboratory, Universitas Airlangga, Surabaya. Protein, crude fat, moisture, and ash were determined using Kjeldahl, Soxhlet extraction, oven-drying, and dry-ashing procedures, respectively. These analytical principles align with established food-composition analysis procedures described in the *Official Methods of Analysis of AOAC INTERNATIONAL* (Latimer, 2023). AOAC methods undergo systematic evaluation for analytical performance and fitness for their intended matrices.

For protein determination, transfer approximately 0.5 g of powdered formula to a Kjeldahl flask and digest with 1 g of selenium-based Kjeldahl catalyst and 15 mL of concentrated H₂SO₄ for approximately 3 h, or until a clear digest is obtained. After cooling, transfer the digest to a 100-mL volumetric flask and dilute with distilled water. A 10-mL aliquot was subsequently mixed with 30 mL of 50% NaOH and distilled. Collect the distillate in 10 mL of 30% boric acid containing three drops of methyl red/methyl blue mixed indicator (3:1) and titrate with 0.02 N HCl. Nitrogen content was subsequently converted to crude protein.

Crude fat was determined using Soxhlet extraction. Place approximately 3 g of sample in an extraction thimble and extract with hexane for approximately 4 h, or until approximately 15 solvent cycles are completed.

After extraction, remove the solvent, heat the receiving flask at approximately 100 °C, cool in a desiccator for 30 min, and weigh gravimetrically.

Moisture content was determined by oven drying. Place approximately 3–5 g of sample in a pre-weighed dish and dry at 105 °C for 3–4 h. Repeat drying, cooling in a desiccator, and weighing until a constant mass was obtained. Ash content was determined by placing approximately 3–5 g of sample in a pre-weighed crucible, charring the sample until smoking ceased, and incinerating it at 600 °C for approximately 6 h. The crucible was subsequently cooled in a desiccator and weighed.

Carbohydrate content was calculated by difference from the measured proximate components. FAO recognizes carbohydrate-by-difference as a calculation based on subtraction of measured water, protein, fat, ash, and, where applicable, alcohol from total sample mass [FAO, \(2003\)](#) in Equation (1):

$$\begin{aligned} \text{Carbohydrate (\%)} \\ = 100 - [\text{moisture (\%)} + \text{ash (\%)} \\ + \text{protein (\%)} + \text{fat (\%)}] \end{aligned} \quad (1)$$

Energy was calculated from the protein, carbohydrate, and fat contents using the general Atwater conversion factors described for food-energy calculations [FAO, \(2003\)](#), using Equation (2):

$$E \text{ (kcal)} = 4P + 4C + 9F \quad (2)$$

Where E represents calculated energy, and P , C , and F represent protein, carbohydrate, and fat, respectively, expressed on the same analytical basis. FAO Food and Nutrition Paper 77 specifically addresses analytical methods for protein, fat, and carbohydrate and the calculation of food energy using energy-conversion factors ([FAO, 2003](#)).

Viscosity measurement

Viscosity of the reconstituted enteral formula was measured using a Digital Rotary Viscometer NDJ-8S. For analysis, 62.8 g of powdered formula was reconstituted with 250 mL of boiling water, stirred until uniformly dispersed, filtered into a beaker, and allowed to cool to approximately 31 °C. The sample was measured using rotor 2 at 60 rpm for approximately 30–60 s, and the displayed viscosity was recorded in mPa·s.

Measurement conditions were kept consistent because formulation characteristics and measurement conditions influence the apparent viscosity of enteral formulas. A study by [Wakita et al., \(2012\)](#) showed that enteral-formula viscosity can vary with factors including formula energy density, temperature, stirring speed, stirring time, and elapsed time after preparation.

Flavonoid screening and TLC-densitometric characterization

Phytochemical analysis of the *E. bulbosa* extract was conducted at the Herbal Laboratory, Materia Medica Batu, East Java, Indonesia. For qualitative flavonoid screening, a portion of the extract was mixed with 5 mL of ethanol and heated for 5 min. Several drops of concentrated HCl were added, followed by 0.2 g of magnesium powder. We interpreted the development of a dark-red coloration as a positive reaction for flavonoids. The magnesium–HCl reaction corresponds to the Shinoda principle commonly used for preliminary qualitative detection of flavonoids in plant extracts ([Sasidharan et al., 2011](#)).

We then performed flavonoid-related characterization using thin-layer chromatography coupled with densitometric detection. TLC is widely used to separate and characterize phytochemicals in botanical extracts, while densitometric analysis enables quantitative evaluation of chromatographic zones ([Sasidharan et al., 2011](#)). TLC-densitometric methods using quercetin as

a chemical reference marker have also been validated for quantitative analysis of botanical extracts (Randhawa et al., 2015).

The flavonoid-related result for the *E. bulbosa* extract was expressed on a quercetin-equivalent basis (mg QE/g). Reporting flavonoid content relative to quercetin has also been applied specifically to *E. bulbosa* extracts; Muthia et al., (2021) reported total flavonoid contents from *E. bulbosa* bulbs collected in Kalimantan as mg QE/g extract. Their study used a colorimetric assay and is therefore relevant to flavonoid content expression rather than to the specific TLC-densitometric procedure used in the present study.

Sensory acceptability

Sensory acceptability of the reconstituted enteral formula was evaluated by 21 semi-trained panelists at the Food Science Laboratory, Poltekkes Kemenkes Malang. Panelists assessed color, aroma, taste, and texture using a five-point hedonic response scale: 1 = dislike, 2 = less like, 3 = somewhat like, 4 = like, and 5 = highly like.

Panelists were seated in the designated evaluation area and received the reconstituted formula, drinking water, a sensory-evaluation form, and writing materials. We briefly explained the evaluation procedure and scoring system before assessment. Each panelist independently evaluated the four sensory attributes and recorded the corresponding scores on the evaluation form.

The use of a quantitative response scale for hedonic sensory assessment is consistent with the general methodological principles described in ISO 4121:2003, which applies to quantitative sensory-response scales used for both objective and hedonic assessments (International Organization for Standardization, 2003).

Summary of analytical endpoints

Table 2 summarizes the analytical endpoints used to characterize the developed formulation. Nutritional composition was characterized using established proximate-analysis principles (FAO, 2003; Latimer, George W., 2023; Kasheem et al., 2025), while viscosity, phytochemical characteristics, and sensory acceptability were evaluated using the procedures described above.

Table 2. Analytical endpoints used for characterization of the *Eleutherine bulbosa*-containing enteral formula

Endpoint	Test Material	Analytical Approach	Reported Output
Protein	Powdered formula	Kjeldahl digestion, distillation, and titration	%
Crude fat	Powdered formula	Soxhlet extraction with hexane	%
Carbohydrate	Powdered formula	Calculation by difference	%
Moisture	Powdered formula	Oven drying at 105 °C	%
Ash	Powdered formula	Dry ashing at 600 °C	%
Energy	Powdered formula	Calculated from protein, carbohydrate, and fat	kcal
Viscosity	Reconstituted formula	NDJ-8S, rotor 2, 60 rpm, approximately 31 °C	mPa·s
Flavonoid	<i>E. bulbosa</i>	Mg–HCl qualitative	Positive/negative

screening	extract	reaction	
Flavonoid-related marker	<i>E. bulbosa</i> extract	TLC-densitometric characterization	mg QE/g
Sensory acceptability	Reconstituted formula	Five-point hedonic assessment	Score 1–5

Data analysis

Data were entered, organized, and summarized using Microsoft Excel. Proximate composition, calculated energy, apparent viscosity, and phytochemical findings were analyzed descriptively to characterize the developed formulation, with carbohydrate content and energy derived using Equations (1) and (2), respectively. Sensory responses from 21 semi-trained panelists were summarized using the five-point hedonic scale, and scores for color, aroma, taste, and texture were tabulated to describe preliminary sensory acceptability. Because the study evaluated a single developed formulation without comparative experimental treatments or alternative formulations, the statistical analysis focused on descriptive characterization rather than between-formulation hypothesis testing.

RESULT AND DISCUSSION

Nutritional Composition and Calculated Energy of the Enteral Formula Prototype (RQ1)

The first research question addressed the proximate composition and calculated energy value of the developed *Eleutherine bulbosa*-containing enteral formula prototype. Table 3 summarizes the laboratory-reported nutritional characteristics of the powdered formulation.

Table 3. Proximate composition and energy characteristics of the *Eleutherine bulbosa*-containing enteral formula prototype

Parameter	Reported value
Energy	383.83 kcal
Carbohydrate	72.31 g
Protein	6.57 g
Fat	2.60 g
Moisture	9.61%
Ash	2.07%
Energy density	1.47 kcal/mL

As shown in Table 3, carbohydrate was the largest macronutrient component of the powdered formulation, followed by protein and fat. Measurable moisture and ash fractions were also identified. Collectively, these results provide an initial nutritional characterization of the developed prototype and address RQ1 at the formulation level.

The reported energy density was 1.47 kcal/mL. This value describes an energy-related characteristic of the formulation but does not establish its nutritional adequacy for a specific patient population. Clinical nutritional support requires consideration of individual nutritional requirements, tolerance, gastrointestinal function, and the feasibility of oral or enteral feeding. ESPEN guidance similarly recommends individualized nutrition intervention and supports enteral nutrition when oral intake remains inadequate and enteral feeding is feasible (Muscaritoli et al., 2021).

Accordingly, the present nutritional analysis provides a preliminary compositional profile rather than evidence that the prototype constitutes a nutritionally complete enteral formula for clinical use. Further characterization

of micronutrients, osmolality, microbiological quality, storage stability, and nutrient delivery after reconstitution is required before a more comprehensive evaluation of nutritional suitability.

Viscosity of the Reconstituted Enteral Formula Prototype (RQ2)

The second research question examined the apparent viscosity of the reconstituted prototype under the specified measurement conditions. Table 4 presents the measured viscosity and its descriptive classification.

Table 4. Measured Viscosity

Measurement	Result	Descriptive Classification
Apparent viscosity	8 mPa·s	Thin

As shown in Table 4, the reconstituted prototype had an apparent viscosity of 8 mPa·s under the measurement conditions used in this study. As described in the Methods, we measured viscosity using an NDJ-8S digital rotary viscometer with rotor 2 at 60 rpm and approximately 31 °C. The reported value therefore characterizes the prototype under these specific analytical conditions rather than representing an invariant physical property.

This distinction matters because the apparent viscosity of enteral formulas can vary with formulation characteristics and measurement conditions, including energy density, temperature, stirring speed, stirring time, and elapsed time after preparation. Among these factors, energy density, stirring time, and elapsed time after preparation have been reported to influence enteral-formula viscosity (Wakita et al., 2012).

Viscosity also affects the practical flow characteristics of enteral formulas. More viscous formulations have been associated with longer gravity-feeding times and a greater tendency toward tube obstruction, whereas larger feeding-tube diameters can reduce delivery time. Accordingly, the relatively low apparent viscosity observed in the present prototype provides preliminary information regarding its flow characteristics (Casas-Augustench & Salas-Salvadó, 2009).

Nevertheless, the present viscosity measurement does not establish tube-feeding compatibility or clinical tolerance. Direct tube-flow testing using clinically relevant tube diameters, together with assessments of sedimentation, physical stability, and changes in viscosity over time after reconstitution, is required before practical enteral-delivery performance can be established.

Flavonoid-Related Phytochemical Characterization of the *E. bulbosa* Ingredient (RQ3)

The third research question examined the flavonoid-related content and TLC-densitometric characteristics of the *E. bulbosa* ingredient under the analytical conditions used. Qualitative Mg–HCl screening produced a positive flavonoid reaction, while TLC-densitometric analysis yielded a flavonoid-related content of 4.4403 mg quercetin equivalents (QE)/g. Table 5 summarizes the quantitative and chromatographic findings.

Table 5. Flavonoid-related characterization of the *Eleutherine bulbosa* ingredient

Analytical parameter	Method/replicate	Result
Qualitative flavonoid screening	Mg–HCl reaction	Positive
Flavonoid-related content	TLC-densitometry	4.4403 mg QE/g
Sample Rf	Replicate 1	0.72–0.79; Rfmax = 0.76
Sample Rf	Replicate 2	0.71–0.78; Rfmax = 0.75

Sample Rf	Replicate 3	0.71–0.79; Rfmax = 0.75
Quercetin reference Rf	Reference standard	0.71–0.78; Rfmax = 0.75

As shown in Table 5, chromatographic migration was similar across the three analytical replicates. The sample showed maximum Rf values of 0.76, 0.75, and 0.75, respectively, whereas the quercetin reference standard showed an Rfmax of 0.75. This reproducible migration pattern provides descriptive evidence of chromatographic similarity between the sample zone and the quercetin reference under the applied TLC conditions.

The calibration model used for densitometric quantification was $y = 770.05x - 2051.9$, with an R^2 of 0.9964. The high coefficient of determination indicates a close fit between concentration and densitometric response over the calibration range used. However, this value demonstrates calibration linearity only and does not, by itself, establish complete analytical-method validation. Contemporary analytical-validation guidance treats linearity alongside other characteristics such as specificity/selectivity, accuracy, precision, and reportable range.

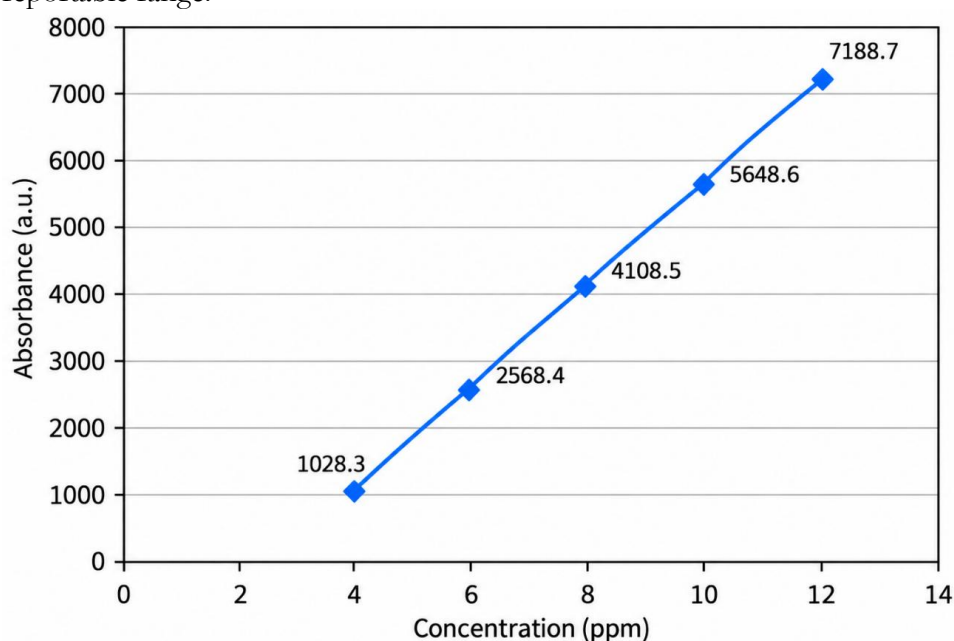


Fig 2. Quercetin calibration curve prepared from a 100 ppm stock solution for TLC-densitometric analysis

Figure 2 presents the calibration relationship used to interpret the densitometric response quantitatively. The 100 ppm designation refers to the stock solution, whereas the plotted working concentrations range from 4 to 12 ppm. For the final publication figure, the individual points can represent the original measured responses for the calibration standards, with the fitted regression line superimposed. The reproducibility of chromatographic migration across the sample replicates is further illustrated in Figures 3–5.

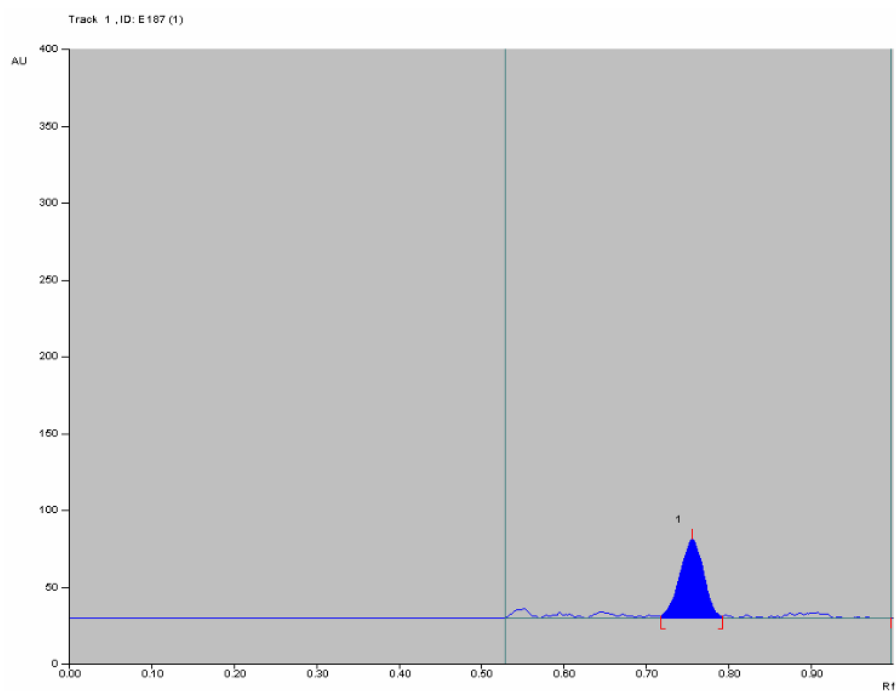


Fig 3. TLC densitometric profile of the first analytical replicate

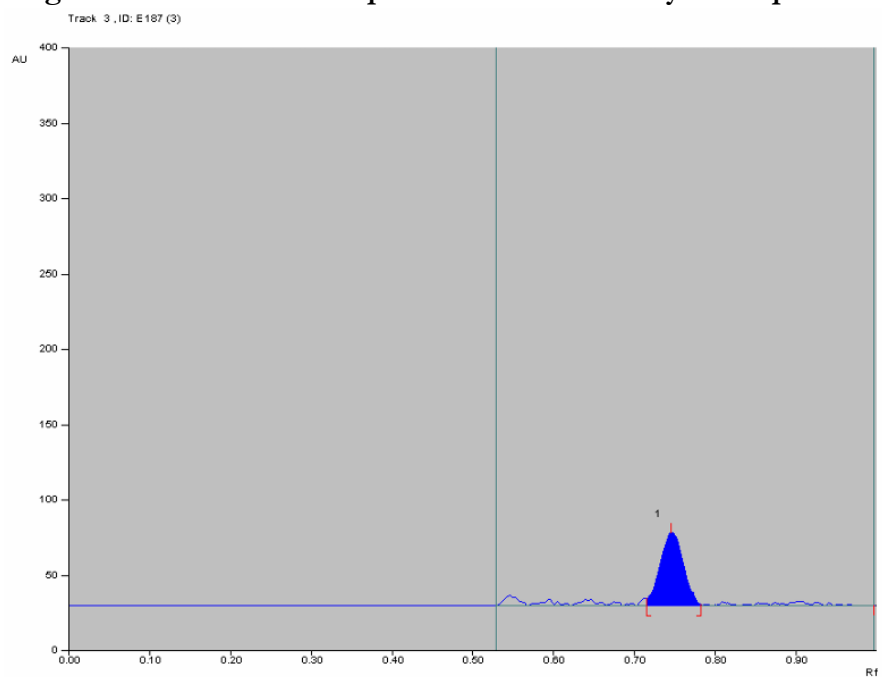


Fig 4. TLC densitometric profile of the second analytical replicate

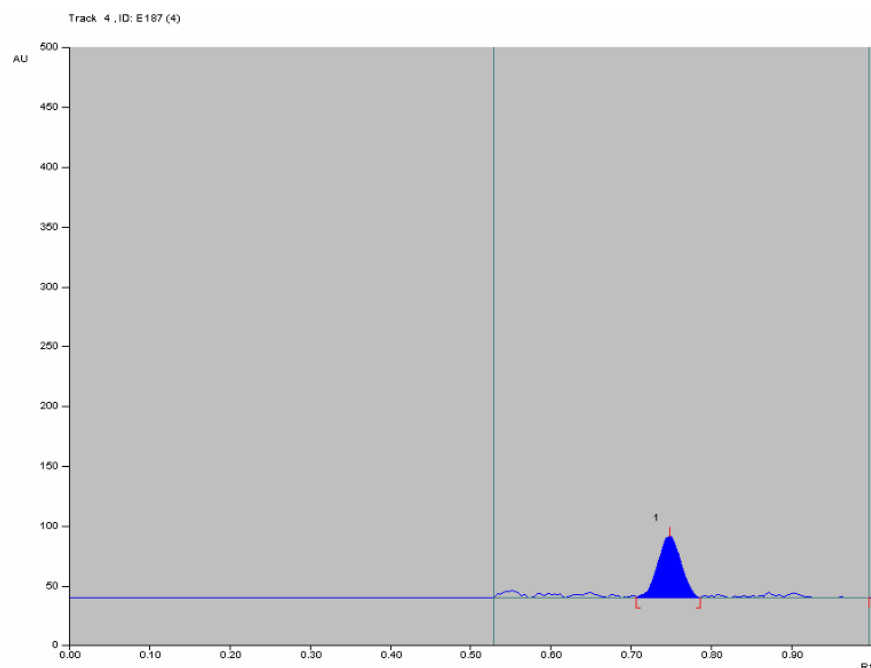


Fig 5. TLC densitometric profile of the third analytical replicate

As shown in Figures 3–5, the principal densitometric zones occurred within a narrow Rf range, with Rfmax values between 0.75 and 0.76. This close agreement among the three analytical replicates indicates consistent chromatographic migration under the applied conditions. The corresponding quercetin reference profile is presented in Figure 6.

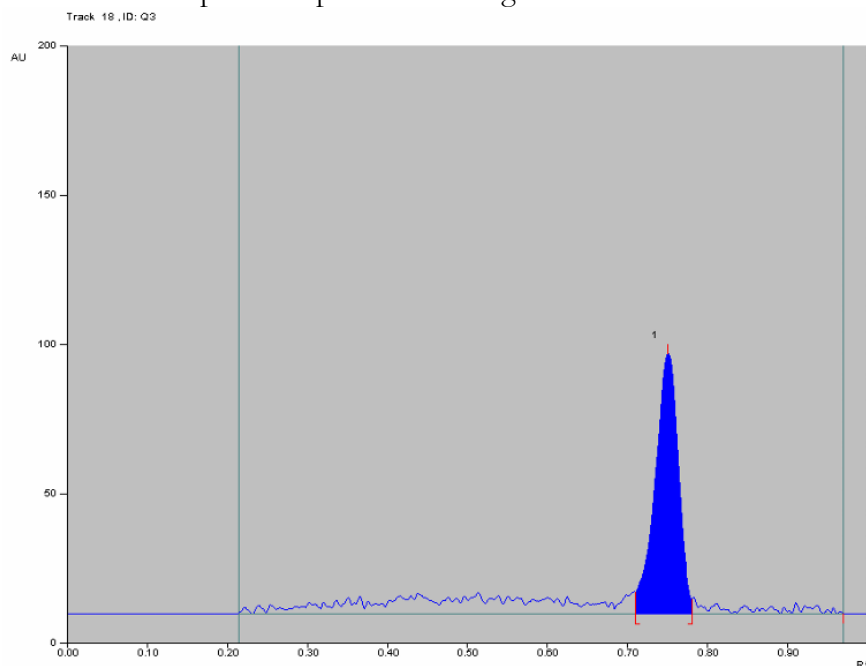


Fig 6. TLC chromatogram of the quercetin reference standard

Figure 6 shows the principal chromatographic zone of the quercetin reference at approximately Rf 0.75, which closely corresponds to the maximum migration values observed in the three sample replicates. Comparison with a reference standard is a recognized component of chromatographic identification approaches for botanical materials, and TLC-densitometric methods have also been used to quantify quercetin as a reference marker in plant extracts.

Taken together, Table 5 and Figures 3–6 demonstrate reproducible chromatographic similarity between the sample zone and the quercetin reference under the experimental conditions used. However, similarity in R_f values does not, on its own, establish definitive molecular identification of quercetin. The finding is therefore appropriately reported as flavonoid-related content expressed in quercetin equivalents, rather than as proof that quercetin is the dominant or uniquely identified flavonoid in the extract.

The measured flavonoid-related content is also broadly consistent with previous evidence that *E. bulbosa* bulbs contain quantifiable flavonoids. A study by Muthia et al., (2021) reported total flavonoid contents of 5.035, 6.499, and 7.585 mg QE/g extract for bulbs collected from different regions of Kalimantan. Nevertheless, direct numerical comparison is limited because that study used a colorimetric method, whereas the present investigation employed TLC-densitometric characterization. Differences in extraction procedures, botanical source, analytical method, and reporting basis can influence the resulting values.

The present study therefore establishes the presence of measurable flavonoid-related material in the *E. bulbosa* ingredient under the analytical conditions used. It does not demonstrate antioxidant efficacy, bioavailability, anticancer activity, or clinical benefit. This inferential boundary aligns with the Introduction, which explicitly distinguishes preclinical biological evidence for *E. bulbosa* extracts from the therapeutic efficacy of an *E. bulbosa*-containing food formulation in patients.

Preliminary Sensory Acceptability of the Reconstituted Prototype (RQ4)

The fourth research question examined preliminary hedonic responses to the reconstituted prototype among 21 semi-trained panelists. Panelists evaluated color, aroma, taste, and texture using the five-point hedonic scale described in the Methods. Using a quantitative response scale for hedonic assessment is consistent with ISO 4121:2003, which guides quantitative sensory-response scales in hedonic evaluation. Table 6 presents the summarized sensory responses.

Table 6. Preliminary hedonic responses to the *Eleutherine bulbosa*-containing enteral formula prototype

Sensory attribute	Reported acceptability (%)	Interpretation
Color	94.3	Highly liked
Aroma	90.5	Highly liked
Taste	94.3	Highly liked
Texture	86.7	Highly liked

As shown in Table 6, all four sensory attributes received high descriptive acceptability scores. Color and taste had the highest reported percentage scores (94.3% each), followed by aroma (90.5%) and texture (86.7%). Under the evaluation conditions used, the findings indicate favorable preliminary sensory responses to the prototype.

The formulation had a pink coloration. Because the study evaluated only one formulation and did not analytically quantify the compounds responsible for color, the present data do not establish which individual ingredient or phytochemical produced this appearance. The color result is therefore most appropriately interpreted as a sensory characteristic of the complete formulation rather than as evidence of a specific pigment mechanism.

Taste was predominantly described as milk-like, while some panelists reported a slight bitter aftertaste. Because skim milk powder and full-cream milk powder were major components of the formulation, the milk-like sensory

profile is consistent with the product composition. However, because the study did not experimentally isolate the sensory contribution of each ingredient, it cannot assign the bitter aftertaste to a specific phytochemical component.

Aroma was likewise predominantly described as milk-like, with most panelists reporting no strong Dayak-onion aroma. This finding describes the overall aroma profile at the ingredient proportions used in the prototype. Because the study evaluated only one formulation, it does not establish how changes in *E. bulbosa* concentration would alter aroma intensity.

Texture received the lowest reported acceptability value (86.7%) but remained within the reported "highly liked" category. The prototype was described as liquid with some visible sediment. This observation is particularly relevant for subsequent formulation development because sedimentation warrants direct evaluation of physical stability, homogeneity, and tube-delivery performance.

These sensory findings represent preliminary descriptive acceptability data, rather than population-level consumer-preference estimates. The analysis involved 21 semi-trained panelists, one formulation, and no blinded comparator or alternative formulation. This interpretation is consistent with the study design, which used descriptive rather than between-formulation inferential analysis.

Integrated Interpretation, Limitations, and Implications of the Formulation Characteristics

Taken together, the findings provide an initial multidomain characterization of the developed *Eleutherine bulbosa*-containing enteral formula prototype and address the four research questions. RQ1 characterizes the nutritional composition and energy-related properties of the formulation, RQ2 describes its apparent viscosity under the specified measurement conditions, RQ3 identifies measurable flavonoid-related content and reproducible TLC-densitometric characteristics relative to the quercetin reference, and RQ4 summarizes preliminary sensory responses from 21 semi-trained panelists. Considered together, these domains provide a formulation-level profile of the prototype rather than evidence of clinical efficacy or therapeutic effectiveness.

This distinction is particularly important for interpreting the phytochemical findings. The detection of flavonoid-related compounds does not establish antioxidant activity in the final formulation, and similarity in chromatographic migration relative to a quercetin reference does not constitute definitive molecular identification of quercetin. Likewise, neither the present chromatographic findings nor previously reported preclinical activities of *E. bulbosa* demonstrate that the developed prototype has anticancer or other therapeutic effects. The present evidence is therefore limited to phytochemical characterization within the analytical conditions applied in this study. A similar boundary applies to the nutritional findings. Although the prototype could be characterized in terms of proximate composition, calculated energy, and apparent viscosity, these measurements do not establish clinical nutritional adequacy, tolerance, or suitability for patient feeding. ESPEN guidance emphasizes individualized nutritional assessment and the selection of oral, enteral, or parenteral nutrition according to clinical condition and intake adequacy (Muscaritoli et al., 2021). The present study is therefore appropriately positioned as a laboratory-based product-development and descriptive characterization study.

Several limitations further define the scope of interpretation. The investigation evaluated a single developed formulation without comparative treatment groups or between-formulation hypothesis testing; consequently, the findings do not establish superiority over commercial enteral products or alternative formulations. Reproducibility across independent production batches was not assessed. Phytochemical characterization relied on qualitative flavonoid screening and TLC-densitometric analysis using quercetin as a reference marker, which limits conclusions about the identity and biological activity of individual compounds. Sensory evaluation was restricted to 21 semi-trained panelists and one formulation, so the results represent preliminary descriptive acceptability rather than population-level consumer or patient acceptance. Microbiological safety, osmolality, storage stability, sedimentation, tube-flow compatibility, bioavailability, clinical tolerance, and patient outcomes were also outside the scope of the present study.

Within these boundaries, the study provides a useful formulation-level basis for further product development. The findings demonstrate the feasibility of incorporating *E. bulbosa* into a milk-based powdered enteral formula prototype and characterizing the resulting product across nutritional, physicochemical, phytochemical, and sensory domains. This integrated approach provides information relevant to subsequent formulation refinement, including nutrient composition, reconstitution behavior, flow characteristics, phytochemical markers, and sensory acceptability. In particular, the viscosity and sensory findings offer preliminary information for later evaluation of physical stability and administration performance, while the TLC-densitometric results provide an analytical basis for more specific phytochemical verification.

The principal contribution of the study lies in extending *E. bulbosa* research from predominantly phytochemical and preclinical contexts into a nutrition-oriented product-development application. Rather than positioning *E. bulbosa* as an anticancer or therapeutic intervention, the study establishes an initial formulation-level evidence base for incorporating this botanical ingredient into an enteral nutrition matrix. Its novelty lies in integrating nutritional composition, apparent viscosity, flavonoid-related characterization, and preliminary sensory acceptability within a single prototype-development framework. Further investigation can build on this foundation by examining batch reproducibility, broader nutrient and phytochemical profiles, microbiological and physicochemical stability, administration-related performance, safety, and appropriately designed preclinical or clinical nutrition outcomes before patient-level effectiveness is evaluated.

CONCLUSION

The present study achieved its objective of developing and providing an initial laboratory characterization of a Dayak onion (*Eleutherine bulbosa* (Mill.) Urb.)-based enteral formula prototype. The resulting formulation could be characterized across complementary nutritional, physicochemical, phytochemical, and sensory domains, providing evidence of its feasibility as a prototype for further product development. The principal novelty lies in translating *E. bulbosa* from predominantly phytochemical and preclinical investigation into a nutrition-oriented formulation context and integrating nutritional composition, apparent viscosity, flavonoid-related characteristics, and preliminary sensory acceptability within a single product-development framework.

The findings provide a formulation-level basis for subsequent optimization and analytical validation rather than evidence for immediate clinical application. Further development can examine production reproducibility, microbiological safety, osmolality, storage and reconstitution stability, sedimentation, nutrient stability, tube-flow performance, and more specific phytochemical identification before clinical suitability is evaluated. The present evidence does not establish clinical nutritional adequacy, antioxidant or anticancer efficacy, therapeutic benefit, or suitability for tube feeding; instead, it defines a preliminary evidence base from which the safety, stability, administration characteristics, and nutritional performance of the prototype can be investigated more directly.

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DECLARATIONS

Author contribution

Miftahul Jannah: data curation, writing-original draft preparation and editing, conceptualization, **Nur Rahman:** methodology, validation, visualization, **Endang Widajati:** supervision, software.

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The authors declare that this research was conducted without any conflict of interest in the research.

Ethical clearance

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