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Effect of ultrasonic-cellulase treatment towards bamboo shoot (*Gigantochloa albociliata*) powder properties

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Abstract

This study was to evaluate the optimum condition of ultrasonic-cellulase treatment for the highest conversion of insoluble to soluble dietary fibre in bamboo shoot powder. The interaction between independent variables (frequency, time and cellulase concentration) with response variables (water holding capacity, oil holding capacity and swelling capacity) was evaluated and optimized using Response Surface Methodology (RSM) coupled with a Central Composite Design (CCD). The results showed that the optimum condition of ultrasonic-cellulase treatment was as follows, the ultrasonic frequency at 21 Hz, ultrasonic time at 5 mins, and cellulase concentration at 30 mg/g of bamboo shoot powder. The model generated by RSM was validated since all the percentage errors for all the responses were less than 5%. A comparison between treated and untreated bamboo shoot powder was performed where treated bamboo shoot powder showed significant differences from untreated bamboo shoot powder in terms of water holding capacity (85.68%), oil holding capacity (39.45%) and swelling capacity (50.75%) with $P<0.05$. In conclusion, the result indicated that ultrasonic-cellulase treatment on the conversion of the insoluble to soluble dietary fibre in bamboo shoot powder had been successfully achieved.

1. Introduction

Bamboo is woody grasses with hard and hollow stem cells usually found in tropical, subtropical, and mild temperature zones. The bamboo plant plays a vital role in economics because of its wide application such as in construction, food, biofuel, and the production of paper pulp, craft, and fabrics (Hossain *et al*., 2015). One of the edible parts of bamboo is bamboo shoots. Bamboo shoots are young edible sprouts that are traditional forest vegetables with a long history of use in China and Southeast Asia as sources of food and medicine (Bao, 2006). It is recommended as food for a healthy diet because high in dietary fibre (DF) content (6 to 8 g/ 100 g fresh weight), low in calories and fat, and rich in various nutrients (Chongtham *et al*., 2011).

Total DF in bamboo shoots primarily consist of 73.4% insoluble dietary fibre (IDF) with only 1.1% soluble dietary fibre (SDF) (Li *et al*., 2016). Consuming a large amount of indigestible IDF in bamboo shoots will result in some health effects. Excessive intake of IDF might cause gas production in the human body and impact health such as abdominal bloating, stomach cramps and flatulence (El-Salhy *et al*., 2017). Meanwhile, SDF is beneficial for human physiological function. One of the benefits of SDF is it can dissolve in gastrointestinal fluid forming a gel-like substance that effectively enhances digestion in the digestive system (Chawla and Patil, 2010). It also improves glycemia and insulin sensitivity (Anderson *et al*., 2009), increasing micronutrient adsorption, lowering serum lipids, and stabilising blood glucose (Slavin *et al*., 2009). Moreover, SDF helps in adding bulk to the stool, promotes bowel movement and relieves constipation (Dhingra *et al*., 2012).

Therefore, many researchers have been conducting studies in dietary fibre treatment to increase SDF content including physical treatment such as stretching (Miao and Hamad, 2013), chemical treatments using chemical reagents of acid or alkali (Kumar *et al*., 2020) and enzymatic treatment (Canela-Xandri *et al*., 2018). Some researchers have studied the combination of physical with enzyme treatment for DF where the physical method was ultrasound with the aid of an enzyme called ultrasound-assisted enzymatic extraction (UAEE).

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UAEE method was a green and new extraction technology that increased the yield of extraction and physiological activities of extracts of various plants (Li *et al*., 2017). Ultrasound has mechanical and chemical effects on enhancing the extraction of the components from a plant (Vilkhu *et al*., 2008). An enzyme in UAEE improves the yield of the compound to be extracted (Angelina *et al*., 2018). In enzymatic treatment, the role of the cellulase enzyme is to hydrolyse the β-1,4 glycosidic bonds of cellulose to glucose. Hence, this cellulase modification also increased porosity on the surface of the fibre, reduced crystallinity and changes the chemical composition (Chen *et al*., 2011). The UAEE treatment on DF were conducted by previous research on pods (Chen *et al*., 2011), garlic straw (Zhao *et al*., 2019) and pomelo peel (Tang *et al*., 2016). Dual treatment shows more efficiency and gives a significant advantage over single treatment (Odendaal *et al*., 2016). Proven by the previous work of Yu and Zhao (2012), the yield of soluble dietary fibre from peanut shells is up to 18.54%. This is because introducing the ultrasound field into enzyme processing solution greatly promotes the transport of enzyme macromolecules towards the substrate surface. The mechanical impact produces by the collapse of cavitation causes opening up of solid substrate surfaces that allow the action of enzymes (Yachmenev *et al*., 2009).

However, there is no detailed study on the application of ultrasound-assisted enzyme treatment towards bamboo shoot powder. This study focused on the effect of ultrasonic-cellulase treatment on bamboo shoot powder based on water holding, oil holding and swelling capacity. The optimization was conducted using Central Composite Design (CCD) with variable parameters of ultrasonic frequency, time and cellulase concentration. The comparison between optimum treated bamboo shoots powder with untreated bamboo shoots powder based on its solubility was also measured.

2. Materials and methods

2.1 Sample preparation

The fresh edible bamboo shoots (*Gigantochloa albociliata*) were purchased from a wet market in Pasar Tani, Kangar. The fresh bamboo shoots were cleaned to remove foreign materials and dirt on the surface. The outer culm sheath was peeled off and the edible part of the bamboo shoots was washed and cut into smaller pieces around 5 cm. The bamboo shoots were boiled at 100°C for 30 mins and water was changed at every interval of 10 mins. Next, the bamboo shoots were dried in food dehydrator (Excalibur Products, Sacramento, CA) at 50°C for 24 hrs and were ground by using a blender (model 7010BU; Waring Commercial, Torrington, CT) to collect the bamboo shoot powder. Then, bamboo shoot powder was sieved at 60-mesh screen and stored in airtight containers.

2.2 Ultrasonic treatment

The bamboo shoot powder was placed in a beaker and was mixed with 1 mL of extraction solution at solid-water ratio of 1:10 (g/mL). Ultrasonic extraction equipment (Elmasonic S120H, Germany) was operated at the frequency range from 20 to 40 Hz and the time from 1 to 10 mins (Kumar *et al*., 2021).

2.3 Cellulase treatment

The treated ultrasonic bamboo shoot powder was mixed with 4 mL acetate buffer at pH 5.0. The concentration for enzymatic treatment of cellulase was used from 30 to 70 mg/g of bamboo shoot powder at 50°C for 24 hrs in a water bath (Memmert, Schwabach, Germany). After that, the sample was boiled to inactivate the enzyme activity at 95°C for 15 mins and then cooled to room temperature. The sample was centrifuged at 10000 rpm for 15 mins, the supernatant was decanted and the final residue was collected. The residue was dried in the oven (Memmert, Schwabach, Germanyat) 60°C for 24 hrs (Angelina *et al*., 2018).

2.4 Water holding capacity analysis

One gram of treated dry bamboo shoot powder sample was hydrated with 20 mL of distilled water in a centrifuge tube for 18 hrs at room temperature. Next, the sample mixture was centrifuged at 4000 rpm for 15 mins. The supernatant was decanted from the centrifuge tube and the new sample weight was recorded. The water holding capacity (WHC) was calculated by using Equation 1 below (Song *et al*., 2018).

$$\mathrm{WHC}\left(\frac{g}{g}\right) = \frac{m_1 - m_0}{m_0} \qquad (1)$$

where, m_1 = weight of the residue containing water (g), and m_0 = weight of the dry sample (g).

2.5 Oil holding capacity analysis

One gram of dry bamboo shoot powder sample was mixed with 20 mL of corn oil in a centrifuge tube for 18 hrs at room temperature. Next, the sample mixture was centrifuged at 4000 rpm for 15 mins. The supernatant was removed from the centrifuge tube and the new sample weight was recorded. The oil holding capacity (OHC) was calculated by using Equation 2 below (Luo *et al*., 2018).

$$\mathrm{OHC}\left(\frac{g}{g}\right) = \frac{m_2 - m_0}{m_0} \qquad (2)$$

where, m_2 = weight of residue containing oil (g), and

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m_0 = weight of the dry sample (g).

2.6 Swelling capacity analysis

One gram of dry bamboo shoot powder sample was weighed in a graduated test tube and the volume was recorded. Next, the sample was mixed with 10 mL of distilled water. Then, the sample was stirred and hydrated for 18 hrs at room temperature. The wet sample volumes were recorded. Swelling capacity was expressed as the volume of water (mL) per sample weight (g). The swelling capacity was calculated using Equation 3 below (Ma and Mu, 2016).

$$\text{Swelling Capacity}\left(\frac{mL}{g}\right) = \frac{V_1 - V_0}{m} \quad (3)$$

where, V_1 = volume of sample after absorbing moisture (mL), V_0 = volume of dry sample (mL), and m = weight of dry sample (g).

2.7 Optimization of ultrasonic-cellulase treatment

Response surface methodology (RSM) was used to investigate the effects of three independent variables, namely ultrasonic frequency, time and concentration of cellulase on three dependent variables which are water holding, oil holding and swelling capacity. The parameter value was set at a specific range where the frequency was 20 to 40 Hz, time was 1 to 10 mins, and cellulase concentration was 30 to 70 mg/g. RSM using Design Expert Version 12.0.10 (Stat-Ease Inc. Minneapolis, USA) derived condition results in 20 sets of experiments run. Statistical analyses were performed to evaluate an analysis of variance (ANOVA) of the data obtained. Criteria for all statistical significance followed the rule of having a 5% significant level ($p \leq 0.05$).

2.8 Validation of model

The experimental results were compared with predicted results obtained from the optimised model to determine the accuracy of response surface mode. Percentage error (PE) was used to determine the validation of the RSM model by using equation 4 below and PE that less than 5% denotes a good correlation (Pathera *et al*., 2017).

$$E(\%) = \frac{m_{ev} - m_{pv}}{m_{ev}} \times 100\% \quad (4)$$

where m_{ev} = experimental value and m_{pv} = predicted value.

2.9 Statistical analysis

An independent T-test was applied to compare the water-holding capacity, oil-holding capacity and swelling capacity of optimum treated bamboo shoot powder with untreated bamboo shoot powder by using IBM SPSS Statistics (Version 26). The data were reported as mean ± standard deviation (SD) with triplicate analysis of samples (n = 3) and the significance level was determined at probability 0.05.

3. Results and discussion

3.1 Model fitting

Table 1 shows the lower and upper values for the independent variables (frequency, time and cellulase concentration) and the experimental results for water holding capacity (WHC), oil holding capacity (OHC) and swelling capacity of treated bamboo shoot powder as responses. Each of the response surface variables was fitted to a second-order polynomial response surface model. The corresponding fitting of the models and the experimental data of the WHC, OHC and swelling capacity were analysed and compared in terms of the P-value (Prob > F), lack of fit, and predicted coefficient of determination (R^2). These criteria were used in the model selection that determine the appropriate model for the response variables (Aydar, 2018). Table 2 shows all the responses fitted to the quadratic model that gave a significant P-value that was less than 0.05, R^2 value that was closer to 1.0 and a lack of fit is non-significant for all the models (P>0.05).

3.2 Effect of ultrasonic frequency, time and concentration of cellulase on water holding capacity

Water holding capacity (WHC) is the ability of fibre to absorb or prevent water from being released from a three-dimensional structure (Ramasamy *et al*., 2015). The ANOVA results for the quadratic equation in the WHC of the treated bamboo shoot powder are shown in Table 3. According to the statistical analysis, all the model terms X_1, X_2, X_3, $X_1 X_2$, $X_1 X_3$, $X_2 X_3$, X_{12}, X_{22} and X_{32} were found to be significant. The second-order polynomial equation was fitted using the equation 5 model for WHC (Y_1) as follows:

$$\text{WHC}(Y_1) = 5.58 - 0.0300X_1 - 0.0330X_2 - 0.0240X_3 - 0.0225X_1X_2 - 0.0450X_1X_3 + 0.0250X_2X_3 - 0.0514X_1^2 - 0.0864X_2^2 - 0.1114X_3^2 \quad (5)$$

The increment in ultrasound frequency, time and cellulase concentration resulted in a WHC increase. Ultrasonic-assisted enzymatic hydrolysis methods enhance WHC due to ultrasound treatment loosens the fibre network structure, and exposes more polar groups and water-binding sites to the surroundings, which increases the absorption of water molecules (Xie *et al*., 2017). While the enzymatic modification hydrolyses cellulose and hemicellulose components and disrupts the structure of dietary fibre (Cheng *et al*., 2017). A similar trend was observed in the study conducted by He *et al*. (2020) on the increased WHC in ultrasonic (150W, 30 mins) – assisted enzymatic (230 U of cellulase and 900

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Table 1. Experimental design in actual level and experimental results of all responses towards treated bamboo shoots powder.

Run	Independent variables			Responses		
	Frequency (Hz) (X_1)	Time (mins) (X_2)	Cellulase concentration (mg/g) (X_3)	Water holding capacity (g/g) (Y_1)	Oil holding capacity (g/g) (Y_2)	Swelling capacity (mL/g) (Y_3)
1	30	5.5	50	5.62	1.50	0.70
2	30	5.5	50	5.53	1.47	0.73
3	40	1.0	30	5.31	1.26	0.45
4	30	5.5	50	5.60	1.51	0.65
5	20	10	30	5.45	1.27	0.40
6	20	1.0	30	5.42	1.25	0.43
7	30	5.5	70	5.46	1.45	0.53
8	30	5.5	50	5.59	1.52	0.63
9	40	1.0	70	5.40	1.38	0.35
10	40	10	70	5.24	1.20	0.23
11	40	10	30	5.26	1.22	0.30
12	40	5.5	50	5.50	1.41	0.57
13	20	10	70	5.26	1.34	0.33
14	30	5.5	50	5.60	1.55	0.70
15	30	1.0	50	5.54	1.46	0.57
16	30	5.5	50	5.55	1.54	0.65
17	20	1.0	70	5.32	1.44	0.37
18	30	5.5	30	5.48	1.39	0.63
19	20	5.5	50	5.56	1.49	0.65
20	30	10	50	5.45	1.33	0.50

Table 2. Summary for linear, 2FI (two-factor interaction) and quadratic model on response variable of bamboo shoots powder.

Responses	Model	Prob>F Sequential p-value	Lack of Fit	Predicted R^2
Water holding capacity	Linear	0.6747	0.0020	-0.6750
	2FI	0.7150	0.0013	-5.1374
	Quadratic	< 0.0001	0.9700	0.9469
Oil holding capacity	Linear	0.3154	0.0018	-0.4328
	2FI	0.7963	0.0011	-4.2291
	Quadratic	<0.0001	0.5899	0.8895
Swelling capacity	Linear	0.6570	0.0014	-0.6349
	2FI	0.9808	0.0007	-5.7705
	Quadratic	< 0.0001	0.9782	0.9538

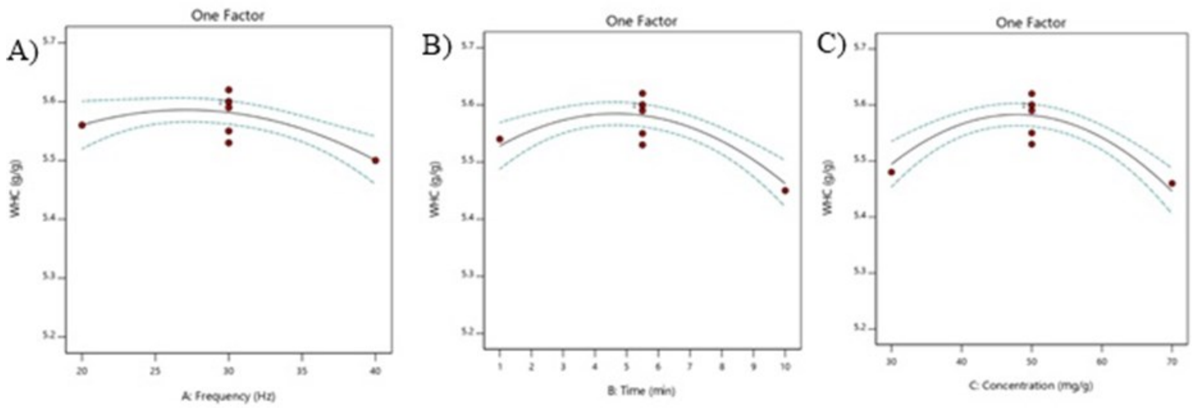

Figure 1. A) The effect of frequency, B) time and C) cellulase concentration on water holding capacity (WHC) of bamboo shoot powder.

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Table 3. ANOVA result for the water holding capacity of treated bamboo shoots powder.

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.2820	9	0.0313	46.20	< 0.0001	significant
X_1	0.0090	1	0.0090	13.27	0.0045	
X_2	0.0109	1	0.0109	16.05	0.0025	
X_3	0.0058	1	0.0058	8.49	0.0155	
$X_1 X_2$	0.0041	1	0.0041	5.97	0.0346	
$X_1 X_3$	0.0162	1	0.0162	23.88	0.0006	
$X_2 X_3$	0.0050	1	0.0050	7.37	0.0217	
X_1^2	0.0073	1	0.0073	10.70	0.0084	
X_2^2	0.0205	1	0.0205	30.24	0.0003	
X_3^2	0.0341	1	0.0341	50.28	< 0.0001	
Residual	0.0068	10	0.0007			
Lack of fit	0.0009	5	0.0002	0.15	0.97	not significant
Pure Error	0.0059	5	0.0012			

*X_1, X_2 and X_3 are the linear terms for treated bamboo shoot powder.
*X_1X_2, X_1X_3, and X_2X_3 are the interaction term between independent variables.
*X_1^2, X_2^2 and X_3^2 are the quadratic terms for treated bamboo shoot powder.

U of xylanase) treated rose pomace dietary fibre.

Figure 1 shows all the factors have a bell-shaped graph. The WHC in bamboo shoot powder was increased with the increasing of ultrasonic frequency, time and cellulase concentration until reached the maximum condition at the frequency at 30 Hz, time at 5.5 mins and 50 mg/g of cellulase concentration. However, further increased in frequency, longer time and higher cellulase concentration causes the WHC of the treated bamboo shoot powder to decrease. This may be due to the higher ultrasound frequency and time causing cell structure more serious damage (Wu *et al*., 2020). In addition, the higher cellulase concentration in the treatment causes degradation of soluble dietary fibre due to cellulase converting certain soluble dietary fibre into short-chain oligosaccharides (Ma *et al*., 2022).

3.3 Effect of ultrasonic frequency, time and concentration of cellulase on oil holding capacity

Oil holding capacity (OHC) is commonly attributed to the physical entrapment of fat by the protein (Nguyen *et al*., 2015). The ANOVA results for the quadratic equation in the OHC of the treated bamboo shoot powder were tabulated in Table 4. According to the statistical analysis, the model was significant since the P-value with P < 0.0001 less than 0.05. Most of the model terms X_1, X_2, X_3, X_2 X_3, X_{12}, X_{22} and X_{32} were significant except for X_1 X_2 and X_1 X_3. The second-order polynomial equation was fitted using the equation 6 model for OHC (Y_2) as follows:

$$\text{OHC } (Y_2)= 1.51 - 0.0320X_1 - 0.0430X_2 + 0.0420X_3 - 0.0175X_1X_2 + 0.0200X_1X_3 - 0.0325X_2X_3 - 0.0432X_1^2 - 0.0982X_2^2 - 0.0732X_3^2 \quad (6)$$

Figure 2 shows all the factors have a bell-shaped graph. The OHC in bamboo shoot powder was increased with the increase of ultrasonic frequency, time and cellulase concentration until it reached a certain level which was the frequency at 30 Hz, time at 5.5 mins and 50 mg/g of cellulase concentration. However, beyond this condition, the OHC started to decrease. Similar work done by Hassan *et al*. (2021) states ultrasound treatment increases the OHC in chia seeds dietary fibre until reaches a certain frequency and time. OHC level decrease might be due to the enzyme degrading the linkage of polysaccharides, polar groups and hydrogen bonds. The OHC decreased with a decrease in particle size due to the destruction of the dietary fibre matrix structure (Zheng and Li, 2018).

3.4 Effect of ultrasonic frequency, time and concentration of cellulase on swelling capacity

Swelling capacity is determined by the content of water against the fibre components of foods. The contents of hydrophilic components such as hemicellulose and cellulose affect the swelling capacity which is related to hydration properties. The ANOVA results for the quadratic equation in the swelling capacity of the treated bamboo shoot powder were tabulated in Table 5. According to the statistical analysis, the model was significant since the P-value with P < 0.0001 less than 0.05. Most of the model terms X_1, X_2, X_3, X_1 X_2, X_{12}, X_{22} and X_{32} were significant except for X_1 X_3 and X_2 X_3. The second-order polynomial equation 7 was fitted using the equation model for swelling (Y_3) as follows:

$$\text{Swelling Capacity } (Y_3)=0.6787-0.0280X_1-0.0410X_2-0.0400X_3-0.0250X_1X_2 + 0.0050X_1X_3-0.0025X_2X_3-0.0718X_1^2-0.1468X_2^2-0.1018X_3^2 \quad (7)$$

The increment in ultrasound frequency, time and cellulase concentration resulted in a swelling capacity

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Table 4. ANOVA result for the oil holding capacity of treated bamboo shoots powder.

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.2323	9	0.0258	34.41	< 0.0001	significant
X_1	0.0102	1	0.0102	13.65	0.0041	
X_2	0.0185	1	0.0185	24.65	0.0006	
X_3	0.0176	1	0.0176	23.52	0.0007	
$X_1 X_2$	0.0025	1	0.0025	3.27	0.1008	
$X_1 X_3$	0.0032	1	0.0032	4.27	0.0658	
$X_2 X_3$	0.0084	1	0.0084	11.27	0.0073	
X_1^2	0.0051	1	0.0051	6.84	0.0258	
X_2^2	0.0265	1	0.0265	35.34	0.0001	
X_3^2	0.0147	1	0.0147	19.63	0.0013	
Residual	0.0075	10	0.0008			
Lack of fit	0.0034	5	0.0007	0.8074	0.5899	not significant
Pure Error	0.0042	5	0.0008			

*X_1, X_2 and X_3 are the linear terms for treated bamboo shoot powder.
*X_1X_2, X_1X_3, and X_2X_3 are the interaction term between independent variables.
*X_1^2, X_2^2 and X_3^2 are the quadratic terms for treated bamboo shoot powder.

Table 5. ANOVA result for the swelling capacity of treated bamboo shoots powder.

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.4281	9	0.0476	55.83	< 0.0001	significant
X_1	0.0078	1	0.0078	9.20	0.0126	
X_2	0.0168	1	0.0168	19.73	0.0013	
X_3	0.0160	1	0.0160	18.78	0.0015	
$X_1 X_2$	0.0050	1	0.0050	5.87	0.0359	
$X_1 X_3$	0.0002	1	0.0002	0.2347	0.6385	
$X_2 X_3$	0.0000	1	0.0000	0.0587	0.8135	
X_1^2	0.0142	1	0.0142	16.65	0.0022	
X_2^2	0.0593	1	0.0593	69.57	< 0.0001	
X_3^2	0.0285	1	0.0285	33.46	0.0002	
Residual	0.0085	10	0.0009			
Lack of fit	0.0010	5	0.0002	0.1311	0.9782	not significant
Pure Error	0.0075	5	0.0015			

*X_1, X_2 and X_3 are the linear terms for treated bamboo shoot powder.
*X_1X_2, X_1X_3, and X_2X_3 are the interaction term between independent variables.
*X_1^2, X_2^2 and X_3^2 are the quadratic terms for treated bamboo shoot powder.

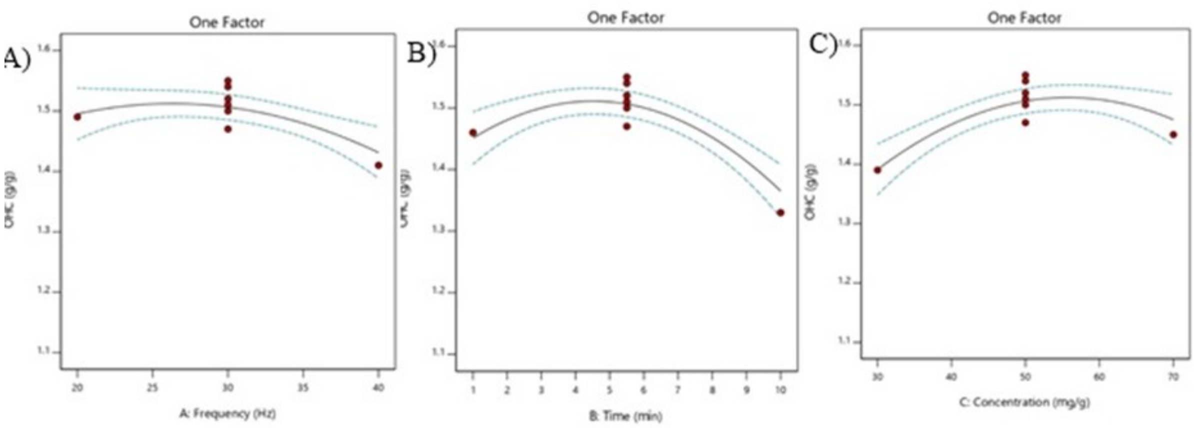

Figure 2. The effect of A) frequency, B) time and C) cellulase concentration on oil holding capacity (OHC) of bamboo shoots powder.

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increase. The study by Sang *et al*. (2021) using ultrasound-assisted enzymatic treatment in orange by-products which were peel and residue states the ultrasound treatment can loosen the inner structure of orange fibres and break hydrogen bonds. Whereas, the enzymatic treatment can further break cellulose chains and convert insoluble dietary fibre content into low molecular weight substances, thus increasing the content of the soluble dietary fibre (Thị Hồng Hạnh *et al*., 2021).

Figure 3 shows the swelling capacity in bamboo shoot powder was increased with the increasing of ultrasonic frequency, time and cellulase concentration until reached the condition at the frequency at 30 Hz, time at 5.5 mins and 50 mg/g of cellulase concentration. Nevertheless, the further increase in frequency, the longer time and the higher cellulase concentration the swelling capacity started to decrease. According to the work done by Song *et al*. (2014) using ultrasonic-enzymatic extraction of dietary fibre using cellulase on peanut meal, the increase in ultrasonic power, time extraction and concentration enzyme increase the swelling capacity of peanut meal until the maximum point and start to reduce. As the ultrasonic strength increases, pores and channels in the surface of the fibrous particles will be ruptured, this might reduce their ability to interact with water molecules (Fan *et al*., 2020). In addition, higher concentrations of cellulase eventually degrade cellulose and hemicellulose into oligosaccharides which decrease the hydrolysis of the substrate.

3.5 Optimization and validation

The goal for frequency and time for ultrasound treatment and cellulase concentration for enzymatic treatment was set in range. Meanwhile, the goal responses were set to maximize WHC and swelling capacity to obtain the maximum conversion of soluble dietary fibre while minimising OHC to obtain the minimum content of insoluble dietary fibre in bamboo shoot powder. The optimised factors for ultrasonic-cellulase treatment on bamboo shoot powder were the ultrasonic frequency at 21 Hz and ultrasonic time at 5 mins as well as cellulase concentration at 30 mg/g. These optimum conditions are predicted from mathematical models involving a maximum desirability of 0.75. The percentage error calculated was not more than 5% of experimental data thus confirming the accuracy of the model produced by the RSM.

3.6 Comparison between untreated and treated bamboo shoot powder

The optimum condition of ultrasonic-cellulase treatment on treated bamboo shoot powder that was obtained from RSM was used to compare with untreated bamboo shoot powder. The comparison between untreated and treated bamboo shoot powder was done in terms of WHC, OHC and swelling capacity. Table 6 shows that the treated bamboo shoot powder was significantly ($P<0.05$) higher in terms of WHC (5.518±0.001 g/g) as compared to the untreated (2.208±0.007 g/g). The percentage difference between the treated and untreated bamboo shoot powder in terms of WHC was 85.68%, indicating the solubility of soluble dietary fibre was increased after the ultrasonic-cellulase treatment. In terms of OHC of treated bamboo shoot powder (1.384±0.014 g/g) results were shown significantly ($P<0.05$) higher than untreated bamboo shoot powder (0.928±0.004 g/g). The percentage difference between the treated and untreated bamboo shoot powder in terms of OHC was 39.45%. Whereas the swelling capacity, the result showed that treated bamboo

Table 6. Comparison of WHC, OHC and swelling capacity of untreated and optimum treated bamboo shoots powder.

Analysis	Sample	
	Untreated	Treated
Water holding capacity (g/g)	2.208±0.007[a]	5.518±0.001[b]
Oil holding capacity (g/g)	0.928±0.004[a]	1.384±0.014[b]
Swelling capacity (mL/g)	0.347±0.006[a]	0.583±0.001[b]

Values are presented as mean±SD, n = 3. Values with different superscripts within the same column are statistically significantly different ($P\leq0.05$).

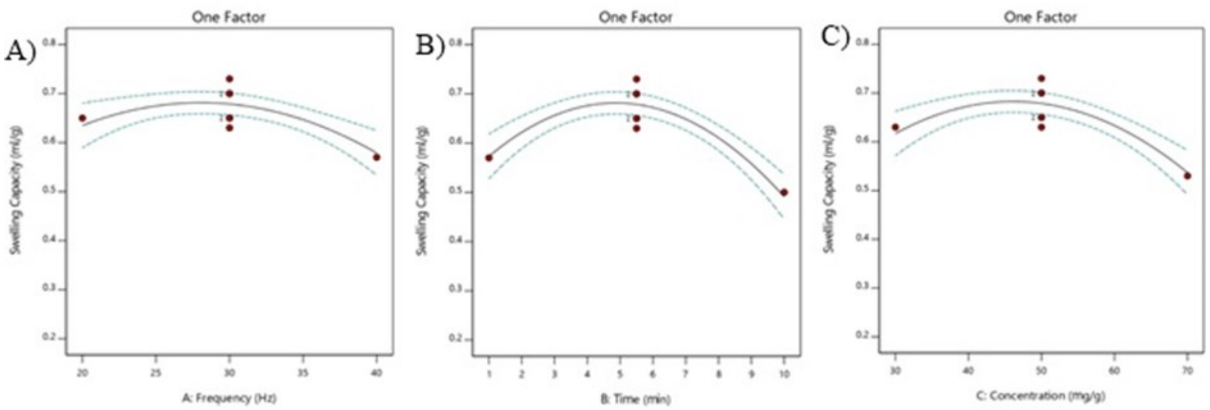

Figure 3. The effect of A) frequency, B) time and C) cellulase concentration on swelling capacity of bamboo shoots powder.

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shoot powder (0.583±0.001 mL/g) had significantly (P<0.05) higher than untreated bamboo shoot powder (0.347±0.006 mL/g). The percentage difference between the treated and untreated bamboo shoot powder in terms of swelling capacity was 50.75%. This indicates that the treated bamboo shoot powder had undergone a conversion of insoluble to soluble dietary fibre. The increased WHC and swelling capacity in treated bamboo shot powder could be due to the ultrasound treatment increasing the swelling capacity due to the cavitation process that breaks the intermolecular and intramolecular covalent crosslinks of macromolecules in the cell wall and releases freer hydroxyl group (Martinez-Solano *et al*., 2020). While, cellulase modification damages the crystalline area and creates amorphous domains in dietary fibre and water may more easily permeate into fibre structure, which enhances the swelling capacity (Liu *et al*., 2021). Nonetheless, only OHC showed higher in the treated sample compared to the untreated sample which could be due to the changes in the protein structure upon sonication and exposure to the non-polar groups on the surface of the bamboo shoot powder molecule, with a possibility of creating a larger surface area for oil adsorption, thus changed the OHC (Malik *et al*., 2017).

4. Conclusion

This study set out to assess the physiochemical properties of bamboo shoot powder treated by ultrasonic –assisted enzyme. The optimised condition of ultrasonic –assisted enzyme was set based on the highest content of water holding, swelling and oil holding capacity. Compared with untreated samples, ultrasonic–assisted enzymes significantly resulted in higher water holding and swelling capacity but also caused higher oil holding capacity. Ultrasonics are able to exert the cavitation process and release more hydroxyl groups, which enzyme modification could hydrolyse cellulose and hemicellulose components in the dietary fibre bamboo shoot powder. Overall, ultrasonic–assisted enzyme significantly improves the yield of soluble dietary fibre in bamboo shoot powder.

Conflict of interest

The authors declare no conflict of interest.

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Indicate any source of funding or other contributors to the work in a single paragraph and keep at the minimum.

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