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Physical and Sensory Properties of Synbiotic RUTF Based on Local Foods: Tempeh, Cowpea, Banana, and Probiotics

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Abstract Ready-to-Use Therapeutic Food (RUTF) is a high-energy food used to address malnutrition in children. However, its paste-like form may be less acceptable to children in certain regions. Developing RUTF from locally available food ingredients may improve its acceptability among the target population. This study aimed to analyze the sensory and physical properties of RUTF developed from local food ingredients, namely cowpeas, tempeh, and banana, and supplemented with probiotics. The formulation consisted of tempeh flour, cowpea flour, banana flour, milk powder, powdered sugar, vegetable oil, probiotics, and a mineral mix in accordance with the requirements of the Codex Alimentarius. The treatments consisted of different proportions of cowpea and tempeh flour: FA (0:100), FB (25:75), FC (50:50), FD (75:25), and FE (100:0). Sensory analysis was conducted using a paired-comparison test involving 30 semi-trained panelists and an acceptance test involving 31 mother–child pairs. The physical properties analyzed included color, morphology, particle size, and viscosity of the RUTF. Statistical analyses were performed using one-way analysis of variance (ANOVA), followed by Duncan's multiple range test (DMRT) to determine differences among treatment groups. The paired-comparison test was analyzed using a two-tailed binomial test. The results showed that although the paired-comparison test indicated that the addition of probiotics affected the taste and color of the RUTF, the products remained acceptable to mothers and children. The sensory findings were supported by the physical property analyses, which showed an increase in lightness (L*) and decreases in a* and b* values as the proportion of cowpea flour increased relative to tempeh flour. A higher proportion of cowpea flour was not associated with particle size, whereas viscosity significantly decreased. Further research is warranted to evaluate the efficacy of the developed RUTF in the target population, particularly children with malnutrition.

Keywords: *RUTF, cowpea, banana, probiotics, tempeh*

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1. Introduction

Global child mortality rates remain high, with 20% of deaths directly linked to severe acute malnutrition [1]. This figure reaches as high as 40% in developing countries [2]. In Indonesia, the prevalence of acute malnutrition remains high, despite a decline from 8.5% in 2023 to 7.5% in 2024 [3]. Malnutrition can lead to growth impairments, including stunting, as well as increased infection risk, poor brain development, and reduced work productivity [4]. The WHO and the Indonesian Ministry of Health recommend the administration of ready-to-use therapeutic food (RUTF) for severe acute malnutrition cases without medical complications [5,6]. RUTF is a high-energy, fat-based food that is soft, dissolves easily, and requires no preparation [6]. While RUTF products like Plumpy'Nut are produced globally, their availability in Indonesia is limited. Developing local RUTF using plant-based proteins, such as peanuts, soybeans, and mung beans, is preferable due to ingredient accessibility, affordability, and the reduction of import dependency [5]. Incorporating other local ingredients into RUTF development is crucial for ensuring long-term supply and strengthening national resilience.

Many countries have pursued the development of local food products by substituting some or all ingredients with locally available alternatives, while still adhering to standards established by the WHO. Beyond ensuring greater availability, lower costs, and reducing reliance on imports, the use of local ingredients often fosters greater

public acceptance, as the resulting taste, aroma, and texture are already familiar to the community [7]. Several study on RUTF in Indonesia found that the use of local ingredients, such as combinations of soybean, mung bean, and local peanut; cowpea and tempeh; local peanut and milk; rice, corn, soybean, and tempeh; and banana and peanut were as effective at promoting weight gain as standard RUTF, with some formulations achieving higher levels of acceptability [8,9,10,11,12]. Other countries are also increasingly developing RUTFs based on local foods; for instance, Bangladesh and Ethiopia have developed versions using rice, lentils, and chickpeas, while Tanzania has utilized sorghum and millet [13].

A novel RUTF has been developed using a combination of tempeh, cowpea, and banana, with the addition of probiotics. The selection of tempeh and cowpea as primary ingredients was based on their high energy and protein content, which is comparable to that of soybean and mung bean [14]. Cowpea also exhibits higher vitamin B1 levels, that was essential for energy metabolism, as well as elevated concentrations of sulfur- containing amino acids [15,16]. Furthermore, tempeh offers superior nutrient bioavailability and lower antinutrient levels compared to unfermented soybean [17,18,19]. Banana was incorporated to enhance flavor and mask the characteristic beany off-flavor of legumes. It also contains flavonoids and polyphenols functioning as antioxidants, along with fructooligosaccharides serving as prebiotics [20]. Additionally, probiotic supplementation was proposed to ameliorate intestinal morphological changes and restore gut microbiota equilibrium, thereby enhancing nutrient absorption and mitigating infection risk [21]. This product contains both prebiotics and probiotics, suggesting its potential as a synbiotic product.

This formulation has been disclosed in Patent Application No. S00202611991 with the title Composition of Ready-to-Use Therapeutic Food Based on Soybean Tempeh (*Glycine max* L. *Merr*.), Cowpea (*Vigna unguiculata* L. Walp.), Kepok Banana (*Musa paradisiaca* L.), and Probiotics. Based on the reported formulation, the adequacy of macronutrients meets WHO requirements [6]. However, its potential acceptability among the target population has not yet been established, particularly in relation to its physical properties, which may influence consumer acceptance.

A high level of RUTF acceptability can enhance nutritional intake and support successful recovery from malnutrition. This acceptability is influenced by how much the target population likes the product's taste, aroma, color, and texture. Since sensory attributes are subjective and vary among individual panelists, physical property testing serves as a means to quantify these characteristics. Assessing both sensory and physical properties in new RUTF formulations is crucial, given that each raw material possesses unique characteristics [7]. Therefore, this paper aimed to analyze the impact of an RUTF formulation utilizing a local blend of tempeh, cowpeas, and banana, supplemented with probiotics on sensory acceptability and physical properties such as viscosity and color.

2. Methods

2.1. Materials

The ingredients used to produce the RUTF included tempeh flour and kepok banana (*Musa paradisiaca* L.) flour that was purchased from PT Kusuka Ubiku, while cowpea (*Vigna unguiculata*) flour was obtained from a local market in Yogyakarta, Indonesia. Other ingredients included Bimoli-brand palm oil, Indoprima-brand full-cream powder milk, and local powdered sugar. The probiotic used was the *Lactobacillus acidophilus LA1, Bifidobacterium longum BG7, Streptococcus thermophilus ST3* with total viable count of 2.66 x 10^{10} CFU/gram, produced by Cell Biotech Co. Ltd., Korea and imported by PT Novell Pharmaceutical Laboratories with the Brand of Lacto-Band. Mineral mix was obtained from DSM Firmenich, PT Ridda Manna Sejati, Indonesia.

2.2. RUTF Production

The RUTF formulation used in this study was based on the formulation disclosed in Patent Application No. S00202611991 with the title Composition of Ready-to-Use Therapeutic Food Based on Soybean Tempeh (*Glycine max* L. *Merr*.), Cowpea (*Vigna unguiculata* L. *Walp*.), Kepok Banana (*Musa paradisiaca* L.), and Probiotics. The formulation consisted of 27% mix flour (tempeh flour, cowpea flour, banana flour), 46% of milk powder and powdered sugar, 26% of vegetable oil and mineral mix, also 0.88% of probiotics with calculated fat and protein contents ranging from 29% to 32% and 11% to 16%, respectively, in accordance with the provisions established by the Codex Alimentarius [6]. The treatments consisted of different proportion of cowpea flour to tempeh flour (%w/w): FA (0:100), FB (25:75), FC (50:50), FD (75:25), and FE (100:0). Probiotics were added at a proportion of 0.88 g per 100 g, yielding a microbial density of $7.7x10^{9}$-$4.8x10^{10}$ CFU/gram.

The production of RUTF began by sifting the flours through an 80-mesh sieve. The tempeh and cowpea flours were dry-roasted for 2.5 min and then mixed with banana flour, milk powder, and powdered sugar. The mixture was subsequently dry-roasted with continuous stirring for 1 min, followed by the addition of oil and blending for 180 s. The probiotic and mineral mix were then manually incorporated into the formulation at the end of the process, after the paste had reached a temperature of 25–30°C. Samples for sensory and physical analyses were prepared immediately and were not subjected to storage before analysis.

2.3. Sensory Analysis

Sensory analysis was conducted in two stages: a paired-comparison sensory test and an acceptance test.

2.3.1. Paired-comparison Sensory Test

The paired-comparison sensory test was conducted with

30 semi-trained panelists who met the following inclusion criteria: students or alumni of the Undergraduate Nutrition Program at Universitas Alma Ata who had completed sensory testing sessions and practical sessions in the Food and Nutrition Science course; were healthy; had no history of food allergies or sensory impairments; were non-smokers; and had signed an informed consent form. This test was conducted to determine whether there were differences in taste and flavor between samples with and without probiotics.

The samples consisted of two sets. Set 1 comprised probiotic-containing samples from formulas FA, FB, FC, FD, and FE, coded A1, B1, C1, D1, and E1, respectively. Set 2 comprised the corresponding samples without probiotics, coded A2, B2, C2, D2, and E2, respectively. Each panelist was presented with two samples from the same formula in pairs, beginning with A1 and A2. After evaluating each pair, the panelists were instructed to rinse their mouths with neutral water before proceeding to the next pair, B1 and B2, and so forth until the evaluation of E1 and E2 was completed.

The panelists were asked to indicate their response by checking one of two options on the evaluation form: “different” or “not different.” They were not provided with any information regarding the sample composition or the differences between the formulations. The samples were prepared on the same day as the sensory evaluation and served at room temperature. Each sample was presented in a quantity of 2 g in a clear, disposable cup and accompanied by a spatula.

Sensory evaluation was conducted in individual booths designed to minimize visual, auditory, and interpersonal distractions among panelists. The sensory testing area was maintained under controlled environmental conditions, with neutral-colored surfaces, uniform lighting, adequate ventilation, and minimal extraneous odors and noise. The testing booths were equipped with clean, odor-free surfaces and sufficient space for sample presentation and response recording, following the general principles of ISO 8589 for sensory test room design [22].

2.3.2. Acceptance Test

The acceptance test was conducted with 31 panelists of mother-child pairs living in Bembem RT 01, Trimulyo, Jetis, Bantul, Yogyakarta, Indonesia. The panelists were selected based on the following inclusion criteria: mothers with children aged 6–59 months; good health; no history of food allergies or sensory impairments; children who were already consuming complementary foods; and provision of written informed consent. The exclusion criterion was the inability to assess the child's level of liking.

The sensory evaluation was conducted in a village meeting room, where mothers and their children were invited to participate. Before the evaluation, the mothers were provided with general information about the types of samples and the basic ingredients used, without being informed of the specific formulations. They were also given instructions on the sample evaluation procedure, including the requirement to drink water between samples, as well as instructions on how to complete the evaluation form. Each mother was also asked to select the sample she liked the most and subsequently offer the selected sample to her child for evaluation.

Each mother received one set of samples consisting of the five formulations, which were coded using three-digit random numbers. The codes for formulas FA, FB, FC, FD, and FE were 371, 714, 995, 631, and 156, respectively. The samples were prepared on the day of the sensory evaluation, served in a-3g-portion, placed in covered, clear, disposable cups, and each cup was provided with a spatula. The samples were served at room temperature.

The evaluation forms for the mothers and children were provided separately. The mothers' preference test used a five-point hedonic scale: 1 = strongly dislike, 2 = dislike, 3 = like slightly, 4 = like, and 5 = like very much. Meanwhile, the children's level of liking was assessed using a seven-point facial expression scale: 1=super bad, 2=really bad, 3=bad, 4=maybe good or maybe bad, 5=good, 6=really good, and 7=super good [23].

2.4. Physical Analysis

Physical analysis includes tests for color, macro-morphology, particle size, and viscosity. RUTF color assessment used a colorimeter (Chromameter, Konica Minolta CR-400) with the assessment parameters L* (brightness), a* (reddish–greenish), and b* (yellowish–bluish). For the paste samples, color measurements were performed on four different sections. Prior to this, the paste was stirred to ensure uniformity.

The macro morphology and granule size of paste was observed using a light microscope (BX51, Olympus Corp., Tokyo, Japan) equipped with an OptiLab prodigital camera (PT Miconos, Indonesia). The granule size was determined by randomly selecting six particles within a single image field.

The viscosity of the paste was measured using a viscometer NDJ 5s from Huanghua Faithful Instrument Co.,LTD. A 100 mL sample of the paste was placed in a beaker, and its viscosity was measured at rotational speeds of 6 and 12 rpm using spindle number 4 for 1 minute. Six replications for each sample were performed.

2.5. Statistical Analysis

The experimental data were presented as mean ± standard deviation (SD). Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 26. Differences between groups of viscosity, particle size, color, and sensory acceptance test for mother and children were assessed using one-way analysis of variance (ANOVA), followed by Duncan’s Multiple Range Test (DMRT). A paired comparison sensory test in the stage 1 was evaluated using a two-tailed binomial test. A p-value of less than 0.05 was considered statistically significant.

2.6. Ethics Approval

Ethics approval for this study was received from the Universitas Alma Ata Ethics Committee (KE/AA/V/10113402/EC/2026). Written informed consent was obtained from all the mothers of the participating children before recruitment into the study.

Table 1. Number of panelists reporting differences in RUTF formulations with different KT (Cowpea Flour) and TM (Tempeh Flour) ratios, with and without commercial probiotics (n=30)

Parameter		FA (0KT:100TM)		FB (25KT:75TM)		FC (50KT:50TM)		FD (75KT:25TM)		FE (100KT:0TM)	
		D	ND	D	ND	D	ND	D	ND	D	ND
Taste	n	28	2	24	6	25	5	26	4	24	6
	%	93.3	6.7	80.0	20	83.3	16.7	86.7	23.3	80.0	20.0
	p	0.00		0.00		0.00		0.00		0.00	
Color	n	28	2	18	12	10	20	9	21	27	3
	%	93.3	6.7	60.0	40	33.3	66.7	30	70	90.0	10.0
	p	<0.01		0.58		0.09		0.04		<0.01	

3. Results and Discussion

3.1. Sensory Properties

3.3.1. Paired-comparison Sensory Test

The results of the paired difference test for RUTF are presented in Table 1.

The majority of panelists indicated a difference in taste between the samples with and without the addition of probiotics, with a statistically significant difference ($p < 0.05$). Based on the comments provided by the panelists, differences were detected in sweetness, bitterness, creaminess, spiciness, savoriness, nuttiness, banana, rancidity, tempeh, saltiness, acidity, and biscuit flavor. These findings indicate that the commercial probiotic preparation, which contains additional ingredients besides the bacterial culture, influenced the taste of the RUTF. The difference in sweetness may be attributed to the addition of dextrose; bitterness and saltiness may be associated with the mineral concentrate; creaminess and savoriness may originate from milk and vegetable cream powders; and acidity may be attributed to vitamin C. Meanwhile, the other flavors perceived by the panelists, including nuttiness, banana, tempeh, biscuit, and rancidity, may have originated from the raw ingredients used in the paste, particularly nuts, oil, and tempeh. Among these attributes, rancid flavor is generally associated with the oxidation of fats and is more likely to develop during storage, particularly in high-fat products [24]. However, because the paste samples in this study were prepared on the day of sensory evaluation, the perceived rancid flavor was unlikely to have resulted from prolonged storage. Instead, it may have been associated with the characteristic raw or beany odor of the legume-based ingredients. The perception of these taste and aroma attributes may also have varied among panelists due to differences in olfactory and gustatory sensitivity, age and physiological condition, previous sensory experience and training, sensory adaptation and fatigue, as well as attention and psychological factors [25]. These factors may therefore have contributed to the variation in taste and aroma perceptions reported by the panelists.

Regarding the color parameters, panelists detected significant differences between the samples for formulas FA, FD, and FE ($p < 0.05$). In contrast, no significant differences were detected between the samples for formulas FB and FC ($p > 0.05$). The commercial probiotic preparation had a whitish-yellow color. Its addition did not significantly affect the color of samples containing 100% KT or 100% TM but affected samples containing a mixture of KT and TM, with a maximum KT proportion of 50%. This may be attributed to the brownish color of KT, which allows the whitish color of the probiotic preparation to produce a lightening effect when incorporated into the paste. At higher KT proportions, however, the darker color of KT may have become more dominant, making the color contribution of the probiotic preparation less perceptible.

The lightening effect of the commercial probiotic preparation may also be related to the presence of milk-derived ingredients in its formulation. Previous research has shown that the whiteness of dairy products is influenced by casein content, which enhances light scattering [26]. In addition, skim milk has a lightness (L*) value of approximately 96–97, indicating a very high degree of brightness [27]. These properties may contribute to the whitish appearance of the probiotic preparation and explain its potential to increase the perceived brightness of RUTF formulations containing lower proportions of KT.

3.3.2. Acceptance Test

The level of acceptance for the paste in this study was also assessed using panelists of mothers and children. These panelists provided an indication of the product's level of acceptance among the public, aligning with the intended target market. The results of the RUTF acceptance test among mothers are presented in Table 2.

Table 2. RUTF preference test result among mothers at the different concentration ratio of KT (cowpea flour) and TM (tempeh flour)

Parameter	FA (0KT:100 TM)	FB (25KT:75 TM)	FC (50KT:50 TM)	FD (75KT: 25TM)	FE (100K T:0TM)
Taste	3.29±0.9 0^{a}	3.64±0.8 4^{ab}	3.71±0.8 6^{ab}	3.74±0. 73^{ab}	3.90±0 .98^{b}
Colour	3.77±0.6 7^{a}	3.81±0.4 8^{a}	3.74±0.6 3^{a}	3.84±0. 58^{a}	3.68±0 .91^{a}
Flavor	3.45±0.8 9^{a}	3.74±0.7 7^{a}	3.74±0.7 7^{a}	3.64±0. 66^{a}	3.77±0 .99^{a}
Texture	3.58±0.8 8^{a}	3.84±0.6 4^{a}	3.68±0.7 9^{a}	3.81±0. 70^{a}	3.52±1 .06^{a}
Overall	3.58±0.8 5^{a}	3.87±0.5 6^{a}	3.90±0.6 0^{a}	3.94±0. 57^{a}	3.81±1 .01^{a}

Notes: 1=strongly dislike, 2=dislike, 3=like slightly, 4=like, 5= like very much. The data represent the mean and standard deviation. Identical notation within the same row indicates no significant difference. Data are expressed as mean ± SD. Means followed by different letters within the same row are significantly different ($p < 0.05$).

Based on Table 2, the scores for almost all sensory preference parameters were similar across all RUTF formulas ($p>0.05$), except the taste. The level of

preferences ranged from "like slightly" to "like." Regarding the taste, the RUTF sample with the lowest acceptance score was FA, which utilized 100% tempeh without any added cowpea flour. Two mothers detected a bitter taste; this was attributed to the inclusion of the mineral mix, which typically imparts a bitter and astringent flavor.

The sample most preferred by the mothers was subsequently tested for acceptance among children. Acceptance testing for children involved facial expression assessment [23] while verbal feedback was obtained from children capable of responding. The results of the preference test are presented in Table 3.

Table 3. Results of RUTF acceptability testing among children

Sample	Number of children	Average of acceptance level	Percentage of child's spitting out (%)	p-value
FA (0KT:100TM)	4	4.75±0.50	25	0.89
FB (25KT:75TM)	1	5.0±0.00	0	
FC (50KT:50TM)	8	4.88±0.83	25	
FD (75KT:25TM)	2	5.50±0.71	0	
FE (100KT:0TM)	8	4.25±1.83	0	
No code	8	4.50±1.85	0	
Total	31			

Notes: 1=super bad, 2=really bad, 3=bad, 4=maybe good or maybe bad, 5=good, 6=really good, and 7=super good

Based on Table 3, most mothers selected formulas FC and FE as the most suitable formulations for their children. The children's evaluation of the samples showed acceptance scores ranging from 4.25 to 5.55, corresponding to the qualitative facial-response categories of "maybe good or maybe bad" to "really good," although the scores did not differ significantly among the formulations ($p > 0.05$). These findings indicate that none of the children showed an apparent negative response to the products. However, 25% of the children who consumed formulas FA and FC were observed to spit out the product. he discrepancy between facial expressions and spitting behavior may reflect children's initial responses to unfamiliar foods, which can be influenced by food neophobia, food selectivity, tactile sensitivity, or negative responses to the texture of unfamiliar foods [28].

3.2. Physical Properties

3.2.1. Colour

RUTF color assessment was conducted using a chromameter, measuring the parameters L* (lightness), a* (redness–greenness), and b* (yellowness–blueness). The color test results are presented in Table 4.

L* values ranged from 42.78 ± 2.38 to 49.49 ± 0.54. These results indicate that increasing the proportion of cowpea flour tended to increase the lightness of the product ($p < 0.05$). This may be attributed to the lighter color of cowpea flour compared with tempeh flour; thus, increasing the proportion of cowpea flour while reducing the proportion of tempeh flour resulted in higher L* values. The darker color of tempeh flour may be attributed to both fermentation and drying processes. During fermentation, the development of a darker color may be associated with fungal growth and maturation [28]. During drying, brown-colored melanoidin compounds may be formed through non-enzymatic reactions, including the Maillard reaction, caramelization, and lipid oxidation [29].

Table 4. Colour of RUTF at the different concentration ratio of KT (cowpea flour) and TM (tempeh flour)

Parameter	FA (0KT:100 TM)	FB (25KT:75 TM)	FC (50KT: 50TM)	FD (75KT: 25TM)	FE (100KT: 0TM)
L* (lightness)	42.78 ± 2.38^{a}	47.90 ± 1.16^{c}	45.32 ± 0.96^{b}	49.49 ± 0.54^{c}	48.13 ± 0.60^{c}
a* (reddish-greenish)	5.24 ± 0.25^{d}	4.05 ± 0.03^{c}	4.99 ± 0.05^{d}	3.68 ± 0.30^{b}	3.11 ± 0.24^{a}
b* (yellowish-bluish)	17.21 ± 0.68^{c}	16.96 ± 0.36^{c}	16.84 ± 0.22^{c}	15.59 ± 0.74^{b}	14.06 ± 0.14^{a}

Data are expressed as mean ± SD. Means followed by different letters within the same row are significantly different ($p < 0.05$).

a* values ranged from 3.11 to 5.24 and significantly different among groups ($p<0.05$). The highest a* value (5.24 ± 0.25) was observed in FA (100% tempeh flour), while the lowest (3.11 ± 0.23) was found in FE (100% cowpea flour). These results demonstrate that increasing the proportion of tempeh flour tends to raise the a* value, whereas increasing the proportion of cowpea flour tends to lower it.

b* values ranged from 14.06 to 17.21 and significantly different among groups ($p<0.05$). The highest b* value was obtained with Formula FA, which used 100% tempeh flour (17.21 ± 0.68), whereas the lowest value was observed in Formula FE (14.06 ± 0.13), which used 100% cowpea flour. These results indicate that increasing the proportion of tempeh flour tends to increase the b* value, while increasing the proportion of cowpea flour tends to decrease it. It demonstrates that variations in the ratio of cowpea flour to tempeh flour had a significant effect on the b* value of the RUTF ($p<0.05$).

The decrease in L* values observed in this study, accompanied by increases in a* and b* values, indicates that the RUTF became darker, particularly as the proportion of tempeh increased. The darker color may also be influenced by other ingredients used in the RUTF, such as milk and sugar. The presence of lactose and milk proteins can promote the Maillard reaction, leading to the formation of intermediate compounds such as Amadori products, followed by the formation of various compounds, including 5-hydroxymethylfurfural (HMF), and ultimately melanoidins, which contribute to brown coloration. In addition, vitamin C degradation in milk and caramelization may further contribute to the development of a darker brown color in the product [28].

3.2.2. Granule Morphology and Size

Figure 1 illustrates the relatively uniform appearance of the RUTF granules, with only a small proportion of larger granules visible in the cross-section. The particle size measurements showed no significant differences among the formulations, with particle sizes ranging from 7.76 to 10.26 µm ($p > 0.05$) (Table 5). The relatively uniform

particle size distribution may indicate greater physical homogeneity of the powdered ingredients, which may contribute to a more consistent texture and mouthfeel of the RUTF. In contrast, a wider particle size distribution may increase the presence of coarse particles and contribute to a gritty mouthfeel.

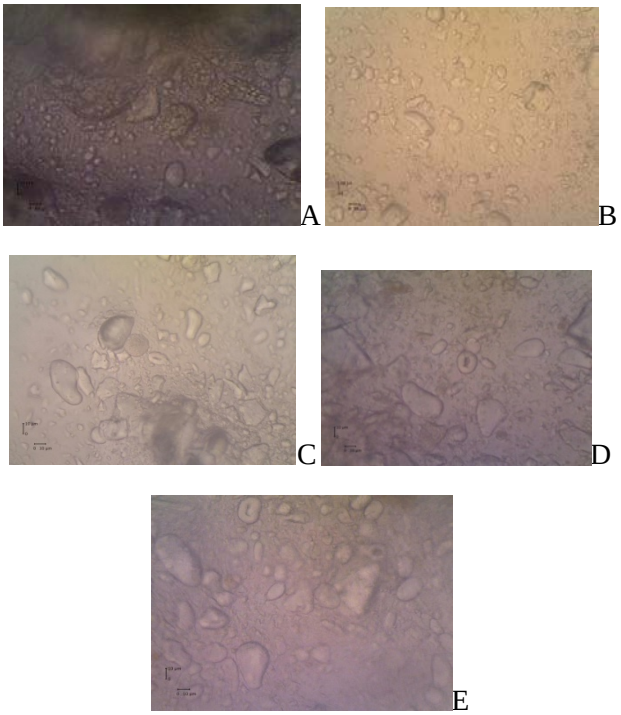


Figure 1. Morphology of granule of RUTF using optical microscope (1 cm represents 10 µm) of for each formula with the percentage ratio of cowpea flour (KT) and tempeh flour (TM): A) FA (0KT:100TM), B) FB (25KT:75TM), C) FC (50KT:50TM), D) FD (75KT:25TM), E) FE (100KT:0TM)

Table 5. Granule size of RUTF at the different concentration ratio of KT (cowpea flour) and TM (tempeh flour)

Parameter	FA (0KT:100TM)	FB (25KT:75TM)	FC (50KT:50TM)	FD (75KT:25TM)	FE (100KT:0TM)
Granule size (µm)	7.76±6.36[a]	8.94±6.95[a]	9.58±10.19[a]	10.26±8.26[a]	10.09±5.84[a]

Data are expressed as mean ± SD. Means followed by the same letters within the same row are not significantly different ($p > 0.05$).

Granule size can influence the texture of RUTF. Previous studies have reported that particle size and paste texture are affected by the oil-to-powder ratio, with a lower oil-to-powder ratio resulting in coarser granules in the cream or paste [30]. In the present study, the oil-to-powder ratio was kept constant across all formulations. Therefore, the differences in particle size may be more closely related to the characteristics of the tempeh and cowpea flours. Although the differences were not statistically significant, the numerical values showed a tendency for particle size to increase with increasing proportions of cowpea flour in the RUTF. This may be attributed to the relatively harder physical structure of cowpeas compared with tempeh, which may have limited the complete breakdown of some cowpea particles during milling. Although sieving was performed during sample preparation to standardize particle size, differences in the structural characteristics of the raw materials may have resulted in distinct particle characteristics after milling.

In tempeh, the smaller particle size may be related to the fermentation process, which alters the structural properties of soybeans and may facilitate the formation of finer particles during milling [31].

3.2.3. Viscosity

Viscosity describes the thickness of the RUTF. The analysis results of paste viscosity are presented in Table 6.

Table 6. Viscosity of RUTF made from tempeh flour and cowpea flour

Spindle rotation	Viscosity (mPa.s)				
	FA (0KT:100TM)	FB (25KT:75TM)	FC (50KT:50TM)	FD (75KT:25TM)	FE (100KT:0TM)
6 rpm	23,489±1467.22[c]	22,738±2037.36[c]	19,438±839.36[b]	12,495 ±1050.47[a]	13,403±1217.64[a]
12 rpm	23,654±1433.39[c]	21,071±2008.20[bc]	20,466±2067.85[b]	12,916 ±3532.86[a]	15,036±1707.34[a]

Data are expressed as mean ± SD. Means followed by different letters within the same row are significantly different ($p < 0.05$).

Based on Table 6, the viscosity of the RUTF was classified as very high. The viscosity decreased significantly with increasing cowpea flour content and decreasing tempeh flour content ($p < 0.05$). This finding may be related to the particle size of the paste (Table 5). The tendency toward larger particle sizes may reduce the surface area available for interactions with other components, including water and oil. Consequently, the paste may form a less cohesive structure, with some components remaining less integrated within the matrix, resulting in lower viscosity.

In contrast, increasing the proportion of tempeh flour significantly increased the viscosity of the paste ($p<0.05$). Fermentation of soybeans into tempeh may have contributed to the breakdown of large protein molecules into smaller peptides and amino acids. The smaller molecular size, together with the presence of hydrophilic groups in soybean proteins, may facilitate interactions with water and contribute to increased paste viscosity [32]. Previous research has shown that soy protein can act as an effective emulsifier, promoting the formation of a stable emulsion system and contributing to the thickening of food products. Furthermore, tempeh contains approximately four times more protein (20.8% wet basis) than cowpeas (5% wet basis) [14]. Soybean proteins include major protein fractions such as globulins and glycinin, which can contribute to increased hydrodynamic volume and water absorption, as well as the formation of a three-dimensional protein network. These properties may contribute to the thickening capacity of soy protein [33].

4. Conclusion

This study demonstrates that RUTF can be produced from local ingredients, specifically cowpea flour and tempeh with the addition of probiotics. Although a difference test conducted by semi-trained panelists

revealed that the probiotic addition affected the RUTF's taste and color, the product remained acceptable in the acceptance test involving mothers and children. Sensory test results were validated through physical property analyses, which showed an increase in lightness (L*) and a decrease in a* and b* values (color parameters) as the ratio of cowpea flour to tempeh increased. A higher proportion of cowpea flour was not associated with particle size, whereas viscosity significantly decreased. Further research is warranted to evaluate the product's efficacy among the target population, particularly malnourished children.

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