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RESEARCH ARTICLE

# Effect of autoclaving-time treatment on physicochemical, antioxidant properties and shelf-life prediction of Indonesian instant cassava leaves porridge

**Ade Chandra Iwansyah[1]*, Dewi Desnilasari[2], Enny Sholichah[3], Wawan Agustina[3], Hazrulrizawati Abd Hamid[4]**

*[1]Research Center for Food Technology and Processing, National Research and Innovation Agency, Yogyakarta, Indonesia, [2]Research Center for Applied Microbiology, National Research and Innovation Agency, Indonesia, Bogor, West Java, Indonesia, [3]Research Center for Appropriate Technology, National Research and Innovation Agency, Subang, West Java, Indonesia, [4]Faculty of Industrial Sciences and Technology, Universiti Malaysia Pahang, Gambang, Kuantan, Malaysia*

## ABSTRACT

This study investigated the effects of autoclaving-time treatment (0, 3, 5, and 7 minutes) on the physicochemical and antioxidant properties of Indonesian instant cassava porridge or rowe luwa. The shelf-life prediction of rowe luwa porridge also was determined. The rowe luwa porridge contained nutrition, such as moisture content (4.41%), fat (7.69%), protein (11.77%), carbohydrates (67.15%), energy (384.89 kcal), zinc (2.73 mg/100g), calcium (174.48 mg/100 g), and iron (2.9 mg/100 g). Furthermore, rowe luwa has a complete composition of essential amino acids the body needs. The rehydration time and pH of rowe luwa porridge showed the highest value on autoclaving for 3 minutes (AU3) and decreased with increasing autoclaving time ($p < 0.05$). The rehydration time was in line with the solubility and WAI values. The rowe luwa porridge with three minutes autoclave time treatment (AU3) also had the highest total phenolic contents (TP) and antioxidant activity (AOA), followed by AU0 > AU5> and AU7 ($p < 0.05$). Based on the FTIR spectra, the antioxidant of this instant cassava porridge might be linked to phenolic chemicals. The shelf-life prediction of rowe luwa porridge with aluma packaging is 61 days or two months.

**Keywords:** autoclaving-time treatment; antioxidant; cassava leaves porridge; *Moringa oleifera*; shelf-life prediction

## INTRODUCTION

Indonesia has various types of traditional foods, one of which is a porridge made from cassava leaves and rice. Porridge mixed with cassava leaves and rice is a traditional food from the East Nusa Tenggara region. The porridge is known as "ro'o luwa" or "rowe luwa." ro'o or rowe means leaf, and luwa means cassava (Astarini, 2018; Iwansyah et al., 2022).

As the main raw material used to manufacture cassava leaf porridge, cassava leaves have very good nutritional content. The nutritional content in cassava leaves includes crude protein, fiber, vitamins, minerals, and beta-carotene (Awoyinka et al., 1995; Wobeto et al., 2007; Oni et al., 2011). Cassava leaves (*Manihot esculenta* Crantz) contain (in dry weight) 29.3–32.24% crude protein, 4.6–6.4% ash, 26.9–39% dietary fiber, and 29.7 mg/g tannin (Awoyinka et al., 1995). Cassava leaves grown at different cultivars and planting ages contain vitamin C 43.64–181.90 mg/100g, beta carotene 50.36–137.38 mg/100g, neutral dietary fiber (21.60-29.62 mg/100g), and mineral content such as Fe, Zn, Mn, Cu, S, Mg, Ca, P, and K (Wobeto et al., 2007). In this research, we added moringa extract, known for its high nutritional profile and can improve health. Hence, it is being used to alleviate malnutrition in malnourished kids and people. It can be used as a source of nutrition to prevent stunting, especially in the East Nusa Tenggara Region (Iwansyah et al., 2022).

Using cassava leaves as a source of nutrition can be done by developing products that combine local traditions or

***Corresponding author:**
Ade Chandra Iwansyah, Research Center for Food Technology and Processing, National Research and Innovation Agency, Yogyakarta, Indonesia. **E-mail:** chandra.iwansyah@gmail.com

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habits with existing technology. One of the efforts is to develop rowe luwa porridge as a traditional food typical of NTT into instant porridge products. Making instant rowe luwa porridge is intended to provide added value to the product to meet consumers' needs and desires (Indriati et al., 2021). In addition, to extend shelf life and facilitate the distribution process and service.

One method to extend the product's shelf life was a thermal process by autoclave treatment. Thermal treatment has been primarily used in food manufacturing; however, heat destroys microorganisms and nutrition (Chysirichote and Phongpipatpong, 2015). Research by Chysirichote & Phongpipatpong (2015) using autoclave for sterilization rice porridge only reports the physical effect but not the nutrition of the porridge. It is crucial to test the physicochemical and antioxidant properties of the product after the autoclave process to ensure that the product has good quality. It helps identify the level of good quality and safe for consumption (Carter, 2021). The study aimed to obtain information about the effect of autoclaving-time treatment on the physicochemical characteristics, antioxidant content, and shelf-life of instant cassava leaf porridge.

## MATERIAL AND METHODS

### Materials

Fresh cassava (*Manihot esculenta* Crantz) leaves, rice, garlic, shallots, salt, salam leaves, lemongrass, ginger, sugar, coconut milk which were bought from traditional market in Subang, West Java, Indonesia), and *Moringa oleifera* leaves from Kelorina SME's in Pagaden, Subang, West Java, Indonesia). The chemicals used include sucrose ($C_{12}H_{22}O_{11}$), $C_6H_{14}$, $CuSO_4.5H_2O$, $H_2SO4$, $(NH4)_2HPO_4$, HCl, $Na_2CO_3$, $KIO_3$, and NaOH (Sigma-Aldrich, Singapore). The other chemicals and materials such as citric acid, distilled water, starch, phenolphthalein 1 percent, luff schoorl solution, and Pb-acetate were available in the laboratory stock room of Indonesia's National Research and Innovation. All of the reagents were of analytical grade.

### Preparation samples

Four to six-month old young cassava leaves (7.25%), moringa leaves (2.63%), rice flour (3.99%), bay leaves (0.22%), shallots (1.16%), garlic (0.36%), lemongrass (2.17%), ginger (1.76%), salt (0.48%), sugar (0.74%), coconut milk (1.49%), and water (78.75%) were weighed. The fresh cassava leaves were washed and blanched at 70 °C for 3 minutes. Then, crush cassava leaves by adding shallots, garlic, and ginger according to the composition using a chopper (Philips HD 3115, China) at a speed of 21,080 - 28,520 rpm until the ingredients are crushed and homogeneous. Mix moringa extract rice with cassava leaves, then cook with the addition of bay leaves, lemongrass, salt, sugar, coconut milk, and water at 75 °C for 40 - 45 minutes, until gelatinized. The drying process of porridge is based on rice cassava leaves with the addition of moringa leaves extract, using a cabinet dryer at 50 °C for 14 hours. The dried slurry milling using a blender at a speed of 21,080 - 28,520 rpm for one minute or until the size of the material becomes small or powder (Fig. 1). The samples were collected and then given a cooling autoclave-time treatment.

### Experimental design

The experimental design used in the study was a completely randomized design (CRD), with autoclaving-time treatment, namely: 0 minutes (AU0), 3 minutes (AU3), 5 minutes (AU5), and 7 minutes (AU7). It was repeated three times, with a total of 12 experimental units. Our research was conducted from January until December 2021.

### Procedure analysis

#### *Nutrition composition*

The nutrition composition of Indonesian instant cassava leaves porridge, or rowe luwa was determined (Horwitz and Latimer 2005). The profile of amino acid was determined using high-performance liquid chromatography (HPLC) (Landry and Delhaye, 1992; Solichah et al., 2021). Protein content was analyzed using a semi-Kjeldahl tool, fat content using the Weibull method, moisture content using the direct heating method, ash, and carbohydrates were calculated. The total energy of the sample was determined using the at water factor, i.e., 1 g of carbohydrates is 4 kcal, 1 g of lipids is 9 kcal, and 1 g of protein is 4 kcal.

#### *Physical properties*

The physical properties which analyze were rehiydartion (Zielinska and Markowski, 2012), Color analysis (Indriati et al., 2021), swelling power (Leach et al., 1959), solubility (Kainuma, K., Odat, T., Cuzuki, 1967), water absorption indeks (Yağci and Göğüş, 2008).

#### *Antioxidant properties*

The total phenolic content, flavonoid content, and antioxidant capacity of instant cassava leaf porridge were investigated by Iwansyah et al., (2020) using the 1,1-diphenyl-

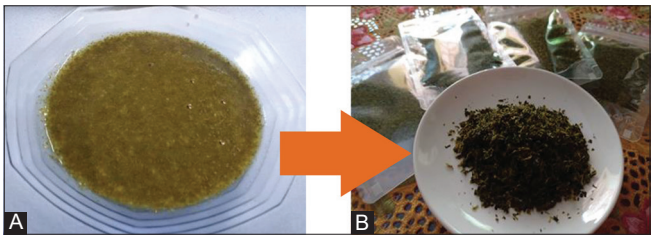


**Fig 1.** Rowe Luwa fresh (A) and instant (B)

2-picrylhydrazyl (DPPH) assay. The amount of phenol in each gram of sample was measured in milligrams of gallic acid equivalents (GAE). The flavonoid amount in each sample gram was measured in mg of quercetin equivalents (QE). Using a UV-Vis Spectrophotometer, antioxidant capacity was measured as the percentage of absorbance at 517 nm inhibited (Shimadzu UV-1900, Tokyo, Japan).

### *Fourier transform infra red (FTIR)*

Instant cassava leaf porridge was analyzed using FTIR. The samples were directly put into a Bruker A7.8 FTIR spectroscope with a scan range of 450 to 4000 $cm^{-1}$, and each sample was scanned three times (Iwansyah et al., 2020).

### *Accelerated shelf-life testing: critical moisture content approach*

The porridge sample was weighed (2 g) and kept in a desiccator with a saturated salt solution in a porcelain pot (stored in calcium oxide for 2 weeks). The saturated salt solution used was NaOH, LiCl, $MgCl_2$, $Mg(NO_3)_2$, $NaNO_3$, NaCl, KCl with a relative humidity range of 32.4-90% (Table 1). The sample was weighed simultaneously every day until the weight remained consistent (Kusnandar et al., 2010).

The slope of the isothermal curve is obtained by describing the relationship between the equilibrium moisture content of the sample and the water activity ($a_w$) of the storage space (a jar containing saturated salt) with modifications (Wijaya and Nocianitri, 2008). The equation models employed were guggenheim-Anderson-de Boer (GAB), Hasley, Chen-Clayton, Henderson, Caurie, and Oswin (Bell and Labuza, 2000). After the data was assessed, the best model was chosen based on the mean relative determination (MRD). To determine the shelf-life of the porridge, the model with the lowest MRD value was designated a fit model.

Estimating shelf-life of Indonesian instant cassava leaves porridge was calculated with equation 4 (Bell and Labuza, 2000). The product's shelf-life was assessed at 30 °C with a humidity of 80% in the aluma packaged. A month unit that is assumed one month was 30 days determined Shelf-life.,

$$\theta = \frac{ln\ \frac{(Me - Mi)}{(Me - Mc)}}{\frac{k}{x}\left(\frac{A}{Ws}\right)\frac{Po}{b}} \quad (4)$$

Where is the estimated shelf life (days)(θ)(initial moisture content of the product (g $H_2O$/g solid) (Mi); product balance moisture content (g $H_2O$/g solid) (Me); critical moisture content of the product (g $H_2O$/g solids) (Mc); vapor permeability of packaged water (g/$m^2$·day.mmHg) (k/x); surface area of the packaging ($m^2$) (A); dry weight of packaged product (g solids) (Ws); saturated vapor pressure (mmHg) (Po); slope of the isothermic sorption curve (b).

### Statistical and Analysis Data

Data are presented in mean ± standard deviation (sd). Analysis of variance (ANOVA), with a confidence interval of 95% and normality of the data, were measured. The difference between each treatment determines using Duncan's comparison test. The program R-Statistic 4.03 for Windows is used for data processing. Linear regression analysis determines the model relationship between the water activity and equilibrium moisture content. Labuza equation estimates the shelf-life of Indonesian instant cassava leaves porridge (De Mendiburu, 2019).

## RESULTS AND DISCUSSION

### Nutritional composition of instant porridge

Rowe luwa is one of the local dishes of Southwest Sumba. Rowe Luwa Brei, rowe means leaf and luwa means cassava. Rowe luwa is a green pulp made by grinding cassava leaves with rice. It can be developed for local food innovation. The following was a picture of the rowe luwa porridge (Fig. 1).

The nutritional composition of Indonesian instant cassava leaves porridge per 100 g is shown in Table 2. Indonesian

**Table 1: Type of salts solution an RH, Aw, and Me**

| Type of salts | RH (%) | $A_w$ | Me BK (g $H_2O$/g solid) |
|---|---|---|---|
| NaOH | 6.8 | 0.068 | 0.031 |
| LiCl | 9.6 | 0.096 | 0.037 |
| $MgCl_2$ | 31.6 | 0.316 | 0.060 |
| $Mg(NO_3)_2$ | 50.2 | 0.502 | 0.106 |
| $NaNO_3$ | 62.3 | 0.623 | 0.172 |
| NaCl | 71.2 | 0.712 | 0.258 |
| KCl | 79.9 | 0.799 | 0.385 |

**Table 2: Nutritional composition of Indonesian instant cassava leaves porridge per 100 g**

| Parameter | Unit | Values |
|---|---|---|
| Carbohydrates | % | 68.45±1.21 |
| Energy | kcal/100g | 384.89±0.37 |
| Moisture | % | 4.41±0.02 |
| Fat | % | 7.69±0.05 |
| Ash | % | 8.98±0.05 |
| Protein | % | 11.77±0.07 |
| Mineral | | |
| Zinc | mg/100g | 2.73±0.02 |
| Calcium | mg/100g | 174.48±1.09 |
| Iodium | µg/100g | 335.98±3.30 |
| Iron | mg/100g | 2.90±0.03 |

Data presented as mean±sd (n=3)

instant cassava leaves porridge contains moisture content (4.41%), fat (7.69%), protein (11.77%), carbohydrates (67.15%), and energy (384.89 kcal). Furthermore, mineral zinc (2.73 mg/100g), calcium (174.48 mg/100 g), iodine (335.97 mg/100 g) and iron (2.9 mg/100 g) were also contained in instant porridge (Table 2). This result was lower than the mineral-supplemented instant pulse porridge powder reported by Subedi et al. (2022), where instant pulse porridge contains carbohydrates (66.67%), protein (20.15%), fat (15%), ash (4.40%), energy (458kcal), iron (4.89 mg/100 g) and zinc (3.95 mg/100 g).

The results at Table 2 are in line with the Indonesian standards (SNI 01-7111.1-2005) for fat level of instant flour companion meal (6–15 g/100 g) and protein content (8–22 g/100 g). Table 2 reveals that one serving of instant cassava leaf pulp or rowe luwa includes 100% iron, 100% zinc, and 70% of the RDA for babies aged 6–12 months. Calcium and zinc are very important in preventing stunting.

Calcium deficiency has detrimental effects on immunity and bone health. Calcium is an essential micronutrient for linear growth early (Gupta et al., 2018). As a result, insufficient calcium intake in toddlers impairs the basic structure of the bones, leading to stunting or other growth problems

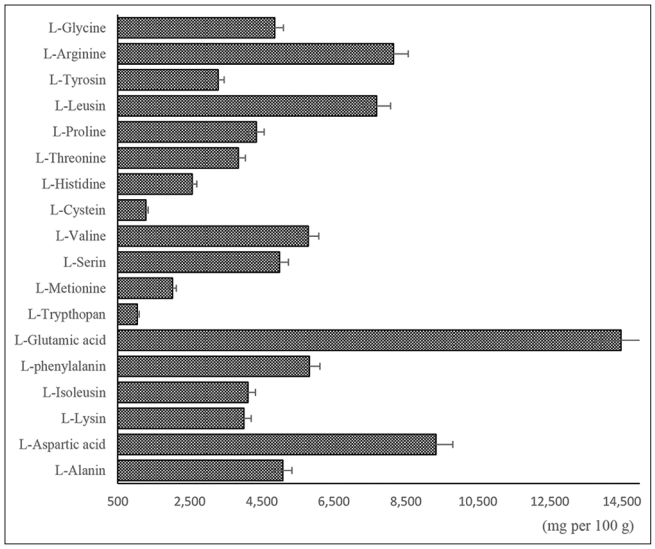


**Fig 2.** Amino acids profile of instant cassava leaves porridge. Data presented as mean±sd (n=3).

(Khatun et al., 2012; Fatima et al., 2014). The essential amino acids are amino acids that the body can't synthesize. Amino acid profiles of Indonesian instant cassava leaves porridge as shown in Fig. 2. Fig 2. indicated that the cassava instant porridge was higher in the total non-essential amino acids than the total essential amino acids and the total arginine and leucine were higher than the other essential amino acids. The limiting amino acid of cassava instant porridge was tryptophan, where the limiting amino acid is known as the acid that has a low protein. The reduction in tryptophan is due to processing methods such as cooking (Ejigui et al., 2007).

## Physical properties

Autoclaving-time treatment affected the reducing pH of rowe luwa porridge (Table 3). This porridge consisted of coconut milk which is rich in fat or oil. Autoclaving treatment at 121°C generated fat oxidation, which produced free fatty acid (FFA) (Wulandari et al., 2017). FFA caused the porridge more acid than the porridge without autoclaving treatment.

The effects of autoclaving-time treatment on rehydration time, solubility, swelling power, and water absorption index (WAI) are shown in Table 3. The rehydration time of rowe luwa porridge showed the highest value on autoclaving for 3 minutes and decreased with increasing autoclaving time. The rehydration time of instant porridge was related to the ability to absorb and bind water molecules. Therefore, the rehydration time was in line with the solubility and WAI values. The autoclaving process involved heating and pressure, which caused changes in the structure of the rice starch. Heating and autoclaving processes could cause depolymerization of starch molecules a decrease in molecular weight, impacting water holding capacity and solubility (Raungrusmee and Anal, 2019). The increasing solubility and WAI also could be due to breaking branches in amylopectin, which could increase water holding capacity (Babu and Parimalavalli, 2013).

The amylopectin concentration and amylose-amylopectin distribution greatly impacted starch swelling power. The rice starch ingredient strongly affected the swelling power of instant rowe luwa porridge, where autoclaving

**Table 3: Physical properties of instant cassava leaves porridge with autoclave-time treatments**

| Sample | $_{P}$H | rehydration time (minute) | Color | | | Solubility (%) | Swelling Power | WAI (%) |
|---|---|---|---|---|---|---|---|---|
| | | | *L* | *a** | *b** | | | |
| AU0 | 5.73±0.00$^{a}$ | 1.20±0.00$^{d}$ | 67.856 | -1.090 | -1.692 | 27.25±10.64$^{ab}$ | 0.08±0.04 | 5.71 |
| AU3 | 5.45±0.00$^{bc}$ | 5.30±0.14$^{a}$ | 68.669 | -1.261 | -2.204 | 24.59±2.93$^{cd}$ | 0.07±0.00 | 5.65 |
| AU5 | 5.41±0.00$^{bc}$ | 2.00±0.35$^{b}$ | 68.173 | -1.149 | -1.890 | 27.80±1.68$^{abc}$ | 0.08±0.01 | 6.04 |
| AU7 | 5.38±0.00$^{d}$ | 1.70±0.00$^{c}$ | 68.234 | -1.182 | -1.783 | 28.61±7.32$^{ab}$ | 0.09±0.03 | 6.34 |

Data are presented as mean±sd (n=3). AU0: autoclave 0 minutes treatment, AU3: autoclave 3 minutes treatment, AU5: autoclave 5 minutes treatment, AU7: autoclave 7 minutes treatment. WAI: water absorption index. a>b > c>d, the values following distinct upper-case letters in the same column are substantially different according to the Duncan's test ($p < 0.05$)

for 3 minutes was not enough to damage the crystalline structure of rice starch. The swelling power value was the lowest. The lowest value of solubility and swelling power at autoclaving for 3 minutes could be caused by the formation of resistant starch, which is insoluble in water (Babu and Parimalavalli, 2013).

The color of rowe luwa pulp was produced by cassava leaves and moringa leaves (Ali and Akhtar, 2014). The color change of instant rowe luwa porridge occurred in the 3-minute autoclaving process for L, a, and b values. Where instant porridge was lighter, it tended to be greener and slightly bluish.

### Antioxidant properties

Antioxidant properties consist of phenol levels, flavonoid levels and antioxidant activity. Antioxidant activity using the 1,1-diphenyl-2-picrylhydrazyl (DPPH), ABTS, FRAP and ORAC assays are applied for many fruit and vegetable matrices, such as orange (Giuffrè et al., 2017), yellow mangosteen (Arazo et al., 2011), goldenberry (Iwansyah et al., 2022), soybean, pornace, olive, and palm (Giuffrè et al., 2018). Table 4 shows the antioxidant characteristics of instant cassava leaf porridge. The results revealed that autoclave-time treatment had a substantial impact on the total phenolic contents (TP) of instant cassava leaf porridge ($p < 0.05$). The instant cassava leaves porridge with three minutes autoclave time treatment (AU3) had the highest TP followed by AU0 > AU5> and AU7 (see Table 4). Furthermore, the total flavonoid contents (TF) of instant cassava leaves porridge also affected by autoclave-time treatment ($p < 0.05$) (Table 4). The autoclave-time treatment reduces the total flavonoid content in instant cassava leaves porridge with increasing time.

Flavonoids are plants' polyphenolic molecules in response to microbial infections and antioxidants. The presence of considerable phenolic and flavonoid components in instant cassava leaf porridge was discovered in this investigation. This finding supports the findings of (Malla et al., 2021), who found that finger millet porridge supplemented with *Moringa oleifera* leaf powder had considerably greater protein, total phenolic content, and -carotene. Polyphenols, especially flavonoids and phenolic acids, are abundant in the dried leaves of *Moringa oleifera* (Leone et al., 2015; Iwansyah et al., 2022).

**Table 4: Antioxidant properties of instant cassava leaves porridge with autoclave-time treatments**

| Samples | TP (mg GAE/g) | TF (mg QE/g) | Ratio TF/ TP | AOA (mg AAE/100g) |
|---|---|---|---|---|
| AU0 (0 minutes) | 108.01±0.00$^{b}$ | 9.63±0.00$^{a}$ | 0.09 | 169.11±0.00$^{b}$ |
| AU3 (3 minutes) | 116.64±0.00$^{a}$ | 7.71±0.00$^{d}$ | 0.07 | 174.27±0.00$^{a}$ |
| AU5 (5 minutes) | 102.70±0.00$^{c}$ | 9.05±0.00$^{b}$ | 0.09 | 143.11±0.00$^{c}$ |
| AU7 (7 minutes) | 99.26±0.00$^{d}$ | 8.71±0.00$^{c}$ | 0.09 | 174.50±0.00$^{a}$ |

Data are presented as mean±sd (n=3). GAE: gallic acid equivalent, QE: quercetin equivalent, AOA: antioxidant activity, AAE: ascorbic acid equivalent. TP: total phenolic contents, TF: total flavonoid contents, AOA: antioxidant activity. a>b > c>d, Values followed different upper-case letters in the same column are significantly different according to the Duncan's test ($p < 0.05$)

Regarding the antioxidant activity parameter, the results showed that the autoclave-time treatment significantly affected the antioxidant activity (AOA) of the instant cassava leaves porridge ($p < 0.05$). The autoclaving-time treatment reduces antioxidant activities in instant cassava leaves porridge with increasing time (Table 4). This finding agrees with (Le et al., 2022), who found that autoclave treatment reduced antioxidant capabilities in green-kernel black bean flours in terms of DPPH free radical scavenging capacity and ferric reducing antioxidant power (FRAP).

The high temperature can damage the cellular contents in plant samples, causing phenolic chemicals to be released more quickly (Arslan and Özcan, 2010). The antioxidant activity of phenolic compounds is the highest. The scavenging action of extracts is not restricted to their phenolic concentration, according to Yusoff and Iwansyah (2011). Other antioxidants, such as secondary metabolites such as volatile oils, carotenoids, and vitamins, might have a role.

### Fourier transform infra red (FTIR)

The FTIR spectra indicated that the peaks shifted to some amount with autoclave-time treatment, based on functional group analysis using FTIR. Chemical linkages generated between the functional groups contained in instant cassava leaf porridge were mostly responsible for variations in peak values. The peaks observed 2917.54 - 2847.58 $cm^{-1}$ correspond to alkane. A similar peak appearing at 2931.66 $cm^{-1}$ was also reported by Shanmugavel et al. (Shanmugavel et al., 2018), indicating the existence of an alkane group (C-H). The other hand, the peaks appeared at around 23.22.92 – 2304.40 $cm^{-1}$, and 999.94 – 748.93 $cm^{-1}$ correspond to X=Y and X=Y=Z and olefine, ether, pheynilderivative, respectively. The peaks at around 1748.76-1744.76 $cm^{-1}$ correspond to ketone, lactone, ester, anhydride and carboxylic acid. C = O bonds of ether, ester, or phenol are represented by the peaks at 1069.90 - 1053.44 $cm^{-1}$ (see Table 5).

All samples showed a same pattern of FTIR spectra including peaks between 3500-4000 $cm^{-1}$ indicated amina groups which could be sourced from protein of moringa leaf. Hydroxyl group was observed as a broad peak at 3000-3500 $cm^{-1}$, it might be obtained from starch as the ingredient of the instant porridge. The peaks were appeared at 2800-2900 $cm^{-1}$, 1730 $cm^{-1}$, and 1000-1100 $cm^{-1}$ correspond to C-H, C=O and C-O, respectively. These

**Table 5: The functional group of instant cassava leaves porridges with autoclave-time treatment**

| Wavelength number (/cm) | Wavelength References | Peak form | Type of compounds | notes |
|---|---|---|---|---|
| 2917.54-2847.58 | 3000-2800 | Sharp | Alkane | All samples |
| 2322.92-2304.40 | 2400-2000 | Wide | X=Y and X=Y = Z | AU3, AU5, AU7 |
| 1748.76-1744.76 | 1780-1660 | Sharp | Ketone, lactone, ester, anhydride, carboxylic acid | All samples |
| 1069.90-1053.44 | 1300-1000 | Sharp | Ester, ether, alcohol and phenol | All samples |
| 999.94-985.54 | 1000-800 | Sharp | Olefine, ether | All samples |
| 851.80-748.93 | 1000-650 | Wide | Pheynilderivative, olefine | AU3, AU5, AU7 |

Source: Skoog *et al.* (1998)

peaks produced by chemical compound that composed the material such as amino acid, starch, polyphenol and others. Fig. 2 reveals increasing autoclaving time treatment reducing the peaks intensity. This result could indicated the longer autoclaving time degrade the composition of instant porridge.

### Estimation shelf-life of instan rowe luwa porridge: critical moisture approach

The shelf life of Rowe Luwa products is determined based on critical moisture parameters. One of the selected samples was an instant cassava pulp sample with a 3 minutes autoclave (AU3). The product's shelf life is assessed at 30 °C with 80% humidity in aluma packaging.

The instant cassava leaves porridge has an initial moisture content (Mo) of 0.0274 g $H_2O$/g solids, with a weight of solids per package of instant porridge is 19.47 g. The reference critical moisture content is the maximum standard moisture content for instant slurry, which is 0.0450 g $H_2O$/g solids. Equilibrium moisture content measurements were carried out by storing instant cassava leaves products at several environmental RH conditions.

MRD values derived from the Guggenheim-Anderson-DE Boer (GAB) equation, BET, Oswin, Smith, Henderson, Hasley, and Peleg are 13.26, 19.17, 19.10, 33.79, 29.57, 8.12, and 1.16, respectively. The equilibrium moisture content is acceptable using the Peleg equation based on the least MRD value. For Indonesian quick cassava leaf porridge, the slope of the sorption isotherm (b) is 0.1279, based on regions that pass the initial moisture content (Mo) on the water sorption curves model (see Fig. 3).

The curve is in line with the research from Wijaya et al, (Wijaya et al. 2014) on instant ledok products, which are Type II curves. This type II curve is the most common in food products, especially dry ones. The shape of the curve in this type is caused by a combination of colligative, capillary, and surface water interactions (Wijaya and Nocianitri 2008). Data and calculation results using aluma for rowe luwa porridge shelf-life are shown in table 6, giving an estimated shelf life of 61 days or 2 months.

**Table 6: Indonesian instant cassava leaves porridge shelf-life calculations based on the critical moisture content approach**

| Parameter | Aluma |
|---|---|
| Initial moisture content (g $H_2O$/g solid) (Mo) | 0.0274 |
| Critial moisture content (g $H_2O$/g solid) (Mc) | 0.0450 |
| Equilibrium moisture content (g $H_2O$/g solid) (Me) | 0.3974 |
| $(M_e-M_o)/(M_e-M_c)$ | 1.0499 |
| ln $(M_e-M_o)/(M_e-M_c)$ | 0.0487 |
| Slope sorption isotherm curve | 0.1279 |
| Packaging permeability (g/m²/day/mmHg.) | 0.0034 |
| Packaging area (m²) | 0.0180 |
| Solid weight per package (g solid) | 19.45 |
| Saturated vapor pressure at 30 °C (mmHg) | 31.88 |
| Shelf-life (days) | 61 |
| Shelf-life (month) | 2.0 |

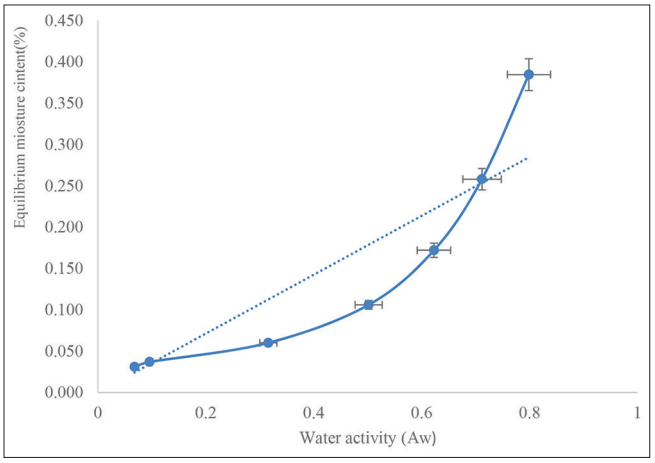


**Fig 3.** The accuracy of Peleg modeling of Indonesian instant cassava leaves porridge. Data presented as mean ± standard error (S.E)

## CONCLUSION

In conclusion, the rowe luwa porridge has good nutrition and complete composition of essential amino acids needed by the body. The rehydration time and pH of rowe luwa porridge showed the highest value on autoclaving for 3 minutes (AU3) and decreased with increasing autoclaving time ($p < 0.05$). The rehydration time was in line with the solubility and WAI values. The rowe luwa porridge with three minutes autoclave time treatment (AU3) also had the highest total phenolic contents (TP) and antioxidant activity (AOA), followed by AU0 > AU5> and AU7 ($p < 0.05$). The FTIR spectra showed phenolic compounds might

be associated with the antioxidant of this instant cassava porridge. The shelf-life prediction of rowe luwa porridge with aluma packaging is 61 days or two months.

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### Author's contribution

Ade Chandra Iwansyah: Conceptualization, Data curation, Writing-Original draft preparation. Dewi Desnilasari, Wawan Agustina, Enny Sholichah: Conceptualization, Methodology, Investigation. Hazrulrizawati Abd Hamid and Ade Chandra Iwansyah: Writing-Reviewing and Editing.

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