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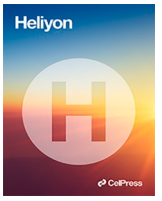

Purification and separation of glucomannan from porang tuber flour (*Amorphophallus muelleri*) using microwave assisted extraction as an innovative gelatine substituent

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ABSTRACT

Gelatine is frequently used as a food ingredient. However, Indonesia imports almost all of its gelatine, totaling 3990152 tons annually. Gelatine could be replaced with glucomannan compound which was found in porang tubers. However, it also contains calcium oxalate, which is harmful for the human body. In this study, calcium oxalate was first eliminated by the purification process using 10 % NaCl (w/w). Moreover, the microwave-assisted extraction method was used to extract the glucomannan compound by applying 300 W of microwave power with different extraction times (5, 10, 15, and 20 min) and different ethanol concentrations (60, 70, 80, and 96 %). Statistical analysis was used to optimize and identify significant parameters influencing the glucomannan concentration. The best conditions for glucomannan extraction were an extraction time of 10 min and an ethanol concentration of 80 % (v/v), resulting in a glucomannan yield of $\geq$96 %. Machine learning was successfully applied for data modelling using a Long Short-Term Memory block with an average R-square of 0.9772 (97.72 % accuracy) and an average MSE of 4.7719. Furthermore, physical and chemical characteristics of the extracted porang flour were accorded with SNI gelatine standards 06–3735 in 1995, which consisted of glucomannan (96.359 $\pm$ 1.164 %), calcium oxalate (0.009 $\pm$ 0.001 %), water (2.290 $\pm$ 0.986 %), ash (0.018 $\pm$ 0.002 %), fat (0.0235 $\pm$ 0.120 %), heavy metals (not identified), and pH (6.455 $\pm$ 0.191). Finally, the extracted glucomannan can be used as a potential regional substitute for gelatine production.

1. Introduction

Gelatine is a colloid type that can dissolve in warm water. The colloidal solution will assume the form of a thixotropic and reversible gel at temperatures below 30 °C, which will liquefy when heated. Gelatine must adhere to Indonesian quality requirements [1], which has a maximum of 16 % water, 3.25 % ash, 5 % fat, and a maximum of 50 mg/kg of heavy metals [2]. The annual consumption of gelatine in Indonesia amounts to 3990152 tons and nearly all of this quantity is imported. This highlights a significant disparity

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between the demand and its domestic production capacity, indicating the inadequacy of the country to fulfill this requirement locally. Additionally, pigs are mostly used to make 98.5 % of the gelatine produced worldwide (meat, bone, and skin). However, this does not comply with the standards of Indonesia Guaranteed Halal Products Law Number 33 of 2014. It is necessary to replace imported non-halal gelatine with raw materials that have equivalent features and qualities to ensure the halalness of gelatine products [3].

One of the substances that has the potential to take the role of gelatine is glucomannan ($C_{24}H_{42}O_{21}$). Glucomannan is a key component of the hemicellulose fraction, which contributes to the structural integrity of the cell walls of various plant tissues and it is particularly abundant in storage organs such as tubers, corms, and roots. Glucomannan can be extracted from porang tubers and used as a thickener, emulsifier, stabilizer, and gelling agent [4]. This compound has a great deal of potential to replace gelatine since it can absorb 100 g of water per gram of glucomannan [2]. Sembiring et al. [5] revealed that the incorporation of 0.4 % glucomannan in ice cream formulation enhances its overall quality. However, calcium oxalate in porang tubers must be eliminated first by purification using 10 % NaCl [6,7]. It can cause kidney failure and skin irritation if it is continuously consumed in amounts above the daily allowance (50 mg/kg) [8].

Microwave technology is a highly efficient and rapid method for the heating process compared to conventional techniques. This is because microwave enables volumetric heating, which means that microwaves penetrate into material uniformly, resulting in homogeneous heating throughout the material [9–11] and it expedites the heating process while minimizing the potential for detrimental effects, ultimately enhancing the overall quality of the product. Moreover, certain foods with high dielectric properties respond even better to this technology, which further enhances the interaction between the microwaves and the food [12,13]. As a result, microwave heating is considered a valuable and effective technology for extraction purpose. Pasaribu et al. [14] successfully increased the extracted glucomannan levels from 32.65 % to 83.96 % by utilizing 50 % (v/v) of ethanol with the addition of 2 % sodium bisulfite solution ($NaHSO_3$). However, it takes a long extraction time of up to 4 h. Bui et al. [15] claimed that Microwave-assisted extraction (MAE) using hydrochloric acid (HCl) solvent can reduce the extraction time to 15 min. However, this method employed harmful acid solvent and the yield of glucomannan obtained was only 35.8 % because of the hydrolysis of glucomannan into carbohydrate monomers by strong acids [16]. Furthermore, Aparamarta et al. [17] successfully separated triglycerides (TG) and free fatty acids (FFA) using microwave-assisted extraction (MAE) technology. This method yielded a TG content of 83.46 % and an FFA content of 7.5 %, indicating high purity and specificity of the extraction process. One of the significant advantages of this method is that it significantly reduces the volume of solvent required and minimizes the extraction time needed. The MAE performance is primarily affected by the power of the microwave and the extraction time [18]. As the microwave power increases, the yield of the extracted product also increases. However, excessive microwave power may result in a high operating temperature that could cause thermal degradation of the extracted compounds [19–21].

This study aims to enhance technology-driven glucomannan purification through a pre-treatment involving NaCl, which aims to eliminate calcium oxalate components. Subsequently, microwave-assisted extraction with green solvent (i.e. ethanol) is utilized to extract glucomannan. Statistical analysis and deep learning are used for modelling the experimental data. It was found that extraction time and ethanol concentration serve as significant parameters in attaining the optimal glucomannan yield. Comprehensive characterization and proximate analysis are conducted to assess the quality of the extracted glucomannan. Finally, the extracted glucomannan from porang tubers and commercial gelatine were compared to explore the potential of glucomannan as a halal gelatine replacement for Indonesian customers.

2. Material and methods

2.1. Materials

The porang tuber (Amorphophallus muelleri) from Situbondo, Indonesia was utilized as the raw material after undergoing a drying and grinding process to achieve flour-like consistency. Food-grade ethanol (>96 %) and sodium chloride (NaCl, >99 %) were purchased from PT. INDO ACIDATAMA Tbk. 3,5-Dinitrosalicylic acid (DNS, 98 %, Sigma-Aldrich) reagent was prepared by mixing 80 ml of 0.5 N sodium hydroxide (NaOH, ≥97 %, Fisher Scientific) with 1 g of DNS. Then, 30 g of potassium sodium tartrate tetrahydrate (Rochelle salt, 99 %, Sigma-Aldrich) was added to the mixture until the reagent was completely dissolved. Finally, distilled water was used to dilute the DNS reagent to a volume of 100 ml for glucomannan analysis [22].

2.2. Characterization of porang flour

The surface functional group analysis of porang flour before and after extraction were obtained by using a Fourier-Transform Infrared Spectroscopy (FTIR, SHIMADZU Tracer-100); the analysis was conducted in the range of 400–4000 cm^{-1} wavenumbers with scan rate 2 cm^{-1} and KBr pellets were applied as the background. The morphology of porang flour was determined using a Scanning Electron Microscope (SEM, 7900F, JEOL). The magnification information was displayed on the micrograph.

2.3. Pre-treatment and MAE method

First, 1 g of porang flour sample was added to a beaker glass containing 100 ml of NaCl (10 % w/w) and stirred at 300 rpm for 15 min at room temperature. Then, 100 ml of ethanol was added to the porang flour solution. The filtrate and white precipitate were obtained after 15 min and separated using a filter paper and vacuum pump. This was called the pre-treatment step to remove calcium oxalate. The initial porang flour contained 2.050 % of calcium oxalate, which subsequently decreased to 0.101 % after pre-treatment.

Furthermore, the resultant solid was mixed with different concentrations of ethanol (i.e. 60, 70, 80, and 96 % (v/v)). The 300 W of microwave power with temperature control of 70 °C was employed to extract glucomannan compound from porang flour with different extraction times (i.e. 5, 10, 15, and 20 min). The filtrate and precipitate were then separated using filter paper and a vacuum pump. The precipitate was dried for 12–14 h at 60 °C (until a constant mass). The extracted porang flour was crushed by using a mortar and pestle and passed through an 80-mesh sieve. The detailed experimental process is presented in Fig. 1.

2.4. Glucomannan analysis

The sample was weighed up to 0.2 g and stirred in 50 ml of 0.1 M formic acid-NaOH buffer for 4 h. Then, the resulting mixture was centrifuged for 20 min at 4000 rpm. Added 1 ml of 3 M sulfuric acid to 2.5 ml of the solution. The solution was then hydrolyzed in a water bath for 90 min at room temperature and followed by adding 1 ml of 6 M NaOH to the solution. Added 1.5 ml of DNS reagent to 2 ml of each solution. The solution was heated for 10 min in a boiling water bath, and then rapidly chilled for 10 min in an ice bath. Hydrolyzed glucomannan and glucomannan solutions were assessed using a UV–Vis spectrophotometer at 540 nm, and the results were compared with a reference solution of D-glucose [23]. The percentage of glucomannan was obtained using the following equation:

$$\%Glucomannan = \frac{5000f(5T - T_o)}{m(1-w)} \quad (1)$$

where parameters f, T, T_0, m, and w are correction factor, glucose content of glucomannan hydrolyzed (mg), glucose content of glucomannan extract (mg), mass of glucomannan (mg), and water content of glucomannan, respectively. Moreover, the methodologies for the proximate analysis of glucomannan flour are available in the Supporting Information file.

2.5. Statistical analysis

The effect of extraction time and ethanol concentration were evaluated by ANOVA. The significance level of 0.01 was used to evaluate whether the process parameter had a significant effect on the response variables or not. The experimental design was performed including Residual Probability Plot to examine the goodness-of-fit in regression with ANOVA and Desirability Function Analysis to optimize the experiments with MINITAB software version 20.

2.6. Deep learning modelling

Deep Learning Modelling such as LSTM (Long Short-Term Memory) block has been employed to analyze and comprehend intricate relationships between extraction parameters and glucomannan yield. The predicted data were subsequently compared with the experimental data. The input layer is the ethanol concentration and extraction time, while the output or prediction layer is the glucomannan concentration, as shown in Fig. 2. Table 1 provides a more detailed explanation of the architectural parameters used. The loss function uses the Mean Squared Error (MSE) to measure the difference between the actual data and the predicted result. Another parameter, such as Epoch for training, is set to 1000 iterations with AdamW as an optimizer [24], which is set with weight decay = $1e^{-6}$ and learning rate $1e^{-3}$.

The data modelling was tested using three methods. The first method was randomizing the data. This first test scheme aims to learn from random sampling and predict the data as might happen in real experiments. Available data was randomized and split into 70 % data as data training (seen 166 data) to train architecture and 30 % as testing or unseen data. The machine was asked to learn training data and predict the testing data unseen by the machine. The regression accuracy is determined using the R-squared parameter and Mean Square Error (MSE). R-Square determines accuracy, but MSE determines how far the machine generates the error to predict the

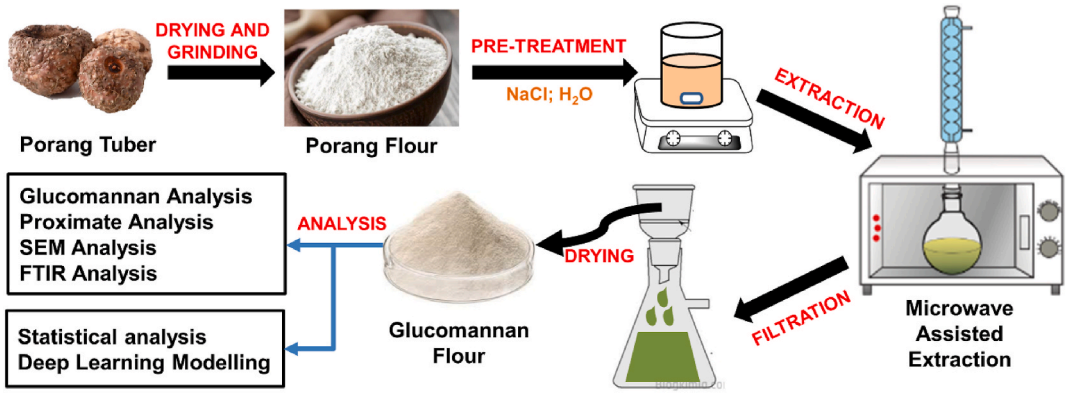

Fig. 1. Schematic representation of the experimental study.

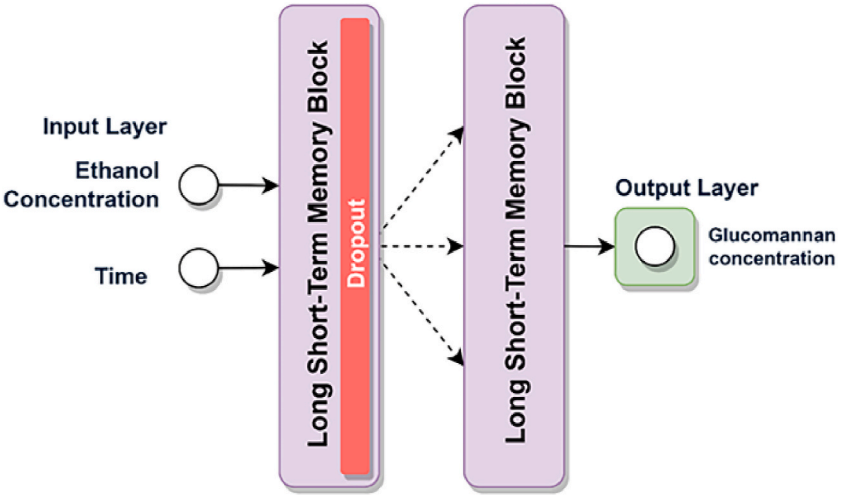

Fig. 2. Block diagram of Long Short-Term Memory architecture.

Table 1
Architecture parameter.

Block Name	Parameter
Input Layer	Input = 2
Long Short-Term Memory Block 1	Unit = 100 Return Sequences = True Dropout = 0.2
Long Short-Term Memory Block 2	Unit = 100 Return Sequences = False
Output Layer	Output = 1 Dense = 1

exact value [25]. For instance, if MSE = 3, the prediction value boundaries might bounce to +3 or −3 from the real value. For example, if the real value is 30, the machine might predict 30 + 3 or 30-3. Furthermore, the second method using higher values was supposed to determine the ability of the machine when it predicts a lower value. This objective could also be relevant in real-world experiments, where users may possess current data but seek insights into historical data trends. As an example, in the received dataset, we collected 112 data samples and planned to use 70 % of the data for training. As a result, we arranged the data by reserving indices 0 to 78 for training and assigning the remaining 30 % of the data from index 78 to the end for testing. For parameter testing, we used similar techniques. The third technique was carried out in a similar fashion, with one major difference. In this situation, we used the lower end of the training data to forecast higher values. As a result, the machine was trained using data from index 34 to the end, and testing data from index 0 to 34.

3. Results and discussion

3.1. Effect of extraction time on the glucomannan level

The extraction time affects the ability of the solvent to extract the compounds from the matrix wall. Therefore, it is necessary to understand how time affects the MAE process to achieve the optimum result. The data analysis of variance in Table 2 shows the p-value <0.01 and F calculate $>$ F 1 %. It indicated that the extraction time of MAE significantly affects the levels of glucomannan produced.

Fig. 3 depicts the correlation between extraction time and the level of glucomannan production. Since the heating occurs volumetrically, microwave radiation expeditiously accelerates the reaction. While a 5 min heating duration yields an insufficient amount of glucomannan, a significant rise is observed within 10 min, indicating that microwave radiation enhances the driving power to break

Table 2
Data analysis of the effect of time on glucomannan.

Diversity Source	Df	SS	MS	F Calculate	F 5 %	F 1 %	P Value
Extraction Time (Minute)	3	5445.6	1815.20	267.56	2.93	4.54	0.0001

Df is the degrees of freedom, SS is the sums of squares, MS is the mean squares, F 5 % and F 1 % are the level of significance, and P value is the probability value.

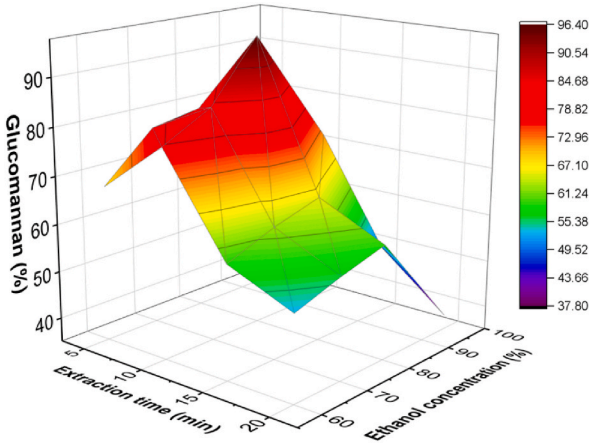

Fig. 3. The effect of extraction time and ethanol concentration on glucomannan levels.

the cell membrane structure [26]. Nonetheless, it is noteworthy that extended extraction time may lead to the breakdown of glucomannan into its monomers, potentially compromising the quality of the final product [27]. As a result, the glucomannan content is decreased when the extraction times are 15 min and 20 min [28]. According to Aparamarta et al. [17], prolonged exposure to microwave radiation causes thermolabile molecules to overheat and degrade. Consequently, extended extraction times are associated with reduced quantities of the intended target component. Additionally, the short extraction time may inadequately break down the matrix wall leading to low glucomannan production. Therefore, the present study determined that utilizing an extraction time of 10 min produced the best results.

3.2. Effect of ethanol concentration on the glucomannan level

The selection of a suitable solvent plays a crucial role in the MAE process. It depends on various factors, including the solubility of the extracted component, its ability to penetrate and interact with the matrix of the sample, the dielectric constant, and the dissipation factor [29]. Ethanol exhibits a high dissipation factor ($\tan \delta = 2500 \times 10^{-4}$), indicative of its pronounced ability to absorb microwave energy. This intrinsic property ensures uniform heat distribution, leading to rapid heating facilitating an efficient extraction process. Moreover, ethanol was chosen because of its significant role as a coagulant agent for glucomannan particles, leading to the aggregation of glucomannan clusters that can be subsequently separated from the solution [30]. The effect of ethanol concentration on glucomannan level is shown in Fig. 3. According to the data analysis of variance in Table 3, the ethanol concentration in the MAE process had a highly significant impact on glucomannan content because it has a p-value <0.01 and also F calculate $>$ F 1 %.

The optimal result was achieved by using 80 % (v/v) of ethanol concentration, as shown in Fig. 3. It suggests that the inclusion of a small amount of distilled water in the ethanol solvent is imperative for efficient glucomannan extraction. This addition capitalizes on the water-absorbing characteristics of glucomannan, allowing it to effectively infiltrate cell matrices and thereby enhancing the extraction process [31]. However, an excessive amount of distilled water in the ethanol solvent can lead to a reduction in extraction efficiency, particularly at high temperatures. This is because ion conduction is more predominant than dipole rotation, which reduces the energy required to break the cell membrane structure at high temperatures [32]. Therefore, precise adjustment of the water content within the ethanol solvent is crucial for maintaining the optimal extraction conditions.

3.3. Residual Probability Plot and desirability function analysis on glucomannan

A factorial experimental design with 2 factors were used in this experiment due to its ability to analyze the main effects of each factor separately and explore their interactions. By using 2 factors, the experiment can be organized efficiently, necessitating fewer experimental runs than designs with higher factors. The first factor (factor A) is the extraction time, which has four levels: 5, 10, 15, and 20 min. The second factor (factor B) is the concentration of ethanol, which has four levels: 60, 70, 80, and 96 % (v/v). Additionally, a prerequisite for regression analysis is tested using the normalcy test, which affects the variables to the anticipated response in Fig. 4. By comparing the residual result points to the diagonal line, it is possible to determine whether the regression model being studied is

Table 3
Data analysis of the effects of ethanol concentration on glucomannan.

Diversity Source	Df	SS	MS	F Calculate	F 5 %	F 1 %	P Value
Ethanol Concentration (%v/v)	3	2258.0	752.65	110.94	2.93	4.54	0.0001

Df is the degrees of freedom, SS is the sums of squares, MS is the mean squares, F 5 % and F 1 % are the level of significance, and P value is the probability value.

normally distributed. The normality test of the residual glucomannan level data was carried out in the MINITAB 20. The p-value >0.05 means that the residual data has been normally distributed according to Table 4.

The desirability function analysis was conducted to ascertain the optimization of the conducted experiments. This analysis involves a synergistic combination of process variables to achieve a maximum response, as shown in Table 5. The composite desirability value is 0.995. Consequently, this analysis serves as a guideline for parameter configuration, indicating that the optimal extraction parameters are an extraction time of 10 min and an ethanol concentration of 80 % (v/v).

3.4. Deep learning modelling

Fig. 5a shows the model using the random-sampling prediction method. The machine randomly chooses data in the range of available data. The R-square value was 0.9714 (97.14 % accuracy), and the MSE value was 6.0815. Fig. 5b shows the model using the Upper Prediction method. The machine predicted upper data, giving an R-square value of 0.9767 (97.67 % accuracy), and the MSE value was 5.0277. Fig. 5c shows the model using the Lower Prediction method to detect the lower data. The value of R-Square is 0.9834 (98.34 % accuracy) with a 3.2067 MSE value. Moreover, this method yielded an average R-square value of 0.9772 (97.72 % accuracy) and an average MSE value of 4.7719. Therefore, deep learning using the LSTM block method was effective for modelling the data of glucomannan extraction using the MAE method and providing probability for further exploration.

3.5. Characterization of glucomannan flour

The proximate analysis was performed to establish whether the resultant glucomannan obtained is in accordance with gelatine standards, as shown in Table 6. The resulting glucomannan flour must have a maximum water content of 16 % to comply with the gelatine substitution standards (SNI 06–3735 of 1995). The water content of the glucomannan flour is 2.290 ± 0.986 %, which is below the standard. In addition, it is recommended to vacuum the samples before the drying process to reduce the water content and expedite the drying time. Ash content denotes the residual inorganic (mineral) matter resulting from the combustion of organic constituents [33]. According to the standard, the ash content of gelatine is less than 3.25 %. The glucomannan obtained has an ash content of 0.018 ± 0.002 %, which is perfectly acceptable. The fat content plays a pivotal role in shaping the quality of glucomannan flour, notably in terms of its storage quality. High-quality gelatine demonstrates a low-fat content and it can increase the storage period of the product without causing a rancid odor and taste [34]. The fat content of glucomannan flour is 0.0235 ± 0.120 %, which already meets with the standards. The pH value significantly impacts the gelation capacity of glucomannan. According to gelatine standards, the pH of gelatine should be in the range of 4.5–6.5. Gelatine with low pH is generally used in the food and beverage industry, while neutral pH for the meat industry, pharmaceuticals, and chromatography. The pH value of the resultant glucomannan flour is 6.455 ± 0.191, which is consistent with the standard.

Viscosity is one of the important parameters in determining the quality of gelatine because it correlates to the emulsion stability of gelatine. The stability of the gelatine in water will be longer when it has high viscosity [35]. The viscosity of glucomannan flour is 6962.5 ± 54.447 cP, which is highly satisfactory and even exceeds the top-grade gelatine standard. The standard for gel strength ranges from 50 to 300 gr bloom. Gelatine is considered stiff and hard when its gel strength value exceeds 300 gr bloom [36]. The gel strength value of glucomannan flour is 140.2 ± 1.273 gr blooms. This result also meets with standard. Moreover, all proximate analysis results align well with the gelatine standard.

Morphological analysis of the initial porang flour and glucomannan flour was performed with a magnification of 5000× using SEM,

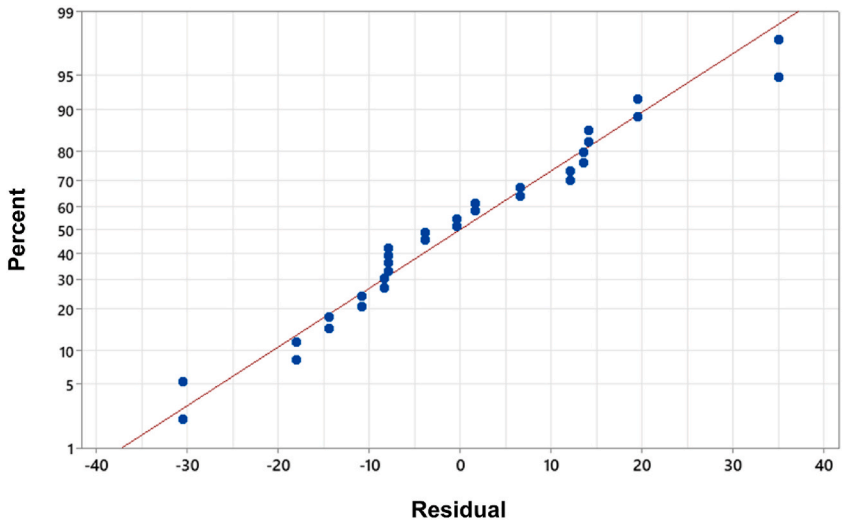

Fig. 4. Normal probability plot on residual glucomannan.

Table 4
Residual probability plot test results on glucomannan.

Source	Df	SS	MS	F-Value	*P*-Value
RESI 1 (Residual)	1	108.5	108.5	0.41	0.526

Df is the degrees of freedom, SS is the sums of squares, MS is the mean squares, and P value is the probability value.

Table 5
Desirability function analysis on glucomannan.

Solution	Ethanol Concentration (%v/v)	Extraction Time (Minute)	Glucomannan Fit	Composite Desirability
1	80	10	96.359	0.995
2	70	10	79.307	0.765
3	80	5	73.991	0.687
4	60	10	73.411	0.678
5	70	5	71.888	0.656

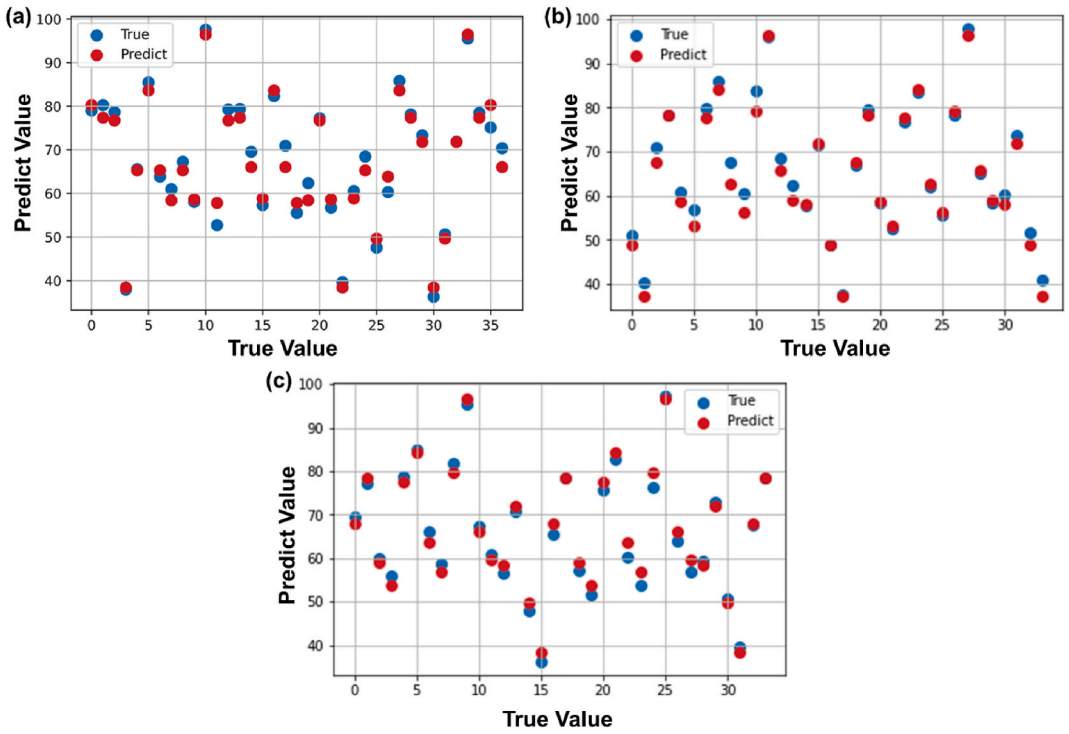

Fig. 5. Results of **(a)** random sampling prediction, **(b)** upper prediction, and **(c)** lower prediction.

as shown in Fig. 6. The glucomannan granules in the initial porang flour were covered in starch and unprocessed fiber contaminants, according to morphological examination. Additionally, small needles revealed that porang flour contained calcium oxalate (Fig. 6a). The glucomannan granules were found to be cleaner in Fig. 6b, which had a glucomannan content of 96.359 ± 1.164 %. However, there was still calcium oxalate present, at a level of 0.009 ± 0.001 %, which resulted in the presence of little needles. The diameter of glucomannan was determined from the results of SEM analysis using ImageJ and Minitab software to be 7.436 ± 2.674 μm. Fig. 7 and Table 7 show the comparison between the FTIR spectrum of porang flour and extracted glucomannan. The band in the region 3200-3300 cm^{-1} correspond to O–H stretching of glucomannan [37]. The band at 2924.48 cm^{-1} and 2926.81 cm^{-1} correspond to C–H asymmetric stretching, while the peaks at 1636.46 cm^{-1} and 1636.61 cm^{-1} are considered as water functional groups in initial porang flour. The decrease in intensity of C═O peak compared to the initial porang flour indicates that there is a decrease in calcium oxalate in the extracted glucomannan. The spectral band at 1369.46 cm^{-1} indicate the angular deformation of C–H. The peaks at 999.88 cm^{-1} and 1000.18 cm^{-1} indicated the presence of a C–*O*–C group. There are peaks at 1148.62 cm^{-1} and 1153.22 cm^{-1}, which indicate the stretching vibration of ether bonds. The characteristic peak of glucomannan was detected at 808–900 cm^{-1} which corresponds to β-pyranose from mannose and glucose [38].

Table 6
Complete Proximate Analysis Results for the best variable of Extraction.

Parameters	Analysis Results	Standard
Glucomannan (%)[a]	96.359 ± 1.164 %	Min 90
Calcium Oxalate (%)[a]	0.009 ± 0.001	Max 3
Water (%)[b]	2.290 ± 0.986	Max 16
Ash (%)[b]	0.018 ± 0.002	Max 3.25
Fat (%)[b]	0.0235 ± 0.120	Max 5
Protein (%)	0.815 ± 0.219	–
Starch (%)	1.829 ± 0.602	–
Rough Fiber (%)	0.016 ± 0.006	–
As (%)	*Nd*	Max 0.25
Pb (%)	*Nd*	Max 0.25
Cd (%)	*Nd*	Max 0.03
Hg (%)	*Nd*	Max 0.05
pH[b]	6.455 ± 0.191	4.5–6.5
Viscosity (cP)[c]	6962.5 ± 54.447	Min 3200
Gel Strength (Gr Bloom)[c]	140.2 ± 1.273	50–300

[a] (Republic of China Patent No. NY/T 494–2002, 2002).
[b] (Indonesia Patent No. 7939:2020, 2020).
[c] (Gelatin Manufacturers Institute of America, 2019).

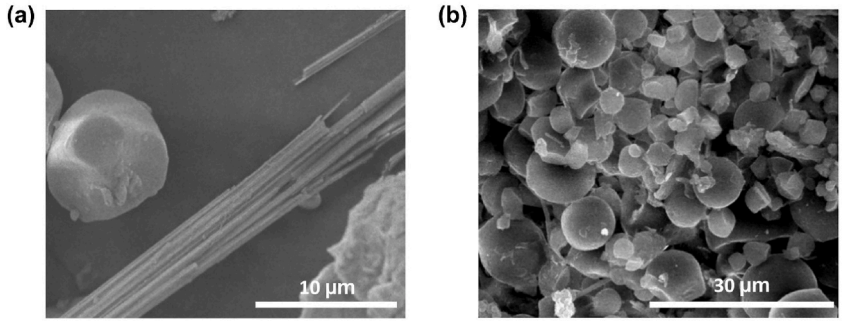

Fig. 6. The results of SEM analysis with a magnification of 5000× **(a)** the initial porang flour, **(b)** the extracted glucomannan.

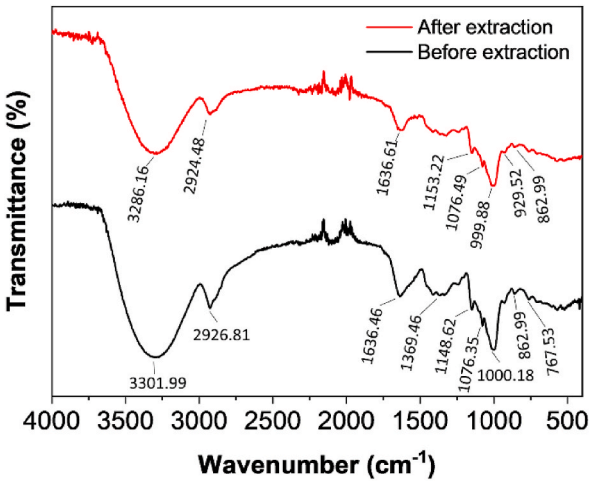

Fig. 7. Comparison between the FTIR spectra of porang flour and extracted glucomannan.

4. Conclusions

A MAE technique has been introduced for the extraction of glucomannan from the porang tuber flour. The findings underscore the pivotal role of extraction time and ethanol concentration in achieving the highest yield of glucomannan. The optimum parameters

Table 7
FTIR Analysis of Porang flour and glucomannan.

Initial porang flour			Extracted glucomannan		
Wavenumber (cm^{-1})	Group	Types of Bonds	Wavenumber (cm^{-1})	Group	Types of Bonds
767.53	C–H	*Bending*			
862.99	C–H	*Bending*	862.99	C–H	*Bending*
1000.18	C–*O*–C	*Stretching*	999.88	C–*O*–C	*Stretching*
1076.35	C–H	*Bending*	1076.49	C–H	*Bending*
1148.62	C–*O*–C	*Stretching*	1153.22	C–*O*–C	*Stretching*
1369.46	C–H	*Bending*			
1636.46	C═O	*Stretching*	1636.61	C═O	*Stretching*
2926.81	C–H	*Stretching*	2924.48	C–H	*Stretching*
3301.99	O–H	*Stretching*	3266.16	O–H	*Stretching*

identified are a 10 min of extraction time and 80 % (v/v) of ethanol concentration, resulting in a remarkable glucomannan content of 96.359 ± 1.164 %. It was found that the deep learning modelling using LSTM block performed well with an average R-square value of 0.9772 (97.72 % accuracy) and an average MSE value of 4.7719. The quality of the glucomannan flour was obtained with proximate analysis: calcium oxalate of 0.009 ± 0.001 %, water content of 2.290 ± 0.986 %, ash content of 0.018 ± 0.002 %, fat content of 0.0235 ± 0.120 %, heavy metals are not detected, pH of 6.455 ± 0.191, viscosity of 6962.5 ± 54.447 cP, and gel strength of 140.2 ± 1.273 g bloom. The analysis results align well with the gelatine standard. Hence, glucomannan flour can be a halal alternative to gelatine, which has the potential to revolutionize the food industry and provide an avenue for the development of innovative products.

Data availability statement

Data will be made available on request.

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Additional information

Data included in article/supp. material/referenced in article.

CRediT authorship contribution statement

Badril Azhar: Writing – original draft, Visualization, Methodology. **Setiyo Gunawan:** Validation, Conceptualization. **Eunike Rhiza Febriana Setyadi:** Methodology, Investigation, Formal analysis. **Lailiyah Majidah:** Formal analysis, Data curation. **Fadlilatul Taufany:** Validation, Investigation. **Lukman Atmaja:** Software, Project administration, Methodology. **Hakun Wirawasista Aparamarta:** Writing – review & editing, Visualization, Validation, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e21972.

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