Journal of Tropical AgriFood 8(Suppl. 1): 7-11 (2026) *p-ISSN 2685-3590, e-ISSN 2685-3604*
3rd International Conference on Food Technology and Nutrition, 2025
September 29-30th, 2025 Samarinda, INDONESIA

RESTRUCTURING VEGETABLES INTO EDIBLE FOLDING PAPER TO IMPROVE NUTRIENT INTAKE

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Submission: 14 April 2025; Acceptance: 12 February 2026; Published: 24 April 2026

ABSTRACT

Vegetable consumption in Indonesia is low, particularly among preschool-aged children, who often do not meet daily intake recommendations. Sensory factors, such as taste, texture, and appearance, strongly influence children’s acceptance of vegetables. Previous studies have shown that modifying vegetables and using play-based learning can improve children’s interest. This study aimed to develop an edible folding paper made from vegetables, serving as both a nutritious food product and an interactive learning tool. Spinach, purple cabbage, and pumpkin were chosen for their good acceptance, nutrient content, and color appeal. The product was analyzed for macronutrients (proximate analysis) and micronutrients, including vitamin C, antioxidant activity, and iron (Fe) content. The results showed adequate levels of energy, protein, fat, and carbohydrates. Micronutrient analysis indicated 3.31 mg of iron, 53 mg of vitamin C, and 56.21% antioxidant inhibition per 100 g of product. Texture evaluation using origami-style folding confirmed good flexibility and tear resistance, supporting its function as an edible paper. Overall, the product retained substantial nutrients and could be folded into origami shapes without losing its structural integrity. This innovation has the potential to increase vegetable intake in children and improve dietary quality during early childhood.

Keywords: Antioxidants, Children, Edible paper, Nutrition, Vegetables

INTRODUCTION

Indonesia has very low vegetable consumption across various age groups, including that of school-aged children. A common problem is insufficient fiber intake, including vegetable consumption, which does not meet the body's needs (Ningrum et al., 2024). According to data from the Indonesian Health Risk Survey (Kemenkes RI, 2019), 95.55% of the population aged ≥5 years consumes insufficient amounts of vegetables and fruits (Ministry of Health, 2020). Low vegetable intake among children is often caused by a lack of interest in vegetables. This is influenced by several factors, such as taste, appearance, and eating habits that have been formed since early childhood (Maulani and Retnoningsih, 2025). To overcome this, innovations in vegetable processing are needed in forms that are more appealing to children while retaining the important components in the vegetables. One such innovation is the processing of vegetables into edible origami paper, known as edible folding paper sheets.

Origami paper was chosen because origami provides meaningful benefits for early childhood development by improving fine motor skills, hand–eye coordination, and concentration (Anisa et al., 2021; Hosotani, 2025). It also strengthens cognitive abilities through the introduction of shape recognition, symmetry, and spatial awareness (Anisa et al., 2021; Dwipadmini, 2025).

Edible paper sheets are generally formulated using starch and its derivatives (Karnwal et al., 2025; Utami Hatmi et al., 2020, 2020; Wibowo et al., 2019). Therefore, the use of vegetables and fruits as primary materials for edible film sheets is relatively novel. The ingredients used are vegetables with striking colors, similar to origami paper in general, but with good nutrient content, including green spinach, purple cabbage, and yellow pumpkin. However, the components in vegetables are very sensitive to heat processing (Ho and Redan, 2022; Lee et al.,

DOI: http://dx.doi.org/10.35941/jtaf.8.5.2026.26708.7-11

2017); therefore, materials that can reduce the effects of heat are needed, such as fiber. The sugar structure in fiber undergoes dehydration during the heating process (Werner et al., 2014), which then undergoes a hardening structural change (Sikora et al., 2022), protecting from heat penetration (Fliri et al., 2024), but on the other hand, it still provides flexible characteristics and does not easily break the product (Wulandari and Saidi, 2019).

The purpose of this study was to restructure vegetables into foldable sheets, Edible Folding Paper, and apply them to origami shapes while maintaining or minimizing the loss of nutritional components in vegetables. It is hoped that edible folding paper products can help increase vegetable intake in children through play and learning.

MATERIALS AND METHODE

Material

Each vegetable exhibits a distinct dominant nutrient or functional compound profile. Green spinach is particularly rich in iron (Fe), pumpkins contain elevated Vitamin C levels, and purple cabbage is known for its high anthocyanin content, which is a potent antioxidant. The vegetables used in this study were fresh and obtained from local markets in Salatiga City. For the binding agent (agar), a commercially available, unflavored product variant was used.

Experiment Design and Analysis

The research design used an experimental research method. The process stages and binder concentrations used in the formulation were the same. Variations were made in the types of vegetables used. Product analysis includes macronutrient analysis (proximate analysis) and micronutrient analysis, which varies depending on the type of vegetable used: Fe analysis for spinach products, antioxidant analysis for purple cabbage products, and vitamin C analysis for pumpkin products.

All analyses were performed in triplicate, and the data are reported as the mean ± standard deviation. The analytical outcomes were benchmarked against the macro- and micronutrient compositions of spinach, pumpkin, and purple cabbage using the Indonesian Food Composition Table (TKPI) as the reference standard.

Research Procedure

The research stages included material preparation, vegetable puree drying, and product analysis.

Material Preparation (Puree Process)

Vegetables (500 g) were sorted, washed thoroughly, and blanched in hot water before immersion in cold water for approximately 10-15 min. The mixture was then pureed using a blender, and 15 g of a fiber-based binding agent (agar) was added. The binding agent (agar) was evenly mixed with the vegetable puree.

Drying

The vegetable puree was spread on a baking sheet to a thickness of approximately 1 millimeter (1 mm). The samples were dried at a temperature of ±75 °C or at low heat if using a microwave dryer for approximately 75 min. The target product moisture content is below 14%, with the indicator being that the product surface is dry and not sticky.

Analytical Procedure

Macronutrient Analysis (Proximate Analysis)

Moisture Content (AOAC, 2023)

The porcelain dish was cleaned and dried in an oven for 15 min at 105°C, then cooled in a desiccator for 30 min and weighed. Weigh 5 g of the sample and place it in a porcelain dish of known weight. The samples were then dried in an oven at 102-105 °C for 6 h.

Ash Analysis (BSN, 2009)

The porcelain ash dish was cleaned and dried in an oven at 105 °C for 30 min, cooled in a desiccator for 30 min, and weighed. Five grams of the sample was placed in a porcelain ash dish. The dish was placed in an oven at 105 °C for 30 min. Subsequently, it was incinerated in a furnace at 600 °C for 7 h until a gray color was formed. The sample was then cooled in a desiccator for 30 min and weighed. The treatment was repeated until a constant weight was achieved.

Carbohydrate Analysis (FAO, 2003)

For the "carbohydrates by difference" method, 100% was subtracted from the total content of other nutrients.

% Carbohydrate = 100% - (Moisture content + Ash+ Protein + fat)

Fat Analysis (Stefanie et al., 2023)

Fat content analysis was performed using the direct extraction method with a Soxhlet apparatus. The procedure began with drying the extraction flask in an oven, cooling it in a desiccator, and weighing it until its weight was constant. A total of 100 g of the sample was ground and wrapped in a filter paper to form a thimble. The sample was placed in a Soxhlet apparatus with hexane solvent added until 1.5 cycles (150 min) of extraction occurred, which took approximately 6 h until the solvent returned through the siphon into a clear fat flask. The extraction results from the fat flask were separated between hexane and extracted fat using a rotary evaporator at a temperature of 69 °C and a speed of 50 rpm. The fat separated by hexane was then heated in an oven at 105 °C for 1 h. The fat flask was cooled in a desiccator for 15 min and weighed to obtain the weight of the extracted fat. The content can be calculated using the following equation:

$$\% \text{ Fat} = \frac{W_3 - W_2}{W_1} \times 100\%$$

Where are:
W_1 : Sample mass (g)
W_2 : weight of empty Fat flask (g)
W_3 : weight of empty Fat flask + Extracted fat (g)

Protein Analysis (Syahfitri et al., 2025)

Protein content analysis was performed using the Semimikro Kjeldahl method. The sample was crushed and weighed to 1 g and then placed in a Kjeldahl flask. To facilitate the destruction process, 2 g of the mixed catalyst and 25 mL of concentrated H_2SO_4 were added and stirred until homogeneous. The solution was heated to boiling until the color changed to clear green, and then cooled. After cooling, the destruction solution was diluted with 100 ml of distilled water. A total of 5 ml of this diluted solution was pipetted into a distillation flask. Subsequently, 30% NaOH was added until the solution became alkaline, followed by the addition of several boiling stones. Distill the solution for 5-10 minutes. The distillate was collected in an Erlenmeyer flask containing 10 mL of 2% boric acid solution and several drops of a mixed indicator (methylene red + bromothymol blue). Subsequently, the distillate was titrated with 0.02 N hydrochloric acid standard solution, and the titration was terminated when the color changed from blue to orange. The same procedure was repeated to prepare a blank sample as a control. The concentration was calculated using the following formula:

$$\% \text{ N} = \frac{(v_1 - v_2) \times \text{N HCl} \times 0.014 \times \text{fk} \times \text{fp} \times 100}{\text{sample}}$$

Where are :
v_1 : Volume of HCl sample
v_2 : Volume of HCl blanko
N HCl : Normality of HCl Solution
0.014 : Conversion factor of nitrogen to protein
fk : Protein conversion factor
fp : Dilution factor

Fiber Analysis (Hardiyanti and Nisah, 2021)

The determination of crude fiber uses the gravimetric method, which is an analytical technique used to measure the amount of fiber in the sample. The sample was ground and weighed at 2-4 g and weighed on a constant filter paper. The sample was then dissolved in 15 mL of 96% ethanol and stirred for 30 s. The sample was allowed to rest for 15 min and then filtered using a Buchner funnel, and the remaining sediment was rinsed with 45 mL of 96% ethanol. Subsequently, the filter paper was dried in an oven at 105 °C until dry. The sample was then placed in a desiccator for 15 min, and the filter paper with the residue was weighed again. The residue was dissolved in 50 mL of 1.25% H_2SO_4. The sample solution was heated in a water bath at 60 °C for 30 min, and 50 mL of 3.35% NaOH was added, followed by heating again in a water bath. The sample was prepared for filtering using a stabilized filter paper. The residue on each filter paper was washed with 25 mL of hot 25% H_2SO_4, 25 mL of hot distilled water, and 25 mL of 96% ethanol. The residue was placed in a dish and dried again in an oven at 105 °C. The mixture was cooled in a desiccator for 15 min. The constant weight was calculated. Crude fiber analysis was performed using the following formula:

DOI: http://dx.doi.org/10.35941/jtaf.8.5.2026.26708.7-11

$$\text{Crude Fiber(\%)}=\frac{\text{(W. filter paper+sample)-W. filter paper}}{\text{W. Sample}}\times 100\%$$

Where are :
W Filter paper + sample: weight of dried filter paper + sample (g)
W Filter paper : Weight of filter paper (g)
W sample : Weight of sample (g)

Micronutrient Analysis

Vitamin C (Fitriana and Fitri, 2020)

Sample preparation

To 10.00 g of the sample, 100 mL of 3% (w/v) metaphosphoric acid was added. The mixture was homogenized until uniform, and then centrifuged to obtain a clear extract.

Titration process

The sample (10 mL) was added to a 100 ml measuring flask, distilled water was added, and the mixture was homogenized. Then, 10 mL of the sample was taken, 2 mL of amylum solution was added, and the mixture was titrated with 0.01 N I_2 solution until the color changed to blue violet.

Antioxidant activity (%inhibition)

The sample extract (1 mL) was added to 1 ml of DPPH solution and incubated in the dark for approximately 30 min. Absorbance was measured at 517 nm. Compare with the blank. The inhibition percentage was calculated using the following formula:

$$\%\ \text{Inhibition}=\frac{\text{Abs. Control-Abs. Sample}}{\text{Abs. Control}}\times 100\%$$

Fe Content Analysis (Putri et al., 2020)

Then, 10 mL of concentrated HNO_3 was added to 1 g of the sample, and the mixture was heated until fully dissolved. The mixture was allowed to cool, and distilled water was added to a volume of 100 ml. The absorbance of the standard solution was measured from the lowest to the highest concentration at a wavelength of 248.3 nm. Measurements are performed using the test sample. If the test sample reading is outside the calibration range, the test sample should be diluted and measured again.

Fold Test (Widiastuti et al., 2024)

The test was performed by folding the product repeatedly at the same spot until it broke at the fold. The number of folds that can be made before it breaks is counted. If the product can be folded more than 100 times before breaking, it has excellent fold resistance.

RESULT AND DISCUSSION

Macronutrient Analysis (Proximate)

The edible folding paper vegetable sheets in Figure 1 visually show that the original colors of fresh vegetables are still well expressed, including the green of spinach, purple of cabbage, and yellow of pumpkin. This is an initial indication that the nutrient content in vegetables is still largely protected. The addition of agar as a binding agent not only provides flexibility to the texture of the Edible Paper product but also protects the color and bioactive components of the vegetables during the drying process (Santoso, 2024; Ziedan et al., 2018). The average weight per product for each variant was approximately 12 g per sheet, with sheet dimensions of 15 cm × 20 cm.

To ensure the content of Edible Paper products, micro-and macronutrient content analyses were conducted on the products. The results of the macronutrient analysis in the form of proximate tests for each Edible Folding Paper product are presented in Table 1.

Figure 1. The edible folding paper of vegetables

Table 1. Proximate Analysis of Edible Folding Paper

Parameter	Spinach	Yellow Pumpkins	Purple Cabbage
Ash	9.91 ±0.33	9.81±0.33	8.70±0.21
Moisture content	13.09±0.41	10.64 ±0.55	7.35±0.44
N-Total of Protein	6.85 ±0.18	7.46 ± 0.18	3.68±0.17
Fat	0.32±0.02	0.34±0.01	1.69±0.02
Carbohydrate	34.75 ±0.44	39.78±1.00	43.26±0.96
Fiber	35.07 ±0.67	31.97±0.38	36.32±0.51

Note: Data are presented as percentages per 100 g of sample.

The analytical results for each variable across all sample types demonstrated excellent standard deviation values, which did not exceed 10% of the mean. Accordingly, the data distribution was considered stable and reliable.

The moisture content of the Edible Paper products listed in Table 1, based on proximate analysis, ranged from 7 to 13%. This value is in line with the initial target of below 14% (Akther et al., 2023). The ash content of the product was generally higher than that of similar dried vegetable products (Ambo et al., 2023; Ashfaq, 2018; Surya et al., 2021). This may be influenced by the high proportion of the binding agent (agar) added to the formulation, which was 15%. At this range, it can affect the high ash content produced (FAO, 2003). The N-total protein content in the product ranges from 3-6%. This value was lower than that of dried spinach (Waseem et al., 2021), dried pumpkin (Bemfeito et al., 2020), and dried purple cabbage (Zhang et al., 2021). This is likely influenced by the amount of binding agent (agar) added, which is a hydrocolloid that increases the total non-protein solids in the product (Waseem et al., 2021). The fiber content of Edible Paper products range from 31-36%. The high fiber content is influenced by the addition of a binding agent (agar), which is a hydrocolloid source of polysaccharides that is recognized as fiber (Savitri, 2019).

The results of the Proximate Analysis were converted into the content of each product sheet, as shown in Table 2.

Table 2. Nutrient and micronutrient of the product sheet

Materials	Nutrient (g/12 g)			Micronutrient		
	Protein	Carbohydrate	Fiber	Vit C (mg / g)	Fe (mg / 100 g)	Antioxidant (%)
Spinach	0.822	4.17	4.21		3.31	
Yellow Pumpkins	0.895	4.77	3.84	0.53		
Purple Cabbage	0.442	5.19	4.36			56.21%

Notes: Nutritional requirements for children (g/day) of protein, carbohydrate, and fiber are 25, 220, and 20 for 4-6 y.o.; and 40, 250, and 23 for 7-9 y.o. (Permenkes No.28 Tahun 2019).

As shown in Tables 3 and 4, the nutrient content in one sheet of the product can only meet 2-3% of protein intake requirements, ±2% for carbohydrate intake, and 18-21% for fiber intake. This means that Edible Folding Paper cannot be used as a primary source of nutrition; other primary sources are still needed. Several sheets must be consumed to meet the daily intake requirements. However, Edible Folding Paper can be used as a product to help meet daily fiber intake.

Micronutrient Analysis

The analysis of iron content (Fe) in spinach Edible Folding Paper products resulted in 3.31 mg/100 g. Based on the recommended daily mineral intake according to the Minister of Health Regulation No. 28 (Kemenkes RI, 2020), children aged 4-12 years require an iron intake of 8-10 mg/day.

DOI: http://dx.doi.org/10.35941/jtaf.8.5.2026.26708.7-11

Each sheet weighed 12 g, and the iron content per sheet was 0.397 g. Additional intake from other food sources is necessary to meet the recommended intakes.

In Edible Paper products made from purple cabbage, the analysis of antioxidant activity as an expression of the anthocyanin content in cabbage showed an inhibition value of 56.21%. This value indicates that the product has a high potential as a food source with high antioxidant activity.

The vitamin C content of the Edible Folding Paper yellow pumpkin products was 0.53 mg/g. Therefore, 12 g or 1 sheet of Edible Folding Paper contains 6.36 mg of vitamin C. This value, when referring to the recommended daily vitamin intake per person for the 4-12 age range according to Permenkes no.28 (Kemenkes, 2020), is 45–50 mg/day. This indicates that the Edible Folding Paper of Yellow Pumpkin has great potential as a complementary/additional source of vitamin C.

Fold Test

Edible Folding Paper products were tested for folding to determine their capabilities and durability as folding papers. The test results are listed in Table 3.

Table 3. Total fold of edible folding paper

Materials	Total fold
Spinach	201±5
Yellow Pumkins	205±6
Purple Cabbage	198±4

Note: Data (mean±SD) were obtained from three replicates.

The test results in Table 3 show that all variants of the Edible Folding Paper products have a folding value above 100, indicating that all product variants have excellent folding capabilities (Widiastuti et al., 2024). This data is further reinforced by the product application test results in Figure 2, where all product variants can be shaped into several types of origami.

The fiber content analysis of all product variants showed consistently high values, exceeding 5% per 100 g, thereby classifying the formulations as fiber-rich products. In edible films, high fiber content typically increases stiffness and tensile strength while reducing extensibility and foldability due to restricted polymer chain mobility (Müller et al., 2009). However, our folding tests revealed excellent foldability for all variants. This unexpected flexibility may be explained by the presence of naturally occurring sugars and other low-molecular-weight constituents in the fruit and vegetable ingredients, which act as internal plasticizers, increasing molecular mobility and counteracting the stiffening effect of the fiber fraction. Similar phenomena have been reported in edible film studies, where the addition of plasticizers, such as glycerol or sugar, markedly enhanced flexibility and elongation at break and improved foldability and mechanical performance despite the presence of reinforcing components (Janowicz et al., 2023; Wu et al., 2025).

Figure 2. Edible folding paper applied in the form of origami

This study is limited by its laboratory-scale processing, restricted batch replication, and the absence of sensory evaluation, shelf-life testing, and child-acceptability assessment. Future research should optimize the formulation and drying parameters to improve nutrient retention, explore larger sheet formats to enhance nutrient delivery, and expand color variants using additional vegetables. Sensory testing and real-use trials with children, as well as shelf-life and microbiological safety evaluations, are strongly recommended to support product refinement and broader implementation.

CONCLUSION

The Edible Folding Paper demonstrated a meaningful nutrient profile for children aged 4–10 years, contributing 2–3% of the daily macronutrient needs per sheet and up to 20% of the daily fiber requirements. The pumpkin variant delivered the highest vitamin C contribution (14%), the purple cabbage variant showed strong antioxidant activity (~50% inhibition), and spinach contributed approximately 5% of the daily intake. All formulations exhibited excellent foldability and structural integrity during origami application, supporting their potential as both nutritious products and interactive learning media.

ACKNOWLEDGMENTS

The authors express their sincere appreciation for the financial support provided by the Directorate of Research and Community Service of Satya Wacana Christian University under contract no. 132/SPK-PP/RIK/08/2025, which enabled the completion of this study.

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