

## Extraction and Characterization of Inulin from Taro Beneng (*Xanthosoma undipes* K. Koch)

(Pengekstrakan dan Pencirian Inulin daripada Keladi Beneng (*Xanthosoma undipes* K. Koch))

ERIS, F.R.<sup>1,2,\*</sup>, PAMELA, V.Y.<sup>1</sup>, KUSUMASARI, S.<sup>1</sup>, MEINDRAWAN, B.<sup>1</sup> & SARI, A.K.<sup>1</sup>

<sup>1</sup>Department of Food Technology, Faculty of Agriculture, University of Sultan Ageng Tirtayasa, Banten, 42111, Indonesia

<sup>2</sup>Center of Excellence Local Food Innovation, University of Sultan Ageng Tirtayasa, Banten, 42111, Indonesia

Received: 7 January 2025/Accepted: 11 December 2025

### ABSTRACT

Inulin acts as a low-calorie dietary fiber and as a prebiotic that can stimulate the growth of probiotic bacteria in the intestines of humans. The development on the production of inulin continues to be carried out through research. This study aimed to determine the optimal acetone concentration and precipitation time for extracting high-purity inulin from Beneng taro (*Xanthosoma undipes* K. Koch) and to evaluate the physicochemical characteristics of the extract. A factorial randomized block design was applied with three acetone concentrations (20%, 45%, and 70%) and three precipitation times (12, 18, and 24 h). The extraction yield, water content, whiteness degree, solubility, inulin content, and functional groups (FTIR) were analyzed. The results showed that acetone concentration and precipitation time significantly affected yield, water content, and solubility ( $p < 0.05$ ), while their interaction significantly influenced inulin content. The highest average yield (10.30%) was obtained with 70% acetone, the lowest average water content (4.97%) with 70% acetone, and the highest average solubility (34.58%) with a 24 h precipitation time. The greatest inulin content (53.05%) resulted from the combination of 20% acetone with 12 h precipitation, showing 97.20% spectral similarity to commercial inulin. The optimal extraction condition was 20% acetone for 12 h, producing inulin with high purity, moderate yield (9.16%), and favorable physicochemical properties. These findings demonstrate Beneng taro's potential as a local inulin source for functional food applications

Keywords: Acetone; Beneng taro; extraction; inulin

### ABSTRAK

Inulin bertindak sebagai serat diet rendah kalori dan sebagai prebiotik yang boleh merangsang pertumbuhan bakteria probiotik dalam usus manusia. Pembangunan penghasilan inulin terus dijalankan melalui penyelidikan. Kajian ini bertujuan untuk menentukan kepekatan aseton optimum dan masa pemendakan untuk mengekstrak inulin berketulenan tinggi daripada keladi Beneng (*Xanthosoma undipes* K. Koch) dan untuk menilai ciri fizikokimia ekstrak tersebut. Reka bentuk blok rawak faktorial telah digunakan dengan tiga kepekatan aseton (20%, 45% dan 70%) dan tiga masa pemendakan (12, 18 dan 24 jam). Hasil pengekstrakan, kandungan air, darjah keputihan, keterlarutan, kandungan inulin dan kumpulan berfungsi (FTIR) telah dianalisis. Keputusan menunjukkan bahawa kepekatan aseton dan masa pemendakan mempengaruhi hasil, kandungan air dan keterlarutan dengan ketara ( $p < 0.05$ ), manakala interaksi mereka mempengaruhi kandungan inulin dengan ketara. Purata hasil tertinggi (10.30%) diperoleh dengan 70% aseton, purata kandungan air terendah (4.97%) dengan 70% aseton dan purata keterlarutan tertinggi (34.58%) dengan masa pemendakan 24 jam. Kandungan inulin terbesar (53.05%) terhasil daripada gabungan 20% aseton dengan pemendakan 12 jam, menunjukkan persamaan spektrum 97.20% dengan inulin komersial. Keadaan pengekstrakan optimum ialah 20% aseton selama 12 jam, menghasilkan inulin dengan ketulenan tinggi, hasil sederhana (9.16%) dan sifat fizikokimia yang baik. Penemuan ini menunjukkan potensi keladi Beneng sebagai sumber inulin tempatan untuk aplikasi makanan berfungsi.

Kata kunci: Aseton; keladi Beneng; pengekstrakan; inulin

### INTRODUCTION

Inulin -a naturally occurring storage polysaccharide composed predominantly of fructose units linked by  $\beta$ -(2-1) glycosidic bonds- is widely recognized for its

role as a soluble dietary fiber and prebiotic with valuable functional and health-promoting properties (Zhang et al. 2024). Globally, inulin is most commonly extracted from chicory roots, Jerusalem artichoke, agave, dahlia, garlic,

and various other tubers, with numerous studies devoted to refining extraction, purification, and characterization techniques for industrial and research applications (Petkova, Ognyanov & Denev 2014).

In Indonesia, particularly in Banten Province, Beneng taro (*Xanthosoma undipes* K. Koch) has emerged as a locally abundant and promising source of inulin. This tuber presents a notably high total carbohydrate content (84.9%) and significant starch levels (75.6%), suggesting a strong potential for inulin extraction from this indigenous resource (Eris et al. 2022). Despite its potential, inulin production in Indonesia remains underdeveloped, highlighting the importance of exploring Beneng taro as a viable local raw material for inulin manufacturing.

Effective separation of inulin from plant extracts typically involves the use of organic solvents such as ethanol or acetone. Acetone is another widely applied solvent for inulin precipitation because of its strong ability to reduce solubility of high-molecular-weight fructans, thereby promoting selective recovery of inulin with minimal impurities (Liu et al. 2011). Compare with ethanol and isopropanol, acetone often produces higher inulin purity due to its lower dielectric constant and stronger dehydrating effect, which enhances the aggregation and sedimentation of inulin polymers (Petkova, Ognyanov & Denev 2014).

In our previous study, an 8-h precipitation method was used to extract inulin from Beneng Taro by using 50% ethanol as solvent produced 19.64% yield, 32.35% solubility, and 66.20% purity (Eris et al. 2024). On contrary, the extraction process using ethanol precipitation may lead to loss of inulin due to solubility factors, so the recovery is not always optimal. Study conducted by Yudhistira and Siswanti (2020) on the extraction of inulin from yellow sweet potato tubers, a 12-h ethanol precipitation resulted in 6.72% yield, and 5.75 solubility. However, the usage of ethanol that not only precipitates inulin but can also co-precipitate other compounds (sugars, polysaccharides), reduce the purity of the extracted inulin. Based on the limitation of ethanol, our study tries to propose acetone as solvent to extract inulin from Beneng Taro. As reported by Ku et al. (2003), when comparing to ethanol, acetone showed markedly higher recovery rates (up to 96% vs 84%). Moreover, at high concentrations, acetone effectively precipitates both high- and intermediate-DP fructans, whereas ethanol mainly captures high-DP fructans. This makes acetone a strong choice for extracting a more complete spectrum of inulin fractions (Huynh et al. 2008).

Based on this explanation, research on the concentration of acetone solvent and precipitation time are necessary to meet the demand for inulin in the community. The purpose of this study was to determine the best concentration of acetone solvent and precipitation time as well as the interaction that occurs in the extraction process on the physical (precipitation time) and chemical (solvent type) characteristics of inulin of taro beneng (IBT).

## MATERIALS AND METHODS

### MATERIALS

The material used in this research were 9-12 month old beneng taro obtained from Juhut Village, Pandeglang, Banten, acetone (Merck), commercial inulin powder (Orfati), distilled water, vaseline, DNS reagent, standard glucose, sodium -alium-artat, petroleum ether, sodium hydroxide, hydrochloric acid, and phenolphthalein indicator.

### INULIN EXTRACTION METHOD

The extraction of inulin from taro beneng was performed using a modified method from Eris et al. (2024). The cleaned taro beneng was first reduced in size to chips and then soaked in 10% NaCl solution for 2 h (3:4). After that, the sample was crushed using a Philips blender with the addition of water at a ratio of 1:2 (w/v) and heated at 90 °C for 30 min using a hot plate-stirrer (Thermoscientific). The filtrate obtained by filtering the blended taro using a filter cloth was then extracted with varied acetone concentrations of, 20%, 45%, and 70% (these three concentrations came from the trial and error process). The amount of acetone used was 40% of the obtained filtrate. Subsequently, the filtrate was frozen at a temperature of -4 °C for 12 h, 18 h, and 24 h. The frozen filtrate was then thawed for 2 h, and centrifuged for 15 min at 1500 rpm using a PCL-025 centrifuge. The resulting precipitate was dried using an AST105E cabinet dryer (Asiatec) for 24 h. The dried inulin sample was then crushed and sieved through an 80 mesh sieve. In this procedure, fractional precipitation with acetone was employed to selectively recover inulin while minimizing the co-precipitation of other polysaccharides, thereby ensuring a purer final product.

### METHODS OF ANALYSIS

#### *Inulin yield*

The IBT extraction yield was carried out using the method according to AOAC (2007). The calculation of inulin yield obtained from the extraction process was based on the initial weight/volume of the tubers (a) and the weight of inulin produced during the extraction process (extract or concentrate) (b) using the following formula:

$$\text{Yield (\%)} = \frac{b}{a} \times 100$$

#### *Water content*

The water content of IBT was analyzed using the AOAC method (1990). The empty dish was weighed and kept constant (a). A sample of 2 g was placed into a pre-constantized aluminum dish (b). Then (b) was placed into the UN55 oven (Mettmert) at 105 °C for 3-5 h, then cooled in a desiccator, and weighed. This treatment was repeated until a constant weight was achieved (c).

$$\text{Water content (\%)} = \frac{b}{c-a} \times 100\%$$

#### *Degree of whiteness*

The whiteness degree of IBT was analyzed using the modified Diaz, Garcia and Dini (2022) method. The prepared sample was placed in a container and the whiteness degree was measured using a HunterLab Chromameter MiniScan EZ 4500L. The color notation system used is the Hunter system, consisting of L (brightness), a (redness), and b (yellowish). The lowest L\* value is 0, indicating blackness, while the highest is 100, indicating whiteness. Negative a\* values indicate green, while positive values indicate red, while negative b\* values indicate blue, and positive values indicate yellow. The degree of whiteness is determined using the following formula:

$$W = 100 - ((100-L^*)^2 + a^{*2} + b^{*2})^{0.5}$$

#### *Solubility analysis*

The solubility analysis of IBT was conducted by modifying the method of Hersoelistyorini, Dewi and Kumoro (2015). A sample of 0.1 gram was weighed and then placed in 10 mL of distilled water at a temperature of 100 °C and stirred for 30 min. The supernatant and resulting paste were separated using a centrifuge at a speed of 3000 rpm for 20 min. The supernatant was taken (a), then dried in an oven until constant weight and the dry residue was recorded (b). The solubility calculation can be done using the following formula:

$$\text{Solubility (\%)} = \frac{a}{b} \times 100\%$$

#### *Analysis of inulin content*

The inulin content was determined based on the difference between the amount of reducing sugars of inulin after hydrolysis and the amount of reducing sugars of inulin before hydrolysis, then multiplied by a constant (0.995). The measurement of reducing sugars was carried out using the dinitrolicyclic acid (DNS) method (Saengkanuk et al. 2011).

The standard curve was determined using a standard glucose solution with a concentration of 2 mg/mL. This was done by weighing 0.05 g of glucose and dissolving it in 25 mL of distilled water. Then, glucose solutions with concentrations of 0.2, 0.4, 0.6, 0.8, 1.0, and 1.2 were prepared by adding 5 mL of the glucose solution to each respective tube. The mixture was then vortexed or homogenized. After adding 3 mL of DNS, the mixture was heated for 5 min and left to cool for 30 min at room temperature. The absorbance was measured using a UV-Vis spectrophotometer, Genesys 150 (Thermoscientific), at a wavelength of 540 nm.

A sample of 0.05 g was weighed and added to 100 mL of distilled water, then stirred for 1 h. Afterward, the sample was hydrolyzed; 2.5 mL of 0.5 N HCl was added to a 10 mL sample solution inside a closed reaction tube and heated with a Bio-Lab water bath for 1 h at 100 °C. The

solution was then cooled and 3 drops of phenolphthalein (PP) were added, followed by 10% NaOH until it became neutral, indicated by a pink color change.

To measure the amount of reducing sugar before hydrolysis, 1 mL of the sample was added to a closed reaction tube, followed by 2 mL of distilled water and 3 mL of DNS reagent. Meanwhile, to measure the amount of reducing sugar in the hydrolyzed inulin sample, 1 mL of the sample was added to a closed reaction tube, followed by 4 mL of distilled water and 3 mL of DNS reagent. The mixture was heated for 5 min and allowed to cool to room temperature for 30 min. The absorbance was measured using a spectrophotometer at a wavelength of 540 nm, with distilled water used as the blank. The concentration of reducing sugar in the sample solution was then calculated using the equation obtained from the standard curve. After determining the concentration of reducing sugar in the sample solution (value x), the percentage of reducing sugar in the sample was calculated using the following formula:

$$\text{Reducing sugar (mg/L)} = \frac{X \times V \times FP}{W}$$

where X is the Value obtained from the absorbance and standard curve; FP is the Dilution factor; W is the Weight of the sample (g); and V is the Volume (L).

The inulin content was determined using the following formula:

$$I = k (F2 - F1) \times 100\%$$

where I is the Inulin content; K is the Inulin constant (0.995); F1 is the Reducing sugar content before hydrolysis (mg/L); and F2 is the Reducing sugar content after hydrolysis (mg/L).

#### FUNCTIONAL GROUP ANALYSIS

Functional group analysis was determined based on the method described by Kusmiyati, Wahyuningsih and Widodo (2018) using Fourier Transformed Infrared (FT-IR) spectra of IBT. The spectra were recorded using an IR spectrophotometer, specifically the platinum ATR Alpha II model manufactured by Bruker in Germany. Prior to measurement, the sample (5.0 mg) was homogenized with KBr, and the resulting mixture was pressed to form tablets. The spectra were collected over the range of 500-12500 cm<sup>-1</sup> with a resolution of 4 cm<sup>-1</sup>.

#### STATISTICAL ANALYSIS

All experiments were conducted in triplicate and the data were analyzed using one-way analysis of variance (ANOVA) using IBM SPSS Statistic 25 dan DSAAT. Treatments with significant differences were separated using Duncan's multiple range test at 95% confidence level (P<0,05). All data were presented as mean + standard deviation.

## RESULTS AND DISCUSSION

## YIELD

The yield value was determined to identify the percentage of remaining material after the extraction process and the effectiveness of the resulting extraction process. The concentration of acetone (Table 1) had a significant effect on the yield of beneng tuber inulin ( $p < 0.05$ ) and had no significant effect on the settling time ( $p > 0.05$ ). Table 1 shows that the highest average yield of inulin (10.30%) was obtained as 70% acetone concentration. It was because the higher the concentration of acetone, the more compounds will be extracted, resulting in a higher yield (Zhang et al. 2024). This result was lower than other studies, which reported yields of 39.61% for Jerusalem artichoke inulin (Alabadi & Abood 2020). Similar findings have been reported in recent studies, where acetone was found to be more effective than ethanol or isopropanol in precipitating high molecular weight fructans due to its stronger dehydrating properties and lower dielectric constant (Liu et al. 2011).

In terms of settling time, the highest average yield was obtained at 12 h (9.98%) compared to 18 h (9.06%) and 24 h (9.32%). This suggests that prolonged settling does not consistently improved yield and may even lead to plateau or slight decline. Such a trend can be explained by Fick's diffusion law, which states that once equilibrium is reached, additional time does not significantly increase the precipitation efficiency (Sarkar et al. 2020).

The interaction between acetone concentration and settling time also showed interesting trends. For instance, the combination of 70% acetone and 18 h of settling gave a relatively high yield (11.30%), but extending the settling to 24 h reduced the yield (8.39%). This suggests that excessive settling may cause partial redissolution, aggregation, or degradation of inulin molecules, which needs to be optimized (Dangre et al. 2025).

## WATER CONTENT

Both solvent concentration and settling time significantly affected ( $p < 0.05$ ) the water content of IBT (Table 2). The average water content decrease with increasing acetone concentration, from 6.56% at 20% acetone to 5.35% at 45% acetone, and further to 4.97% at 70% acetone. This indicates that acetone plays a dominant role in reducing residual water, as its strong dehydrating effect promotes more efficient precipitation of inulin and limits water retention in the product (Petkova et al. 2025). Low water content is beneficial because it improves product stability, reduces microbial susceptibility, and extends shelf life, consistent with previous reports on functional carbohydrate powders (Jiang et al. 2025). According to Ida Ayu Maria, I Nengah and I Dewa Gede (2018), the purity of the solvent affects the difficulty in evaporating the water contained in the extract. In addition, water has a higher boiling point of 100 °C (Firmansyah 2018), while acetone has a boiling point of 56.53 °C (Fachrudin 2016), making acetone easier to evaporate than water.

TABLE 1. The response of acetone solvent concentration and settling time on yield in the extraction of inulin taro beneng (*Xanthosoma undipes*)

Concentration (%)	Settling time (h)			Average (%)
	12 (F <sub>1</sub> )	18 (F <sub>2</sub> )	24 (F <sub>3</sub> )	
20 (S <sub>1</sub> )	9.16±0.11 <sup>BC</sup>	7.72±0.29 <sup>s</sup>	8.73±0.48 <sup>BCD</sup>	8.54 <sup>b</sup>
45 (S <sub>2</sub> )	9.57±0.02 <sup>B</sup>	8.16±0.10 <sup>CDs</sup>	10.84±0.93 <sup>A</sup>	9.52 <sup>ab</sup>
70 (S <sub>3</sub> )	11.22±1.66 <sup>A</sup>	11.30±0.64 <sup>A</sup>	8.39±0.20 <sup>BCD</sup>	10.30 <sup>a</sup>
Average (%)	9.98 <sup>a</sup>	9.06 <sup>a</sup>	9.32 <sup>a</sup>	9.45

Remark: Numbers followed by the same uppercase/lowercase letters in row or column indicate no significant difference based on the DMRT test at 5% level

TABLE 2. The response of acetone solvent concentration and settling time on water content in inulin taro Beneng extraction (*Xanthosoma undipes*)

Concentration (%)	Settling time (h)			Average (%)
	12 (F <sub>1</sub> )	18 (F <sub>2</sub> )	24 (F <sub>3</sub> )	
20 (S <sub>1</sub> )	5.53±0.32 <sup>C</sup>	7.93±0.28 <sup>A</sup>	6.22±0.01 <sup>B</sup>	6.56 <sup>a</sup>
45 (S <sub>2</sub> )	5.49±0.09 <sup>C</sup>	5.53±0.04 <sup>C</sup>	5.02±0.08 <sup>s</sup>	5.35 <sup>b</sup>
70 (S <sub>3</sub> )	5.44±0.02 <sup>C</sup>	5.23±0.03 <sup>CD</sup>	4.25±0.07 <sup>E</sup>	4.97 <sup>c</sup>
Average (%)	5.49 <sup>b</sup>	6.23 <sup>a</sup>	5.16 <sup>c</sup>	5.63

The numbers followed by the same uppercase/lowercase letters in row or column indicate no significant difference based on DMRT test at the 5% level

In contrast, settling time showed a weaker influence on water content. The highest value was recorded at 18 h (6.23%), whereas 12 h (5.49%) and 24 h (5.16%) resulted in lower values. This pattern suggests a temporary rehydration during intermediate settling, followed by further dehydration as precipitation progressed (Tai et al. 2020). According to Hariyadi, Erlia N. and Amien (2018), lysis can occur due to the osmotic pressure imbalance between the environment and inside the cell, resulting in water transfer from the environment into the cell, causing the cell to expand and eventually rupture. However, at higher acetone concentrations (45-70%), water content remained consistently low regardless of time, confirming that solvent strength is the key factor in determining final moisture levels (Rubel et al. 2018).

#### WHITENESS DEGREES

The statistical analysis showed that the concentration of acetone and the settling time did not have a significant effect ( $p>0.05$ ) on the whiteness degree of IBT. Table 3 shows that the whiteness degree of inulin extracted from beneng taro remained relatively stable across different acetone concentrations and settling times, with value ranging between 94.24% and 94.86%. Similar to the study conducted by Hilman, Harmayani and Cahyanto (2018), the whiteness degree of inulin from sweet potato tubers was not significantly different in all treatments. However, the whiteness degree of IBT was higher (94.78) than the previous studies on inulin from sweet potato tubers, which were 92.69 (Hilman, Harmayani & Cahyanto 2018) and 81.39 (Ciptaningrum 2015). The use of acetone in the extraction process can decrease the content of color pigments in the material (Lailani et al. 2020) because acetone does not have the ability to maintain a constant pH of the solution. Neither acetone concentration nor settling time had a significant effect, indicating that acetone precipitation efficiently preserved the natural whiteness of inulin. Similar studies have shown that organic solvent aid in removing pigments and impurities, resulting in highly pure, white carbohydrate powders (Yeoh et al. 2025).

Minor differences among treatments suggest that solvent strength is more important than time in maintaining

whiteness. The consistently high whiteness degree ( $>94\%$ ) indicates minimal interference from colored compounds, aligning with findings in other inulin extractions where whiteness was mainly determined by solvent type rather than precipitation duration (Lima et al. 2021; Niu et al. 2018).

#### SOLUBILITY

The concentration of acetone, the settling time, and their interaction significantly affected ( $p<0.05$ ) the solubility of IBT. The solubility of inulin was highest at 20% acetone (31.80%) and decrease with higher acetone concentrations, suggesting that strong solvent effects may lead to aggregation and reduced dispersibility. In contrast, settling time showed a clearer influence, with solubility improving at 24 h (34.58%) compared to shorter times, indicating that prolonged precipitation may favor the formation of water-dispersible inulin structures. The solubility level of inulin is also influenced by solvent's degree of polymerization. According to Das Kirtania and Maity (2021), as a degree of polymerization (DP) increase, inulin becomes progressively less soluble in water due to stronger molecular associations and increased chain rigidity.

The 24 h settling time had the highest inulin is solubility (34.58%), while the 18-h settling time had the lowest solubility (26.02%). This indicates that the longer settling time promotes more complete precipitation while molecular integrity, which improves solubility upon dehydration. As the settling period increases, there is more opportunity for dissolved inulin molecules to diffuse out of the tuber matrix into the solvent, resulting in increased overall solubility (Zhang et al. 2022). However, it is important to note that if settling or extraction time is extended too long, there is a risk of inulin hydrolysis or degradation, which can decrease the final yield and alter the inulin's solubility (Sağcan et al. 2024).

#### INULIN CONTENT

Inulin content can be determined by calculating the fructose content in the sample. The fructose content is measured using the 3,4-dinitrosalicylic acid (DNS) method (Saengkanuk et

TABLE 3. Response of acetone solvent concentration and settling time to whiteness degree in inulin taro beneng extraction (*Xanthosoma undipes*)

Concentration (%)	Settling time (h)			Average (%)
	12 (F <sub>1</sub> )	18 (F <sub>2</sub> )	24 (F <sub>3</sub> )	
20 (S <sub>1</sub> )	94.68±0.10	94.72±0.09	94.65±0.35	94.68
45 (S <sub>2</sub> )	94.24±0.57	94.73±0.11	94.58±0.20	94.52
70 (S <sub>3</sub> )	94.86±0.38	94.80±0.04	94.68±0.23	94.78
Average (%)	94.60	94.75	94.64	94.66

The numbers followed by the same uppercase/lowercase letters in row or column indicate no significant difference based on DMRT test at the 5% level

al. 2011). Table 5 shows the inulin content in taro Beneng (*Xanthosoma undipes*). Acetone concentration and settling time did not have a significant effect ( $p > 0.05$ ) on IBT, but their interaction had a significant effect ( $p < 0.05$ ). The highest inulin content was obtained from the interaction between 20% acetone concentration and 12-h settling time at 53.05%, lower than the commercial Orafit inulin content of 88.48%. However, this result was still higher than the inulin content of mangrove apple at 1.94% (Wibawanti et al. 2021), chicory root inulin at 4.9% (El-Kholy, Aamer & Ali 2020) and *Dioscorea alata* inulin at 7.67% (Hilman, Harmayani & Cahyanto 2018). According to Saengkanuk et al. (2011), the high level of inulin content is determined by the amount of free fructose present in extracted inulin.

In this study, the interaction between acetone concentration and settling time has an effect on the hydrolysis process, which undergoes several changes in the structure of fructose and glucose. In addition, the role of inulase enzyme in the hydrolysis of IBT can support the hydrolysis process. Enzymes act as catalysts in the hydrolysis process of 1→4-glycosidic bonds, thereby increasing the inulin content. The interaction between acetone concentration and settling time further highlighted distinct patterns. At 20% acetone for 12 h, the highest value of 53.05% was obtained, while the lowest was found at 45% acetone for 24 h (38.71%). Interestingly, 70% acetone produced a relatively high value at 24 h (51.27%), which may be attributed to enhanced removal of non-inulin impurities during longer precipitation (Shi 2016). Such variations demonstrate that optimal precipitation requires balancing solvent strength and settling duration to maximize yield while minimizing structural degradation.

#### FUNCTIONAL GROUPS OF INULIN COMPOUND

The next step was FTIR analysis, with samples of 20% acetone concentration and 12 h settling time, and 70% acetone concentration and 24 h settling time tested. The best treatment combination was determined based on the results of the analysis of the highest inulin content and solubility. This characterization analysis used an FTIR spectrophotometer to confirm that the extracted compound was indeed inulin, based on the functional groups and spectral shape of the sample inulin compared to commercial inulin (Figure 2).

The results showed that the FTIR spectra of commercial inulin and IBT exhibited similar patterns (Figure 1) with 97.20% similarity percentage (Figure 2). The FTIR spectrum of IBT demonstrated absorption bands at wavelengths of 3300, 2940.98, 2885.35, 1644.38, 1416.53, 1336.21, 1242.97, 1211.54, 1150.76, 1077.94, 1015.95, 930.34, 861.11, 766.26, 708.34, and 572.61. Recent research demonstrates characteristic absorption bands associated with inulin's molecular features: a broad band around 3350–3400  $\text{cm}^{-1}$  related to O-H stretching vibrations; peaks near 2920–2930  $\text{cm}^{-1}$  attributed to C-H stretching; and distinctive bands at approximately

1010–1150  $\text{cm}^{-1}$  corresponding to C-O-C and C-O-H stretching vibrations in the fructofuranose units. The presence of a carbonyl group is sometimes detected around 1640–1650  $\text{cm}^{-1}$ , indicating interactions with water or structural components. Studies analyzing inulin extracted from various botanical sources such as yacon, dahlia, and chicory report consistent FTIR profiles signaling high purity and similarity across different origins (Alexander et al. 2023). The presence of fructose with B-(2→1) glycosidic bonds in both commercial inulin and IBT was indicated by a peak at approximately 930.34  $\text{cm}^{-1}$ . This result was also reported by Kusmiyati, Wahyuningsih and Widodo (2018) in their research on inulin extraction from dahlia tubers. The distinction between commercial inulin and inulin extracted from Beneng tubers appears in the 800–600  $\text{cm}^{-1}$  region, which suggests the presence of additional carbohydrates. This variation is likely associated with structural characteristics and the influence of compounds such as glucose, sucrose, and mannan, as well as differences in purification conditions (Eris et al. 2024). These results confirmed that the obtained powder was not entirely composed of pure inulin.

The FT-IR spectrum of inulin extracted using 70% acetone concentration with a precipitation time of 24 h is presented in Figure 1. The spectrum exhibited medium absorption bands in the range of 950–1225  $\text{cm}^{-1}$ , corresponding to C-H groups, observed at 1077.14, 1149.23, and 1206.16  $\text{cm}^{-1}$ . Weak bands were also detected in the region of 1000–1300  $\text{cm}^{-1}$ , indicating the presence of C-O stretching vibrations at 1077.14, 1149.23, and 1206.16  $\text{cm}^{-1}$ . Furthermore, a band was observed in the region of 1445–1485  $\text{cm}^{-1}$ , which is characteristic of -CH<sub>2</sub> bonds, specifically at 1454.00  $\text{cm}^{-1}$ . A strong band appeared in the range of 1410–1470  $\text{cm}^{-1}$ , indicating the presence of C=O bonds at 1415.96  $\text{cm}^{-1}$ . In addition, weak to strong absorption bands were detected between 2400–3400  $\text{cm}^{-1}$ , corresponding to O-H stretching vibrations, particularly at 2929.70 and 2897.04  $\text{cm}^{-1}$ . A distinct band was also present at around 3500  $\text{cm}^{-1}$ , corresponding to N-H stretching at 3300.26  $\text{cm}^{-1}$ .

The FT-IR spectra indicated that all absorption bands of *Xanthosoma undipes* (Beneng taro) inulin samples and commercial inulin were within the characteristic functional group absorption regions, confirming the presence of inulin in the extracted samples. According to Melanie et al. (2015), hydroxyl groups (O-H) represent the primary functional group characteristic of inulin. Moreover, the carbohydrate nature of inulin was further confirmed by the presence of carbonyl (C=O) absorption bands. To further evaluate the degree of similarity with commercial inulin, a *Quick Compare* analysis was performed.

Based on the FT-IR spectral analysis, the *Quick Compare* results indicated 20% acetone concentration and 12 h settling time have a similarity with commercial inulin, as shown in the Figure 2. The spectrum of the commercial inulin standard (Orafit) exhibited the highest similarity of 97.20%. In comparison, inulin extracted using 70%

TABLE 4. Response of acetone solvent concentration and settling time on solubility in the extraction of inulin taro beneng (*Xanthosoma undipes*)

Concentration (%)	Settling time (h)			Average (%)
	12 (F <sub>1</sub> )	18 (F <sub>2</sub> )	24 (F <sub>3</sub> )	
20 (S <sub>1</sub> )	36.31±0.33 <sup>A</sup>	25.87±2.37 <sup>CDs</sup>	33.23±0.30 <sup>B</sup>	31.80 <sup>a</sup>
45 (S <sub>2</sub> )	22.63±0.33 <sup>F</sup>	24.85±0.37 <sup>DE</sup>	34.55±0.49 <sup>AB</sup>	27.34 <sup>b</sup>
70 (S <sub>3</sub> )	23.39±0.29 <sup>EF</sup>	27.33±0.16 <sup>C</sup>	35.96±0.36 <sup>A</sup>	28.90 <sup>b</sup>
Average (%)	27.44 <sup>b</sup>	26.02 <sup>b</sup>	34.58 <sup>a</sup>	29.35

The numbers followed by the same uppercase/lowercase letters in row or column indicate no significant differences based on the DMRT test at the 5% level

TABLE 5. Response of acetone solvent concentration and settling time on inulin content in the extraction of inulin taro beneng (*Xanthosoma undipes*)

Concentration (%)	Settling time (h)			Average (%)
	12 (F <sub>1</sub> )	18 (F <sub>2</sub> )	24 (F <sub>3</sub> )	
20 (S <sub>1</sub> )	53.05±1.42 <sup>A</sup>	47.27±5.39 <sup>ABC</sup>	41.29±0.27 <sup>CDs</sup>	47.20
45 (S <sub>2</sub> )	45.11±4.11 <sup>ABCD</sup>	41.33±5.95 <sup>CDs</sup>	38.71±3.55 <sup>s</sup>	41.72
70 (S <sub>3</sub> )	38.52±4.26 <sup>s</sup>	43.49±1.61 <sup>BCD</sup>	51.27±1.06 <sup>AB</sup>	44.43
Average (%)	45.56	44.03	43.76	44.45

The numbers followed by the same uppercase/lowercase letters in row or column indicate no significant difference based on the DMRT test at 5% level

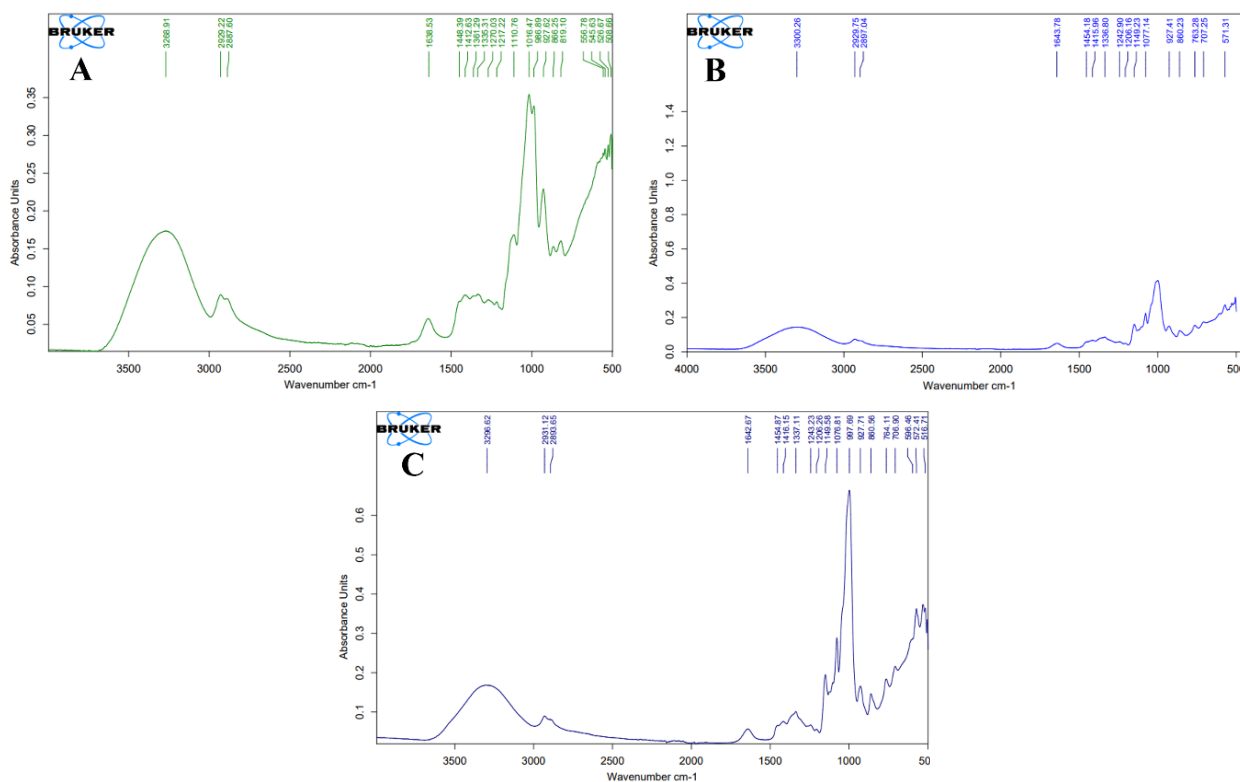


FIGURE 1. FTIR result. A: FTIR result of commercial inulin (Orafti), B: FTIR spectrum of IBT at 20% acetone concentration and 12 h settling time and C: FTIR spectrum of IBT at 70% acetone, concentration and 24 h settling time

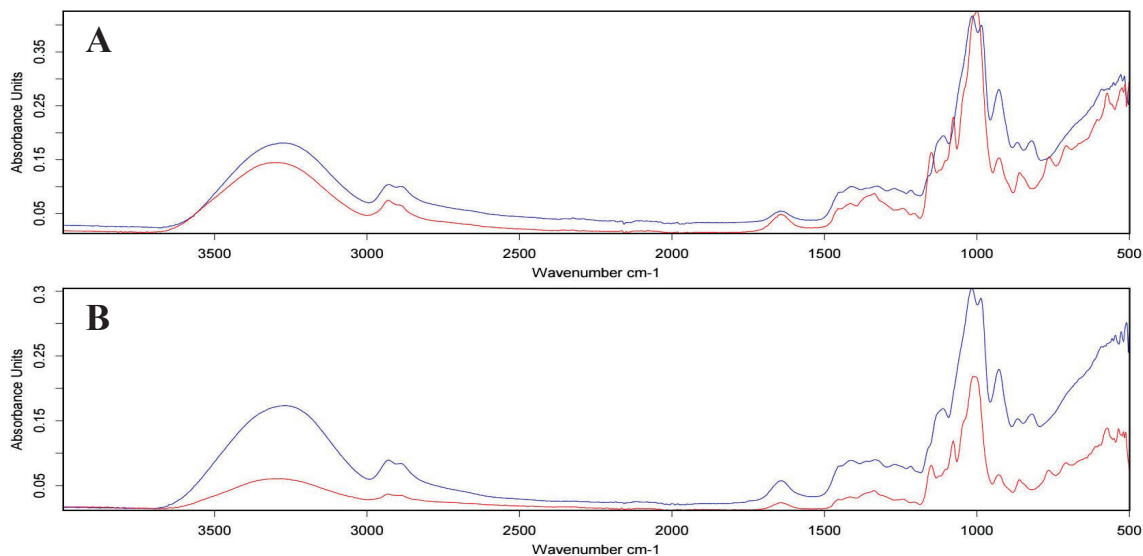


FIGURE 2. Quick comparison between IBT (red line) and Orafti (blue line). A: 20% acetone concentration and 12 h settling time; B: 70% acetone concentration and 24 h settling time

acetone concentration and a settling time of 24 h showed a slightly lower similarity to Orafti commercial inulin, with a value of 94.60%.

#### CONCLUSION

The concentration of acetone solvent and precipitation time significantly influenced the yield, water content, solubility, and inulin content of taro beneng (*Xanthosoma undipes*) inulin. The highest yield (10.30%) was obtained at 70% acetone, while lower water content was achieved with higher acetone concentrations, reaching 4.97% at 70%. Solubility was highest (36.31%) at 20% acetone with 12 h settling, whereas extended precipitation (24 h) generally improved dispersibility. The maximum inulin content (53.05%) was achieved at 20% acetone and 12 h. FTIR analysis confirmed that the extracted inulin shows up to 97.20% similarity with commercial inulin. Overall, the best extraction condition was 20% acetone with 12 h precipitation, producing inulin with high solubility, good purity, and close similarity to the commercial product.

#### ACKNOWLEDGMENTS

This work was funded by the Indonesian Ministry of Education, Culture and Higher Education through Matching Fund Kedaireka-2022.

#### REFERENCES

Alabadi, A.M.D. & Abood, S.C. 2020. Microwave-assisted extraction of inulin from Jerusalem artichoke and partial acid hydrolyses. *The Iraqi Journal of Agricultural Science* 51(1): 401-410.

- Alexander, I.J., Bulan, R., Zaidar, E., Silaban, R., Soripada, T.A. & Sirait, G. 2023. The analysis of inulin from yam tubers using FTIR (Fourier Transform Infra Red). *International Journal of Computer Applications Technology and Research* 12(3): 53-55. <https://doi.org/10.7753/IJCATR1203.1012>
- AOAC. 2007. *Official Methods of Analysis 18th*. MD: AOAC International. Gaithersburg.
- AOAC. 1990. *Official Methods of Analysis of the Association of Analytical Chemists*. Washington.
- Ciptaningrum, A.B. 2015. Extraction of inulin from gembili tuber chips (*Dioscorea esculenta*) with variations in the ratio of chips and water and evaluation of their potential as prebiotics. Master Thesis. Gadjah Mada University (Unpublished).
- Dangre, P.V., Kotkar, K.S., Pimple, A.D. & Meshram, S.S. 2025. Chemistry, isolation, and pharmaceutical applications of inulin. *Current Drug Therapy* 20(1): 8-17. <https://doi.org/10.2174/0115748855274579240103042126>
- Das Kirtania, M., Kahali, N. & Maity, A. 2021. Inulin-based hydrogel. In *Plant and Algal Hydrogels for Drug Delivery and Regenerative Medicine*, edited by Giri, T.K. & Ghosh, B. Woodhead Publishing. pp. 261-292. <https://doi.org/10.1016/B978-0-12-821649-1.00005-2>
- Diaz, A., Garcia, M.A. & Dini, C. 2022. Jerusalem artichoke flour as food ingredient and as source of fructooligosaccharides and inulin. *Journal of Food Composition and Analysis* 114: 104863. <https://doi.org/10.1016/j.jfca.2022.104863>



- El-Kholy, W.M., Aamer, R.A. & Ali, A.N.A. 2020. Utilization of inulin extracted from chicory (*Cichorium intybus* L.) roots to improve the properties of low-fat synbiotic yoghurt. *Annals of Agricultural Sciences* 65(1): 59-67. <https://doi.org/10.1016/j.aas.2020.02.002>
- Eris, F.R., Pamela, V.Y., Kusumasari, S. & Meindrawan, B. 2024. Extraction of inulin from Beneng tuber (*Xanthosoma undipes*) and its application to yogurt. *Future Foods* 9: 100339. <https://doi.org/10.1016/j.fufo.2024.100339>
- Eris, F.R., Riziani, D., Pamela, V.Y., Febriansah, M.R., Kusumasari, S. & Sari, A.K. 2022. A review of the potential of beneng taro as material for inulin making and its application to yogurt. In *2nd International Conference for Smart Agriculture, Food, and Environment (ICSAFE 2021)* Atlantis Press. pp. 37-44.
- Fachrudin, A. R. 2016. Performance analysis of a closed thermosyphon with varying concentrations of acetone and ethanol mixtures. *Info Teknik Journal* 17(1): 85-94.
- Firmansyah, J. 2018. Scientific explanation of boiling water at room temperature. *Indonesian Journal of Philosophy* 1(1): 75-79.
- Hariyadi, S., Narulita, E. & Amien Rais, M. 2018. Perbandingan metode lisis jaringan hewan dalam proses isolasi DNA genom pada organ liver tikus putih (*Rattus norvegicus*). *Proceedings Biology Education Conference* 15(1): 689-692.
- Hersoelistyorini, W., Dewi, S.S. & Kumoro, A.C. 2015. Sifat fisikokimia dan organoleptik tepung mocaf (*modified cassava flour*) dengan fermentasi menggunakan ekstrak kubis. *Proceedings of Engineering and Design Field, Institute for Research and Community Service, Universitas Muhammadiyah Semarang (UNIMUS)*. *Journal of Chemical and Industrial Technology* 2(1): 246-256.
- Hilman, A., Harmayani, E. & Cahyanto, M. 2018. Inulin extraction and characterisation of fresh and chip gembili (*Dioscorea esculenta*) extract by ultrasound-assisted extraction. *Proceedings of the International Conference of Science, Technology, Engineering, Environmental and Ramification Researches (ICOSTEERR)* 1: 47-53. <https://doi.org/10.5220/0010084000470053>
- Huynh, B.L., Palmer, L., Mather, D.E. & Wallwork, H. 2008. An improved method for quantitative analysis of total fructans in plant tissues. *Journal of the Science of Food and Agriculture* 88(9): 1584-1591. <https://doi.org/10.1002/jsfa.3253>
- Ida Ayu Maria Christina, I Nengah Kencana & I Dewa Gede Mayun Permana. 2018. Pengaruh metode pengeringan dan jenis pelarut terhadap rendemen dan kadar kurkumin ekstrak kunyit (*Curcuma domestica* Val.). *Jurnal Ilmiah Teknologi Pertanian* 3(2): 319-324.
- Ku, Y., Jansen, O., Oles, C.J., Lazar, E.Z. & Rader, J.I. 2003. Precipitation of inulins and oligoglucoses by ethanol and other solvents. *Food Chemistry* 81(1): 125-132. [https://doi.org/10.1016/S0308-8146\(02\)00393-X](https://doi.org/10.1016/S0308-8146(02)00393-X)
- Jiang, H., Zhang, N., Xie, L., Li, G., Chen, L. & Liao, Z. 2025. A comprehensive review of the rehydration of instant powders: Mechanisms, influencing factors, and improvement strategies. *Foods* 14(16): 2883. <https://doi.org/10.3390/foods14162883>
- Kusmiyati, N., Wahyuningsih, T.D. & Widodo. 2018. Extraction and identification of inulin-type fructooligosaccharides from *Dahlia pinnata* L. *Asian Journal of Chemistry* 30(2): 355-358. <https://doi.org/10.14233/ajchem.2018.20965>
- Lailani, T. S. 2020. Extraction of phycoerythrin pigment from red seaweed and its potential as an antioxidant compound. Bachelor's thesis. Syarif Hidayatullah State Islamic University Jakarta.
- Lima, E.C.D.S., Manhães, L.R.T., Santos, E.R.D., Feijó, M.B.D.S. & Sabaa-Srur, A.U.D.O. 2021. Optimization of the inulin aqueous extraction process from the açai (*Euterpe oleracea*, Mart.) seed. *Food Science and Technology* 41: 884-889. <https://doi.org/10.1590/fst.24920>
- Liu, Z., Mouradov, A., Smith, K.F. & Spangenberg, G. 2011. An improved method for quantitative analysis of total fructans in plant tissues. *Analytical Biochemistry* 418(2): 253-259. <https://doi.org/10.1016/j.ab.2011.08.004>
- Niu, L., Zhang, H., Wu, Z., Wang, Y., Liu, H., Wu, X. & Wang, W. 2018. Modified TCA/acetone precipitation of plant proteins for proteomic analysis. *PLoS ONE* 13(12): e0202238.
- Petkova, N., Ognyanov, M. & Denev, P. 2014. Isolation and characterization of inulin obtained from taproots of common chicory (*Cichorium intybus* L.). *Scientific Papers, University of Plovdiv "Paisii Hilendarski"*. 39(5): 25-34.
- Petkova, N., Hambarliyska, I., Ivanov, I., Ognyanov, M., Nikolova, K., Ibryamova, S. & Ignatova-Ivanova, T. 2025. Physicochemical, functional, and antibacterial properties of inulin-type fructans isolated from dandelion (*Taraxacum officinale*) roots by "green" extraction techniques. *Applied Sciences* 15(8): 4091. <https://doi.org/10.3390/app15084091>
- Rubel, I.A., Iraporda, C., Novosad, R., Cabrera, F.A., Genovese, D.B. & Manrique, G.D. 2018. Inulin rich carbohydrates extraction from Jerusalem artichoke (*Helianthus tuberosus* L.) tubers and application of different drying methods. *Food Research International* 103: 226-233. <https://doi.org/10.1016/j.foodres.2017.10.041>

- Saengkanuk, A., Nuchadomrong, S., Jogloy, S., Patanothai, A. & Srijaranai, S. 2011. A simplified spectrophotometric method for the determination of inulin in Jerusalem artichoke (*Helianthus tuberosus* L.) tubers. *European Food Research and Technology* 233(4): 609-616. <https://doi.org/10.1007/s00217-011-1552-3>
- Saçcan, N., Saçcan, H., Bozkurt, F., Güneş, A.N.B., Fakir, H., Dertli, E. & Sağdıç, O. 2024. Optimization of inulin extraction from chicory roots and an ultrafiltration application to obtain purified inulin and hydrolyzed fructooligosaccharides. *Journal of Agricultural Sciences* 30(1): 166-178. <https://doi.org/10.15832/ankutbd.1338572>
- Sarkar, R., Bhowmik, A., Kundu, A., Dutta, A., Nain, L., Chawla, G. & Saha, S. 2021. Inulin from *Pachyrhizus erosus* root and its production intensification using evolutionary algorithm approach and response surface methodology. *Carbohydrate Polymers* 251: 117042. <https://doi.org/10.1016/j.carbpol.2020.117042>
- Shi, L. 2016. Bioactivities, isolation and purification methods of polysaccharides from natural products: A review. *International Journal of Biological Macromolecules* 92: 37-48. <https://doi.org/10.1016/j.ijbiomac.2016.06.100>
- Tai, Y., Shen, J., Luo, Y., Qu, H. & Gong, X. 2020. Research progress on the ethanol precipitation process of traditional Chinese medicine. *Chinese Medicine* 15: 84. <https://doi.org/10.1186/s13020-020-00366-2>
- Wibawanti, J.M.W., Mulyani, S., Legowo, A.M., Hartanto, R., Al-Baarri, A. & Pramono, Y.B. 2021. Characteristics of inulin from mangrove apple (*Sonneratia caseolaris*) with different extraction temperatures. *Food Research* 5(4): 99-106. [https://doi.org/10.26656/fr.2017.5\(4\).662](https://doi.org/10.26656/fr.2017.5(4).662)
- Yeoh, G.L., Mohd Rozalli, N.H., Zulkurnain, M. & Mohammadi Nafchi, A. 2025. Assessment of inulin on anti-freezing properties of silken tofu coagulated with glucono-delta-lactone and calcium sulphate. *Musfirah and Mohammadi Nafchi, Abdorreza, Assessment of Inulin on Anti-Freezing Properties of Silken Tofu Coagulated with Glucono-Delta-Lactone and Calcium Sulphate*. <http://dx.doi.org/10.2139/ssrn.5194958>
- Yudhistira, B. & Siswanti, S. 2020. Pengaruh rasio pelarut dan waktu pengendapan pada isolasi inulin ubi jalar (*Ipomoea batatas*). *Agrointek: Jurnal Teknologi Industri Pertanian* 14(2): 130-138.
- Zhang, X., Zhu, X., Shi, X., Hou, Y. & Yi, Y. 2022. Extraction and purification of inulin from Jerusalem Artichoke with response surface method and ion exchange resins. *ACS Omega* 7(14): 12048-12055. <https://doi.org/10.1021/acsomega.2c00302>
- Zhang, Y., Liu, R., Song, B., Li, L., Shi, R., Ma, X., Zhang, L. & Li, X. 2024. Recent advances in inulin polysaccharides research: Extraction, purification, structure, and bioactivities. *Chemical and Biological Technologies in Agriculture* 11: 136. <https://doi.org/10.1186/s40538-024-00667-w>

\*Corresponding author; email: fitria.eris@untirta.ac.id