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Instant Porridge Formulation Based on Cassava Flour and Tempe Flour Composite for Children

Formulasi Bubur Instan Berbasis Komposit Tepung Singkong dan Tepung Tempe untuk Anak

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Abstract. Improving the nutrition of affordable and economically weaning food is an effective strategy to prevent stunting in children. Cassava, as a source of carbohydrates, and tempe, as a source of protein, when processed into composite flour, have the potential to serve as key ingredients in instant weaning food. This study was conducted in two stages. The first stage involved preparing the raw materials by making composite flour. The formula optimization process was carried out using a mixed experiment optimization method and D-optimal design to identify the best formula. The formula was selected based on predetermined response measurements, including maximum protein content, viscosity within the desired range, rehydration power within range, and appropriate density. In the second stage, the selected formula was evaluated through analysis of its physicochemical properties, sensory attributes, and in vitro protein and starch quality. The optimization results indicated that the best cassava-tempe porridge (CTP) formula consisted of 24.58% tempe flour and 43.42% cassava flour (based on the total material). The nutritional composition (moisture, ash, fat, protein, and carbohydrate content) and microbiological count (total plate count) were as follows: 3.27%, 3.39%, 8.29%, 18.74%, 66.31%, and 7.5×10^{1} CFU/g, respectively. In terms of physical properties, CTP exhibited a viscosity of 2306.67 cP, rehydration power of 3.67 mL/g, density of 0.45 g/mL, and a color (L*) of 83.06. The starch and protein digestibility were 74.60% and 81.25%, respectively. The optimized CTP formula met the quality standards outlined in SNI 7111:2005 for instant powdered complementary foods for infants. The sensory evaluation revealed a hedonic score for the attributes of color (6.31), aroma (6.24), viscosity (6.46), taste (6.06), and overall acceptability (6.06), indicating that the product was well-liked.

Keywords: cassava, D-optimal, product development, tempe, weaning food

Abstrak. *Peningkatan gizi MP-ASI yang ekonomis, terjangkau merupakan cara tepat untuk mencegah stunting pada anak. Singkong sebagai sumber karbohidrat, tempe sebagai sumber protein yang diolah menjadi tepung komposit merupakan komoditas potensial sebagai bahan utama MP-ASI instan. Penelitian terbagi menjadi dua tahap, tahap pertama penyiapan bahan baku dengan pembuatan tepung komposit. Proses optimasi formula dilakukan dengan metode optimasi eksperimen campuran dan desain optimasi (D-optimal) untuk memperoleh formula terbaik. Rumus dipilih didasarkan pada hasil pengukuran respon yang telah ditentukan. Tahap kedua, formula terpilih diuji berdasarkan analisis kualitas fisikokimia, sensorik, dan kualitas protein serta pati secara in vitro. Hasil optimasi menunjukkan proporsi formula terbaik bubur tempe singkong (BTS) adalah 24,58% tepung tempe dan 43,41% tepung singkong. Komposisi nutrisi (kandungan air, abu, lemak, protein, dan karbohidrat) dan mikrobiologi BTS berturut-turut adalah 3,27%; 3,39%; 8,29%; 18,74%; 66,31%; dan* $7{,}5\times10^{-1}$ *CFU/g. Berdasarkan sifat fisiknya, BTS memiliki viskositas 2306,67 cP, daya rehidrasi 3,67 mL/g, berat jenis 0,45 g/mL dan warna (*L) 83,06. Daya cerna pati sebesar 74,60% dan protein 81%. Formula optimal BTS telah memenuhi persyaratan mutu sesuai SNI 7111:2005 tentang makanan pendamping ASI bubuk instan. BTS mempunyai skor hedonik untuk atribut warna (6,31), aroma (6,24), kekentalan (6,46), rasa (6,06), keseluruhan (6,06) yang berarti produk disukai.*

Kata kunci: *D-optimal, gizi, MP-ASI, pengembangan produk, singkong, tempe*

Practical Application: MP-ASI products obtained from cassava flour and tempe flour formulations have high nutritional value and sensory that is preferred by children. The resulting formula is expected to be used as an alternative food in fulfilling children's nutritional needs and as an effort to strengthen local food diversification in Indonesia.

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INTRODUCTION

Toddlerhood is a stage of child growth and development that really needs adequate food intake support, both in quantity and quality. Toddlers are susceptible to nutritional deficiencies that can disrupt their physical growth and mental development. The World Health Organization states that as many as 21.3% of children worldwide experience stunting due to consumption of complementary foods with inadequate nutrients (WHO 2019). Children who do not consume sufficient nutrients are very susceptible to stunting or have a height below standard. The prevalence of stunting in Indonesia is 30.8%, still higher than the world prevalence (Budiastutik and Rahfiludin 2019). Currently, in various developing countries, many children consume complementary foods with inadequate macro and micronutrient composition. This condition is further worsened by the burden of infection. Both of these are the main causes of malnu-trition in children aged 6–24 months (Dewey 2013). Internal factors such as genetics and/or external factors such as malnutrition are the causes and risk factors for children experiencing stunting.

Stunting in children reflects the problem of malnutrition in the world today. Stunting is a result of poor nutrition, especially from pregnancy to early childhood. Children with stunting have the potential to not reach the optimal height and experience cognitive disorders in their brains. The results of the Indonesian Nutritional Status Survey (SSGI) show that the prevalence rate of stunting in Indonesia is 24.4% (Kemenkes 2021). In various developing countries, stunting problems are caused by inadequate provision of complementary foods, especially in children aged 6–24 months (Herminiati *et al*. 2020).

Efforts to process and develop products that have high nutritional content and quality are a concern in preventing the increase in stunting cases in the world. Improving the quality of complementary feeding is the most cost-effective strategy to improve health and reduce child morbidity and mortality. Therefore, the early introduction of complementary feeding rich in protein and energy to children aged 6–24 months is especially important to face the challenges of malnutrition in most developing countries (Udoh and Amodu 2016). In addition, highly nutritious foods with complete and appropriate amino acid content will be extremely helpful in combating the problem of protein and energy malnutrition in children who are growing (Arise *et al.* 2021).

Utilization of local agricultural products is one of the strategies for developing MP-ASI that is cheap and affordable for various levels of society. One of the most potential root crops is cassava. Cassava (*Manihot esculenta*) is an important source of energy for millions of people. Cassava flour can be used to make porridge to meet the nutritional needs of babies (Onyango *et al*. 2020). Cassava porridge is a source of energy with a high starch content, so the proportions need to be considered to ease the children digestion process. For the quality of MP-ASI made from cassava to meet quality requirements, it is necessary to formulate it with excellent quality food sources of protein, fat, minerals, and vitamins.

Tempe is a source of vegetable protein, minerals, and vitamins that are very suitable to be combined with cassava in the formulation of MP-ASI (Astawan *et al*. 2016). For the Indonesian people, tempe is an abundant and economical source of protein, with more affordable and accessible price compared to animal protein sources. The combination of cassava and tempe can be an alternative MP-ASI in fulfilling the nutritional needs of children aged 6-24 months. The purpose of this study was to optimize the formula of MP-ASI using tempe and cassava as the main raw materials that meet the requirements of MP-ASI products.

MATERIALS AND METHODS

Materials

The materials used in this study were cassava (*Manihot esculenta*) tubers of the Manggu variety purchased at Pasar Anyar Bogor, tempe obtained from Rumah Tempe Indonesia, Bogor, vegetable oil, powdered spices from Toko Bumbu, and commercial porridge (CP). The reagents used were distilled water (One-med), NaOH (Merck), *n*-hexane (Merck), 0.2 N Wolphole buffer (Merck), 1% pepsin solution (Sigma-Aldrich) and 20% TCA solution (Merck), α-amylase enzyme solution (Novozymes), DNS solution (Sigma Aldrich), NA media (Merck) and other supporting materials for analysis.

Flour preparation

Tempe flour production was conducted based on Widyastuti *et al.* (2020) with modifications to the temperature and drying time. Soybean tempe was sliced with a thickness of ±0.3 cm using a slicer (Alexand Erwerk UC II, USA), then steamed (at 100 °C for 5–10 minutes. Tempe was dried using a fluidized bed dryer (In House Tools, Integrated Laboratory, IPB University) at 45 °C for 5 hours. The dried soybean tempe was then ground with a grinder (Fomac FCT-Z500, China) and sieved using an 0.177 mm^2 sieve (ABM Industries Incorporated, Indonesia). The flour was stored in airtight polyethylene packaging.

Before the cassava was dried, it was first cut into pieces with a thickness of ±5 cm and washed twice with running tap water. The cassava steaming process was conducted at 100 °C for 15 minutes. The cooked cassava was then dried using a drum dryer (R. Simon Dryers Ltd., Nottingham, England). The dried cassava was ground using a grinder (Fomac FCT-Z500, China) and sieved with an 0.177 mm^2 sieve (ABM Industries Incorporated, Indonesia). The cassava flour was vacuum sealed in airtight polyethylene bags, stored at room temperature 20-30 °C before use within a week.

Instant MP-ASI porridge production

The instant porridge was made based on Moraa (2021) with modifications on the proportion of composite flour (cassava flour 15–25 g and tempe flour 43–53 g) used. These range based on trial and error. A total of 500 mL of water was added with 68 g (com-posite flour) and 32 g of other additional ingredients consisting of skim milk 20 g, spices 7 g and vegetable oil 5 g, then stirred until homogenous. The mixture was cooked and kept boiled in a pan for 8 minutes with continuous stirring to avoid sticking to the bottom of the pan and forming lumps. The cooking results were dried using a drum dryer (R. Simon Dryers Ltd., Nottingham, England), then ground and sieved using an 0.177 mm^2 sieve (ABM Industries Incorporated, Indonesia). Instant porridge was packed in polyethylene plastic and stored in a refrigerator.

Determination of selected MP-ASI formula

The factors used in the optimization process are cassava flour and tempe flour. The upper and lower limits used in the optimization process are the results of trials (trial and error) and literature studies (Puteri *et al*. 2018) as listed in Table 1. Response measurements were conducted on the MP-ASI formula recommended by RSM. The data obtained were processed using Design Expert 13.0 software. In the final optimization stage, the program will recommend one optimal formula combination that is selected by comparing the desirability values for each solution. The selected MP-ASI formula is based on the highest desirability value. In each formula there are also 32% other ingredients consisting of skim milk, vegetable oil, and spices.

Table 1. Determination of minimum and maximum limits for cassava flour and tempe flour content

Parameter	Minimum	Maximum
Cassava flour (% w/w, total material)	15	25
Tempe flour (% w/w, total material)	43	53

MP-ASI analysis

On selected MP-ASI, physical analysis was carried out including viscosity parameters using a Viscometer (Brookfield, Model LVT, Massachusetts) according to the method of Karimah *et al*. (2019), rehydration power was analyzed using the method of Hapsari *et al*. (2022) with modifications to the sample preparation which was left at room temperature (25–30 °C) for 10 minutes, bulk density using the method of Nguyen *et al*. (2017), and color using the method of Yoon *et al*. (2018). Proximate analysis including moisture, ash, protein, fat, and carbohydrate content by difference was conducted using the AOAC method (2019), and amino acid composition using HPLC referring to the In House Method, Integrated Laboratory, IPB University. The microbiological testing conducted was the total plate count using the BSN method (2015). Evaluation of nutritional quality was conducted *in vitro* by measuring starch digestibility using the method of Muchtadi *et al*. (1992) and protein digestibility using Hamidah *et al*. (2016). Sensory testing was conducted based on a hedonic test using the Budiarto *et al*. (2021) method which includes color, aroma, viscosity, taste, and overall parameters on a hedonic scale of 1–7. A value of 1 indicates very dislike and a value of 7 indicates very like. The panelists consisted of thirty young mothers who would choose food for their children, aged between 25–30 years and familiar with MP ASI.

RESULTS AND DISCUSSION

Measurable response to MP-ASI formula

The results of the MP-ASI formula analysis based on the predetermined responses could be seen in Table 2. The predetermined responses consist of protein content, viscosity, rehydration power, and bulk density. The protein content of each formulas MP-ASI porridge was in the range of 14.68–19.81% (Table 2). The two-dimensional graph (Figure 1A) shows that the combination of components mutually influences the protein content. The protein content response will increase along with the increasing amount of tempe flour used which is indicated by a positive constant value. The interaction between the use of tempe flour and cassava flour will decrease the protein content which is indicated by a negative constant value. Higher amount of tempe flour substitution will increase the protein content of MP-ASI. Tempe flour had a protein content of 50.18% (Astawan *et al*. 2016), while cassava flour only had a protein content of 2.78%.

The viscosity of porridge will increase along with the increasing use of cassava flour. It is due to the starch content in cassava flour which can trigger the gelatinization process in the porridge processing. This is in line with the results of Lumentut's study (2018) which reported that starch content was directly proportional to viscosity. In addition, an important functional property of starch is the ability to thicken and form gels. Figure 1 (B) shows a linear line with residual points that were normally distributed following the red line. This indicates that the model was suitable for viscosity response analysis.

Table 2. Optimization response to MP-ASI formulation

Run	Formula		Response Measurement Results			
	Tempe Flour (%)	Cassava Flour (%)	Protein Content (%)	Viscosity (cP)	Rehydration Power (mL/g)	Bulk Density (g/mL)
1	15	53	15.34	3200	4.3	0.48
2	15	53	15.23	3200	4.3	0.48
3	17.4	50.5	16.27	3090	4.1	0.47
4	25	43	19.18	2360	3.6	0.45
5	25	43	19.81	2280	3.6	0.45
6	18.6	49.3	16.60	3020	4.1	0.47
7	16.2	51.7	16.12	3150	4.2	0.47
8	20	48	16.69	2920	4	0.46
9	21.5	46.4	17.32	2640	3.9	0.46
10	25	43	19.63	2320	3.6	0.46
11	15	53	14.68	3200	4.8	0.48
12	25	43	19.51	2400	3.6	0.45
13	23.3	44.6	17.51	2440	3.7	0.46

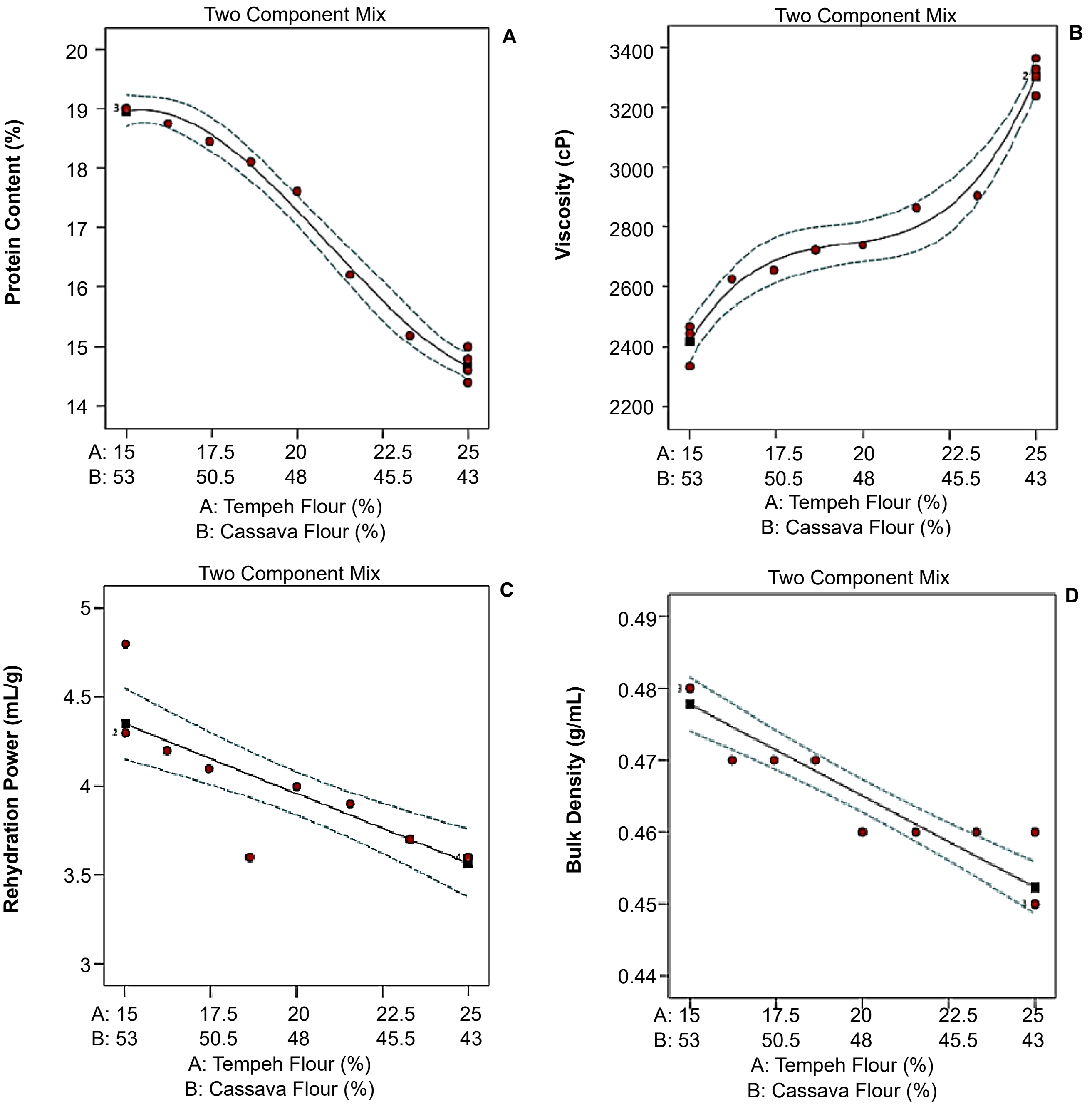

Figure 1. Two-dimensional graph of the response of protein content (A), viscosity response (B), rehydration power (C), and bulk density (D) of MP-ASI

The range of rehydration power values produced by MP-ASI products ranges from 3.6–4.3 mL/g. The two-dimensional graph (Figure 1C) showed that the combination of components can mutually influence the rehydration power value. The composition of raw materials in the porridge formula affects water absorption, which was determined by the high carbohydrate and protein content. Starch is one of the components in determining the amount of absorption power (Palupi and Afifah 2023). The breakdown of starch granules that occur during the processing process will change the structure of the starch from crystalline to amorphous and porous. It increases the starch ability to bind water in greater quantities. Water that enters the material will be trapped in the porous part (Diniyah *et al*. 2018).

The bulk density of MP-ASI increases with the increasing addition of cassava flour. MP-ASI with a high bulk density will automatically also have a high nutritional value density. Water factor that affects bulk density. The moisture content of cassava flour was lower than tempe flour. Water in MP-ASI products will break down the protein structure into porous material granules. This was supported by the results of the water content in the best MP-ASI formula, which is greater than commercial baby porridge, which was 3.77 and 1.24%. The lowest bulk density value of 0.45 g/mL was found in MP-ASI with a percentage of cassava flour and tempe flour of 43 and 25%. The highest bulk density of 0.48 g/mL was owned by the MP-ASI formula with a percentage of cassava flour of 53% and tempe flour of 15%.

Based on the analysis of variance (ANOVA) in Table 3, it is known that the selected model for the entire response had a significant value of less than 0.05 ($p<0.05$), which means that the entire model is significant to the response and the selected model. All responses also have an insignificant lack of fit value, namely $p> 0.05$, so it is concluded that the model has a chance of error of less than 5%.

Optimal formula for MP-ASI

The optimization stage aims to obtain the best MP-ASI formula variables by optimizing the analyzed responses. Desirability value is the function value to fulfil desires based on the criteria of the existing variables. A response is considered optimal if it obtains a desirability value close to one. The criteria for each variable were shown in Table 4. The optimization results obtained were in the form of an optimum formula with the highest desirability value of 0.839. The research results were considered verified if the response test results were in the range of 95% confidence interval (CI) values and the range of 95% prediction interval (PI) values. Based on the verification results (Table 5), all responses were in the range of 95% CI and 95% PI values. It shows that the formula created had response test results that were in accordance with the predictions recommended by the software.

Nutritional value of optimum MP-ASI formula

The nutritional composition of CTP has met the quality requirements of SNI (BSN 2005). The moisture content of CTP (the best MP-ASI formula) was higher than commercial porridge (Table 6). The moisture content of MP-ASI was also influenced by the protein content of tempe. Setyawan *et al*. (2021) reported that the higher the protein content of a food ingredient, the higher its ability to bind water, which causes an increase in the moisture content of a product.

The difference in ash content of a product was caused by the difference in the mineral composition of each ingredient (its constituent materials). Tempe flour had an ash content of 1.93% (Astawan *et al*. 2016). Both MP-ASI samples had a fat content above 8%, in accordance with research by Farida *et al*. (2016) which showed a fat content of 8.1–9.25% in instant baby porridge.

CTP had a higher protein content (18.74%) than commercial baby porridge (15.18%). This is due to the high protein content in tempe flour as its main raw material. The protein content in tempe flour reaches 50.18 g per 100 g of material (Astawan *et al*. 2016). Thus, the use of tempe flour in sufficient portions will increase the protein content in the resulting MP-ASI.

The carbohydrate content of a food ingredient will be influenced by the composition of other nutrients, namely water, ash, fat, and protein content. The higher the proportion of other nutrient components in a product, the lower the carbohydrate content. This was what causes commercial porridge to have a higher carbohydrate content than selected MP-ASI formulas (CTP).

The amino acid composition of complementary feeding products in the form of cassava tempe porridge and commercial porridge could be seen in Table 7. Glutamic acid and aspartic acid dominate the amino acid composition of both products. In addition, arginine, leucine, and histidine appear as essential amino acids that dominate complementary feeding products. CTP produces more amino acids than commercial porridge. Tempe as the main source of protein in CTP contributes to the availability of amino acids in complementary feeding. The amino acid content in tempe increases significantly after the fermentation process compared to beans before fermentation (Kadar *et al*. 2018).

Table 3. Variance fingerprint for test response

Responses	Model	Significant (p<0.05)	Lack of Fit (p>0.05)	R^2	Adjusted R^2	Predicted R^2	Adequate Precision
Protein content (%)	Qubic	<0.0001	0.6589	0.9819	0.9758	0.9593	28.6155
Viscosity (cP)	Qubic	<0.0001	0.4107	0.9910	0.9881	0.9824	36.8998
Rehydration power (mL/g)	Linear	0.0001	0.3739	0.7458	0.7227	0.6484	9.9790
Bulk density (g/mL)	Linear	<0.0001	0.5668	0.8987	0.8895	0.8561	17.3539

Table 4. Criteria for determining the optimum MP-ASI formula.

Variable	Predicted Value	Lower Limit	Upper Limit	Importance
Tempe flour (%)	In range	15	25	3 (+++)
Cassava flour (%)	In range	43	53	3 (+++)
Protein content (%)	maximize	14.68	19.81	5 (+++++)
Viscosity (cP)	In range	2280	3000	4 (++++)
Rehydration power (mL/g)	In range	3.6	4.8	3 (+++)
Bulk density (g/mL)	In range	0.45	0.48	4 (++++)

Table 5. Verification results of the optimum formula for MP-ASI

Variable	Predicted Value	95% PI		Verify Value	95% CI	
		Low	High		Low	High
Protein content (%)	18.99	14.68	19.81	18.74	18.53	19.44
Viscosity (cP)	2360	2280	3000	2306	2292	2429
Rehydration power (mL/g)	3.6	3.6	4.8	3.66	3.28	3.91
Bulk density (g/mL)	0.45	0.45	0.48	0.45	0.44	0.46

Table 6. Nutritional composition of selected MP-ASI

Parameter (%)	MP-ASI Product		SNI 7111-1: 2005
	CP	CTP	
Water	1.44±0.04[a]	3.27±0.03[b]	Maximum 4.0
Ash	3.29±0.01[a]	3.39±0.05[b]	Maximum 3.5
Fat	8.27±0.02[a]	8.29±0.04[a]	6–15
Protein	15.18±0.02[a]	18.74±0.14[b]	8–22
Carbohydrate	71.82±0.01[b]	66.31±0.15[a]	-

Note: CP= commercial porridge, CTP= cassava tempe porridge. Values in the same row followed by different letters indicate significant differences (p<0.05)

Table 7. Amino acid composition of MP-ASI products

Amino Acids	Amino Acids in MP-ASI (g/100 g)		Amino Acids	Amino Acids in MP-ASI (g/100 g)	
	CP	CTP		CP	CTP
Aspartic acid	2.07	2.35	Methionine	0.10	0.19
Threonine	0.67	0.75	Isoleucine	0.82	0.93
Serine	0.91	1.00	Leucine	1.58	1.75
Glutamic acid	4.24	4.77	Tyrosine	0.56	0.65
Proline	1.01	1.09	Phenylalanine	0.76	1.11
Glycine	0.88	0.91	Histidine	1.01	1.16
Alanine	1.01	1.10	Lysine	0.77	0.99
Cysteine	0.08	0.08	Arginine	1.93	2.11
Valine	0.86	0.92	Tryptophan	0.12	0.15

Note: CP= commercial porridge, CTP= cassava tempe porridge

Physical properties of optimum MP-ASI formula

The physical characteristics of MP-ASI could be seen in Table 8. The density of MP-ASI could be affected by water content. The water content of comercial porridge was lower than CTP, so its porosity was lower, and its density volume was higher. If a food ingredient is dried with a drum dryer, the water in the granules of the ingredient will evaporate and leave some empty space between the particles. This was what caused an increase in the density of the bulky in a product (Luna *et al*. 2015).

The rehydration power value of commercial porridge was slightly smaller (3.53 mL/g) than CTP (3.67 mL/g). Good baby porridge products are expected to have low rehydration power to avoid food ingredients from absorbing more water which causes the food product to become bulky and thicken (Husain *et al.* 2020). The criteria for MP-ASI that are easy to spoon and good for baby digestion are in the viscosity range of 1000–3000 cP. Cassava starch affects viscosity, making the CTP viscosity value greater than commercial porridge. Starch is the main component responsible for the viscosity of the product. The most important functional property of starch in the development of a product is its ability to thicken and form a gel (Oladiran *et al*. 2018).

Table 8. Physical characteristics of MP-ASI

Parameter	MP-ASI Product	
	CP	CTP
Viscosity (cP)	1846.67±50.3^a	2306.67±5.77^b
Rehydration power (mL/g)	3.53±0.11^a	3.67±0.06^a
Bulk density (g/mL)	0.55±0.01^b	0.45±0.00^a
Color (L*)	90.23±0.01^b	83.06±0.00^a

Note: CP= commercial porridge, CTP= cassava tempe porridge. Values in the same row followed by different letters indicate significant differences (p<0.05)

Commercial porridge products are white in color, while CTP was white with a slightly brownish yellow color. Tempe flour had a slightly yellowish white color during the processing stage and experiences a decrease in L* value so that it will produce a slightly brownish or dark final product. The decrease in L* value and whiteness were in line with the increase in drying temperature caused by the occurrence of non-enzymatic browning reactions (Maillard reactions). The heating process of flour (starch) conducted before the drying process had the potential to dissolve several chemical compounds (sugar, amylose, and protein) (How and Siow 2020). During the drying process, soluble compounds, especially reducing sugars and proteins, will react and produce brownish pigments (melanoidins). These pigments will reduce the whiteness and brightness of the flour.

Total plate count value for MP-ASI formula

The results of the microbiological analysis of MP-ASI products are presented in Table 9. Based on BSN (2005), the requirements for the number of microbes, which is the total plate count of instant powdered MP-ASI products, are less than 4 log CFU/g. CTP products with cassava flour and tempe flour substitutions met food quality standards according to SNI quality requirements.

Table 9. Total plate count (colonies per gram) in MP-ASI

MP-ASI Product	Total Plate Count (log CFU/g)	SNI 7111-1: 2005 (log CFU/g)
CP	1.92	Maximum 4
CTP	1.87	

Note: CP= commercial porridge, CTP = cassava tempe porridge. Values in the same column followed by different letters indicate significant differences (p<0.05)

In vitro nutrient quality

The heating process of instant MP-ASI porridge will cause gelatinization and damage to the hydrogen bonds in the starch so that amylose and amylopectin separate and come out of the granules. Digestible starch in food is a good indicator of its energy content that can be used in a nutritional fulfillment program. Energy-dense foods with high starch content that are easily digested are highly desirable in foods for infants and people suffering from protein energy deficiency (Onyango *et al.* 2020). The digestibility of commercial porridge and CTP starch did not show a significant difference, namely 75.51 and 74.60%, but the digestibility of commercial porridge starch was slightly higher than CTP. The high amount of amylose will generally be associated with low digestibility. CTP made from rice flour contains more amylose than commercial porridge made from rice flour, which was around 14 and 20% (Pudjihastuti *et al*. 2019). This includes factors that affect the digestibility of CTP starch, which was slightly lower than commercial porridge. Lin and Nichols (2017) explained that amylose has fewer α-(1→6)-glycosidic branches, about 2% compared to amylopectin (about 5%). The fewer branches allow long linear molecular chains to associate with other linear chains to form a double helix structure, which has low susceptibility to digestive enzymes. The helical structure with hydrophobic cavities can form complexes with other hydrophobic compounds, such as lipids. When amylose and lipids form a complex after gelatinization, the complex has lower susceptibility to digestive enzymes. The digestibility of CTP and commercial porridge starches, which was around 70%, is still in the category of being well-digested by children.

The protein digestibility of CTP products was 81.25%, higher than the commercial porridge protein digestibility of 77.64% (Table 10). Tempe is known to have a higher protein digestibility quality than other vegetable protein foods. The presence of protease digestive enzymes produced by *Rhizopus* spp. mold during the fermentation process of tempe causes it to become more easily digested in the body compared to protein in other plant foods (Tamam *et al*. 2023). The fermentation process in tempe causes its nutrients to be more easily digested, absorbed, and utilized by the body. The fermentation process also causes the complex protein in soybeans to become simpler in tempe so that it is easier to be digested, absorbed, and utilized by the body (Astawan *et al*. 2015).

Table 10. *In vitro* starch and protein digestibility of MP-ASI products

MP-ASI Product	Starch Digestibility (%)	Protein Digestibility (%)
CP	75.51±1.05^a	77.64±0.40^a
CTP	74.60±0.10^a	81.25±1.26^b

Note: CP= commercial porridge, CTP = cassava tempe porridge. Values in the same row followed by different letters indicate significant differences (p<0.05)

Sensory characteristics of MP-ASI formula

The color of CTP was preferred by panelists compared to commercial porridge. Commercial porridge products were white while CTP was yellowish brown. This proves that products that have stronger color intensity can provide appeal to panelists so that they can increase the level of panelist preference. Commercial porridge products had a vanilla aroma, while CTP had a distinctive tempe aroma. Panelists still like the aroma of both products.

CTP products were slightly thicker than commercial porridge and were preferred by panelists (Table 11). This was influenced by the higher starch content in CTP due to it being made from cassava flour. Commercial porridge consisted of 21% rice, while CTP consists of 43.4% cassava flour per 100 g, so the availability of starch contained in the product was greater. This makes the viscosity value of CTP greater than commercial porridge. Amylose in food processing is related to providing sticky properties or forming gels and having the ability to absorb water in materials (Nadhira dan Cahyana 2023).

CTP and commercial porridge products were both preferred in every sensory parameter of aroma, taste, texture, and viscosity by panelists with no significant difference in their preference levels. The distinctive taste brought by tempe-based products was influenced by their amino acid content. Several studies have reported that D-amino acids play a role in producing assorted flavors and aromas in food (Marcone *et al.* 2020). Glutamic acid and aspartic acid are the largest contributors of amino acids to CTP products. Both amino acids are non-essential amino acids that contribute to the emergence of umami (savory) taste.

CONCLUSION

The selected MP-ASI formula has better protein content compared to commercial porridge. Based on physical characteristics, the total plate count, the digestibility of starch, and protein of CTP products has met the quality requirements according to SNI on instant powdered MP-ASI. The sensory characteristics of CTP products have a liking score for the attributes of color (6.31), aroma (6.24), viscosity (6.46), taste (6.06), and overall (6.06) in scale of 1–7.

REFERENCES

[AOAC] Association of Oficial Analytical Chemists. 2019. Official methods of analysis, 21st edition. Airlington: Association of Oficial Analytical Chemists.

Arise AK, Akeem SA, Olagunju OF, Opaleke OD, Adeyemi DT. 2021. Development and quality evaluation of wheat cookies enriched with bambara groundnut protein isolate alone or in combination with ripe banana mash. *Appl Food Res.* 1 (1): 100003. doi:10.1016/j.afres.2021.100003

Astawan M, Wresdiyati T, Ichsan M. 2016. Karakteristik fisikokimia tepung tempe kecambah kedelai. *J Gizi Pangan.* 11 (1): 35–42.

Astawan M, Wresdiyati T, Sirait J. 2015. Pengaruh konsumsi tempe kedelai grobogan terhadap profil serum, hematologi dan antioksidan tikus. *J Teknol Industri Pangan.* 26 (2): 155–162. doi:10.6066/jtip.2015.26.2.155

[BSN] Badan Standardisasi Nasional. 2015. SNI 3144: 2015. Tempe Kedelai. Jakarta: Badan Standardisasi Nasional.

[BSN] Badan Standardisasi Nasional. 2005. SNI Makanan pendamping air susu ibu (MP-ASI) - Bagian 1 : Bubur instan. Jakarta: Badan Standardisasi Nasional.

Budiarto R, Poerwano R, Santosa E, Efendi D, Agusta A. 2021. Sesory evaluation of the qua-lity of kaffir lime (C*itrus hystrix* DC.) leaves exposed to different postharvest treatments. *J Tropical Crop Sci.* 8 (2): 71–79. doi:10.29244/jtcs.8.02.71-79

Budiastutik I, Rahfiludin M. 2019. Faktor risiko *stunting* pada anak di negara berkembang. Amerta Nutr. 3 (3): 122–129. doi:10.20473/amnt.v3i3.2019.122-129

Dewey KG. 2013. The challenge of meeting nutrient needs of infants and young children during the period of complementary feeding: an evolutionary perspective. *J Nutr.* 143 (12): 2050–2054. doi:10.3945/jn.113.182527

Diniyah N, Yuwana N, Maryanto, Purnomo BH, Subagio A. 2018. Karakterisasi sera mocaf (*modified cassava flour*) dari ubi kayu varietas manis dan pahit. *J Penelitian Pascapanen Pertanian.* 15 (3): 114–122. doi:10.21082/jpasca.v15n3.2018.114-122

Farida SN, Ishartani D, Affandi DR. 2016. Kajian sifat fisik, kimia dan sensoris bubur bayi instan berbahan dasar tepung tempe koro glinding (*Phaseolus lunatus*), tepung beras merah (*Oryza nivara*) dan tepung labu kuning (*Cucurbita moschata*). *J Teknosains Pangan.* 5 (4): 32–39.

Table 11. Sensory characteristics of MP-ASI

MP-ASI Product	Sensory Attributes of MP-ASI				
	Color	Aroma	Thickness	Taste	Overall
CP	5.97±0.66[a]	6.33±0.50 [a]	5.60±1.00[a]	5.99±0.82[a]	6.02±0.64[a]
CTP	6.31±0.51[b]	6.24±0.54[a]	6.46±0.55[b]	6.06±0.49[a]	6.06±0.46[a]

Note: CP= commercial porridge, CTP = cassava tempe porridge. Values in the same column followed by different letters indicate significant differences (p<0.05)

Hamidah N, Legowo AM, Anwar S. 2016. Tepung ubi kayu (*manihot esculenta*) dan tepung tempe kedelai mempengaruhi pengembangan volume dan mutu gizi protein roti tawar. *J Gizi Indonesia.* 4 (1): 55–62. doi:10.14710/jgi.4.1.55-62

Hapsari DR, Maulani AR, Aminah S. 2022. Karakteristik fisik, kimia, dan sensori flakes berbasis tepung uwi ungu (*Dioscorea alata* L.) dengan penambahan tepung kacang kedelai (*Glicyn max* L.). *J Agroindustri Halal*. 8 (2): 201–212. doi: 10.30997/jah.v8i2.6290

Herminiati A, Kristanti D, Rimbawan R, Dewi Astuti I, Achyadi NS, Yuliantika N. 2020. Characteristics of inulin-enriched instant porridge and its effectiveness to increase calcium absorption in infant rat models. *Curr Res Nutr Food Sci.* 8 (1): 256–267. doi:10.12944/CRNFSJ.8.1.24

How YK, Siow LF. 2020. Effects of convection, vacuum and freeze drying on antioxidants, physicochemical properties, functional properties, and storage stability of stink bean (*Parkia speciosa*) powder. *J Food Sci Technol.* 57 (12): 4637–4648. doi:10.1007/s13197-020-04501-7

Husain N, Azis R, Engelen A. 2020. Karakteristik bubur bayi instan berbahan dasar tepung beras merah dengan penambahan ekstrak daun kelor (*Moringa oleifera* Lam). *J Agritech Sci.* 4 (1): 30–42. doi:10.30869/jasc.v4i1.558

Kadar AD, Aditiawati P, Astawan M, Putri SP, Fukusaki E. 2018. Gas chromatography coupled with mass spectrometry-based metabolomics for the classification of tempe from different regions and production processes in Indonesia. *J Biosci Bioeng.* 126 (3): 411–416. doi:10.1016/j.jbiosc.2018.03.020

Karimah FN, Bintoro VP, Hintono A. 2019. Karakteristik Fisikokimia dan mutu hedonik bubur bayi instan dengan variasi proporsi tepung ubi jalar ungu dan kacang hijau. *J Teknologi Pangan.* 3 (2): 309–314.

[Kemenkes] Kementrian Kesehatan. 2021. Situasi balita pendek (*Stunting*) di Indonesia. Jakarta: Pusat data dan Informasi, Kementrian Kesehatan RI.

Lakshmi C. 2014. Food coloring: The natural way. *Res J Chem Sci*. 4 (2): 87–96.

Lin AHM, Nichols BL. 2017. The digestion of complementary feeding starchesin the young child. Starch-Stärke. 69 (7–8): 1700012. doi:10.1002/star.201700012

Lumentut G. 2018. Formulasi bubur bayi instam dari tepung pregelatinisasi umbi uwi ungu (*Dioscorea alata* L.) dengan tepung kedelai (*Glycine max* L. Merr) sebagai alternatif makanan pendamping air susu ibu [skripsi]. Makassar: Universitas Hasanuddin.

Luna P, Herawati H, Widowati S, Prianto AB. 2015. Pengaruh kandungan amilosa terhadap karakteristik fisik dan organoleptik nasi instan. *J Penelitian Pascapanen Pertanian.* 12 (1): 1–10. doi:10.21082/jpasca.v12n1.2015.1-10

Marcone GL, Rosini E, Crespi E, Pollegioni L. 2020. D-amino acids in foods. *Appl Microbiol Biotechnol.* 104 (2): 555–574. doi:10.1007/s00253-019-10264-9

Moraa MS. 2021. Bioaccessibility of iron and zinc micronutrient powder added in germinated porridge s among children aged 6-23 months in Homabay County, Kenya [tesis]. Kenya: Kenyatta University.

Muchtadi D, Palupi NS, Astawan M. 1992. *Petunjuk Laboratorium: Metoda Kimia Biokimia dan Biologi dalam Evaluasi Nilai Gizi Pangan Olahan*. Bogor: Institut Pertanian Bogor.

Nadhira R, Cahyana Y. 2023. Kajian sifat fungsional dan amilografi pati dengan penambahan senyawa fenolik (review). *J Penelitian Pangan.* 3 (1): 14–19. doi:10.24198/jp2.2023.vol1.1.03

Nguyen DQ, Nguyen TH, Mounir S, Allaf K. 2017. Effect of feed concentration and inlet air temperature on the properties of soymilk powder obtained by spray drying. *Dry Technol.* 36 (7): 817–829. doi:10.1080/07373937.2017.1357040

Oladiran DA, Emmambux MN, de Kock HL. 2018. Extrusion cooking cassava-soy flour with 200 g/kg wheat brand promotes slower oral processing during consumption of the instant porridge and higher derived satiety. *LWT.* 97: 778–786. doi:10.1016/j.lwt.2018.07.068

Onyango C, Luvitaa SK, Unbehend G, Haase N. 2020. Nutrient composition, sensory attributes and starch digestibility of cassava porridge modified with hydrothermally treated finger millet. *J Agric Food Res.* 2: 100021. doi:10.1016/j.jafr.2020.100021

Palupi HT, Afifah S. 2023. Pengaruh lama perendaman dan penambahan susu skim terhadap karakteristik bubur kacang merah (*Phaseolus vulgaris* L.) instan. *Teknol Pangan: Media Informasi Komunikasi Ilmiah Teknol Pertanian.* 14 (2): 295–303. doi:10.35891/tp.v14i2.4337

Pudjihastuti I, Sumardiono S, Supriyo E, Kusumayanti H. 2019. Analog rice made from cassava flour, corn, and taro for food diversification. E3S Web of Conferences. The 4th International Conference on Energy, Environment, Epidemiology and Information System (ICENIS 2019). doi: 10.1051/e3sconf/201912503010

Puteri MDPTG, Fortunata SA, Prabawati EK, Kristianti F, Wijaya CH. 2018. Overripe tempe as source of protein in development of ready-to-eat porridge. *Int Food Res J.* 25 (Suppl. 2): S201–S209.

Setyawan RH, Saskiawan I, Widhyastuti N, Kasirah. 2021. Formulasi makanan pendamping asi (MP-ASI) bubuk instan terfortifikasi tempe dan jamur tiram putih (*Pleorotus ostreatus*). *J Biol Indonesia.* 17 (1): 57–65. doi:10.47349/jbi/17012 021/57

Tamam B, Puryana IGBP, Suratiah, Sutiari NK. 2023. Nutritional aspects and amino acid profiles of temper local, imported, and black soybean relating to the functional properties. IOP Conference Series: Earth and Environmental Science. doi:10.1088/1755-1315/1177/1/012027

Udoh EE, Amodu OK. 2016. Complementary feeding practices among mothers and nutritional status of infants in Akpabuyo Area, Cross River State Nigeria. *Springerplus.* 5 (1): 2073. doi:10.1186/s40064-016-3751-7

[WHO] World Health Organization. 2019.Level and trends in child malnutrition. World Health Organization.

Widyastuti N, Nita HL, Ulfa R, Sulchan M, Anjani G, Nyoman SW, Diana NA, Vita GL. 2020. The Effect of tempe flour from tree bean (*Parkia timoriana (DC) Merr*) Seeds on lipid profile in protein energy malnutrition rats. *Poltravinarstvo Slovak J Food Sci*. 15: 173–180. doi:10.5219/1525

Yoon D-K, Kim Ji-Han, Cho W-Y, Ji D-S, Lee H-J, Kim Jung-Ho, Lee C-H. 2018. Effect of *Allium hookeri* root on physicochemical, lipid, and protein oxidation of *Longissimus dorsi* muscle meatball. *Korean J Food Sci Anim Resour.* 38 (6): 1203–1212. doi:10.5851/kosfa.2018.e53

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