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EFFECT OF EXTRACTION METHODS ON THE PHYSICOCHEMICAL PROPERTIES OF FIBER FROM BAMBOO SHOOT WASTE

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ABSTRACT

Canned bamboo shoot process generated bamboo shoot waste about 50% of raw material. This waste was a rich source of dietary fiber. This study investigates the effect of extraction methods, including (1) water, (2) citric acid, (3) ethanol, acid and base, and (4) enzymatic solution, on the physicochemical properties of dietary fiber of bamboo shoots base and strips. The results indicated that enzymatic extraction of bamboo shoots base provided the highest total dietary fiber (79.05%), soluble dietary fiber (34.72%), water holding capacity (15.08 g/g) and swelling capacity (7.23 mL/g). Therefore, enzymatic extraction of bamboo shoots waste was able to provide a potential dietary fiber which can be used as an ingredient in functional foods.

Key words: Bamboo shoot waste, dietary fiber, physicochemical properties

INTRODUCTION

Bamboo shoot is an economic plant of Thailand that has been processed into pickled bamboo shoots and canned bamboo shoots at the industrial level. In bamboo shoots canning process, most producers use only the tip of bamboo shoots trimmed to a length of about 15-20 cm. The remaining base of bamboo shoots (about 50% of raw material weight) becomes waste and is sold as animal feed and fertilizer at a low cost. However, bamboo shoot waste is a rich source of dietary fiber and antioxidants (Resende *et al*., 2019).

Dietary fiber is carbohydrate polymers that cannot be digested by endogenous enzymes in the human gastrointestinal tract. In general, dietary fiber can be divided into two types according to water solubility, including insoluble dietary fiber (IDF, e.g. cellulose, hemicellulose and lignin) and soluble dietary fiber (SDF, e.g. pectin and some hemicelluloses) (Beres *et al*., 2016). At present, many studies have shown that adequate intake of dietary fiber can reduce the risk of chronic diseases such as obesity, type 2 diabetes, cardiovascular disease and cancer (Lin *et al*., 2019a). The benefit of dietary fiber depends not only on consumption but also on the dietary fiber preparation process. Many factors related to the production process such as structural elements, particle size and properties of dietary fiber can differently influence the quality of dietary fiber.

Dietary fiber extraction involves using various solvents to eliminate other non-dietary fiber substances, i.e. carbohydrates, proteins and lipids. Many extracting solvents were reported in previous kinds of literature including water, ethanol, acid, base and enzyme solutions (Rouhou *et al*., 2018). Each method had the main purpose of eliminating different substances thus affecting the quality of dietary fiber obtained differently. The aim of this work was to study different fiber extraction methods from the bamboo shoots waste and to investigate their effect on physicochemical properties of extracted dietary fibers.

MATERIALS AND METHODS

Materials

Bamboo shoot waste was obtained from Fang Inter Foods Co. Ltd., Chiang Mai, Thailand. Two types of bamboo shoots waste were collected including (1) bamboo shoot base that was trimmed

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off prior to processing and (2) small bamboo shoot strip that became waste during processing. Both bamboo shoot wastes were cleaned and chopped into pieces of 0.5–1.5 cm length for dietary fiber extraction.

Proximate composition

Moisture, ash and fat contents were determined in triplicates according to the methods of AOAC (2000). Protein contents was measured by the biuret method because bamboo shoot had high nucleotides content, which were interferences in Kjeldahl nitrogen method. Soluble, insoluble and total dietary fiber contents were measured by Megazyme test kit (Megazyme, Ireland).

Extraction of fiber

Extraction by hot water

Water extraction was modified from the protocol of Liu (2007). Fresh bamboo shoot waste (100 g) was soaked in water (1:3 w/v) and incubated at 60°C in a shaking water bath at 130 rpm for 90 min. After that, it was filtered and washed twice with 300 mL of distilled water. The obtained residues were dried in a hot-air oven at 60°C for 20 hours and crushed into powder (35 mesh) to obtain bamboo shoot powder extracted with water (BSP-W).

Extraction by citric acid solution

Extraction method was modified from the protocol of Wang *et al*. (2013). Fresh bamboo shoot waste (100 g) was soaked in 1% citric acid (1:3 w/v) and incubated at 80°C in a shaking water bath at 130 rpm for 90 min to eliminate the astringency of bamboo shoots. Then, it was filtered and washed twice with 300 mL of distilled water. The obtained residues were dried in a hot-air oven at 60°C for 20 hours and crushed into powder (35 mesh) to obtain bamboo shoot powder extracted with citric acid (BSP-CA).

Extraction by ethanol, alkali and acid solutions

The method was modified from the protocol of Hu and Chen (2006). Fresh bamboo shoot waste (100 g) was shaken (130 rpm) in 70% ethanol (1:3 w/v) at 60°C for 1 hour to remove pigments followed by shaking in 0.4% sodium hydroxide and citric acid at room temperature for 1 hour, respectively. Then, it was filtered and washed twice with 300 mL of distilled water. The obtained residues were dried in an oven at 60°C for 20 hours and crushed into powder (35 mesh) to obtain bamboo shoot powder extracted with ethanol, alkali and acid (BSP-EAA).

Enzymatic extraction

Enzymatic extraction by amylase and proteases was modified from the protocol of Chen *et al*. (2013). Fresh bamboo shoot waste (100 g) was soaked in phosphate buffer (pH 6.5, 1:3 w/v). Starch hydrolysis was performed by adding 200 U/g of amylase at 60°C for 15 min. Subsequently, it was filtered, washed twice with 300 mL of distilled water and added with 200 U/g of protease at pH 7.0, 40°C for 30 min for protein hydrolysis. Afterwards, it was filtered and washed twice with 300 mL of distilled water. The obtained residues were dried in the oven at 60°C for 20 hours and crushed into powder (35 mesh) to obtain bamboo shoot powder extracted with enzymes (BSP-EN).

Physicochemical properties

Water holding capacity (WHC)

WHC was determined according to Luo *et al.* (2018), with some modifications. An accurately weighed dry sample (1.0 g) was hydrated with 20 mL deionized water in a centrifuge tube at room temperature for 1 hour. The supernatant was removed by centrifugation (3,000 rpm, 20 min) and the residue was immediately collected and weighted. WHC was calculated according to equation (1):

$$\text{WHC (g/g)} = (w_2 - w_1) / w_1 \qquad (1)$$

Where,
w_2: weight of the residue containing water (g).
w_1: was the weight of the dry sample (g).

Swelling capacity (SC)

SC was determined according to Luo *et al*. (2017), with some modifications. An accurately weighted dry sample (0.2 g) was placed in a 10 mL measuring tube. Then 5 mL of distilled water was mixed into the sample and maintained at room temperature for 24 hours. Any trapped air bubbles were removed. The volume (mL) of hydrated sample was recorded and SC was calculated according to equation (2):

$$\text{SC (mL/g)} = (v_1 - v_0) / w_1 \qquad (2)$$

Where,
v_1: volume of the hydrated fiber.
v_0: volume of fiber prior to hydration.
w_1: was the weight of fiber prior to hydration.

Oil binding capacity (OBC)

OBC was determined according to Luo *et al*. (2017), with some modifications. One gram of dry fiber sample was added with 20 mL of sunflower oil in a centrifuge tube and maintained for 1 hour at 37°C. The mixture was centrifuged at 10,000 rpm for 30 min. Then the supernatant was removed and the pellet was recovered by filtration through a nylon cloth. OBC was calculated according to equation (3):

$$OBC\ (g/g) = (w_2 - w_1) / w_1 \qquad (3)$$

Where,
w_2: is the weight of the residue containing oil (g).
w_1: is the weight of dry sample (g).

Color values

The color value in CIE coordinates (L^*, a^*, b^*) were directly read in a glass cuvette with Ultra Scan VIS Spectrophotometer (Hunter Associates Laboratory Inc., Reston, VA, USA). In this coordinate system, the L* value is a measure of lightness, ranging from 0 (black) to 100 (white), the a* value ranges from -100 (greenness) to +100 (redness) and the b* value ranges from -100 (blueness) to +100 (yellowness). Whiteness value (W) was calculated by equation (4) (Ullah *et al*., 2019).

$$W = 100 - ((100 - L^*)^2 + (a^*)^2 + (b^*)^2)^{1/2} \qquad (4)$$

Statistical analysis

Results were expressed as mean ± standard deviations. Mean comparison was performed by one-way analysis of variance (ANOVA), followed by Duncan's multiple range test at the level of significance at $p < 0.05$. Data were analyzed using IBM SPSS Statistics version 20.0.

RESULTS AND DISCUSSION

Proximate composition

The proximate composition of bamboo shoot base and strip are shown in Table 1. The content of total dietary fiber (TDF) of bamboo shoot strip was 12.01 ± 0.05%, consisting of IDF (11.74 ± 0.31%) and SDF (0.32 ± 0.31%), which is higher than bamboo shoot base that was composed of TDF (7.33 ± 0.10%), IDF (7.17 ± 0.05%) and SDF (0.16 ± 0.11%) of wet basis. This result revealed that SDF content was not significantly different. This might be due to both bamboo shoot waste was blanched in boiling water at high temperatures (100°C for 10 min), therefore contributing to a loss of SDF. Furthermore, TDF of bamboo shoot waste was higher than barley bran (17.10 ± 0.4%), quinoa seed (38.39 ± 0.5%), millet seed (38.49 ± 0.23%) (Lin *et al.,* 2019b), strawberry (23.3 ± 1.98 g/100 g), tomato (21.7 ± 2.17 g/100 g) and green pea (30.7 ± 2.43 g/100 g) of dry basis (Pastell *et al.,* 2019). This results indicated that bamboo shoots waste represents a rich source of dietary fiber.

Dietary fiber composition

Bamboo shoot powder yield, total dietary fiber (TDF), insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) contents of bamboo shoots powder extracted by water, citric acid, ethanol with acid and alkali, and enzymes were shown in Table 2.

The powder yield of bamboo shoot strip (17.29–18.45% wet basis) was higher than those of bamboo shoot base (12.17–13.54%), which might relate to differences in the moisture content of raw material (Ullah *et al*., 2019). The powder from bamboo shoot base had TDF content of 68.55 to 79.05% dry basis), with BSP-EN had highest TDF (79.05 ± 8.45%) and

Table 1. Proximate composition of bamboo shoot wastes

Composition	Percentage	
	Bamboo shoot base	Bamboo shoot strip
Moisture	88.26 ± 0.50^a	82.58 ± 0.27^b
Ash	3.45 ± 0.05^a	1.90 ± 0.02^b
Protein	0.80 ± 0.07^b	1.25 ± 0.12^a
Lipid	2.16 ± 0.19^a	1.59 ± 0.18^b
Total dietary fiber (TDF)	7.33 ± 0.10^b	12.01 ± 0.05^a
Insoluble dietary fiber (IDF)	7.17 ± 0.05^b	11.74 ± 0.31^a
Soluble dietary fiber (SDF)	0.16 ± 0.11^a	0.32 ± 0.31^a

Note: Mean ± SD (standard deviation) of triplicates. Different letters within the same row are significantly different at $p < 0.05$.

Table 2. Yield, TDF, IDF and SDF content of bamboo shoot powder obtained by four extraction methods

Fiber	Yield (% wet basis)	Composition (% dry basis)		
		TDF	IDF	SDF
Bamboo shoot base				
BSP-W	12.40 ± 0.22^{b}	72.97 ± 1.78^{a}	68.86 ± 0.81^{a}	4.11 ± 0.96^{d}
BSP-CA	13.54 ± 0.15^{a}	68.55 ± 1.40^{a}	67.46 ± 0.16^{a}	1.09 ± 1.25^{c}
BSP-EAA	12.17 ± 0.38^{b}	75.37 ± 0.35^{a}	59.13 ± 1.02^{a}	16.24 ± 0.67^{b}
BSP-EN	12.50 ± 0.24^{b}	79.05 ± 8.45^{a}	44.33 ± 7.49^{b}	34.72 ± 0.95^{a}
Bamboo shoot strip				
BSP-W	17.60 ± 0.21^{ab}	69.82 ± 0.34^{b}	67.57 ± 3.11^{ab}	2.25 ± 2.77^{b}
BSP-CA	17.29 ± 0.16^{b}	71.21 ± 1.09^{ab}	69.25 ± 0.80^{a}	1.96 ± 1.89^{b}
BSP-EAA	17.62 ± 0.22^{ab}	73.02 ± 1.15^{a}	59.12 ± 5.83^{b}	13.90 ± 6.98^{a}
BSP-EN	18.45 ± 0.36^{a}	67.09 ± 0.49^{c}	47.81 ± 0.31^{c}	19.28 ± 0.18^{a}

Note: TDF: total dietary fiber; IDF: insoluble dietary fiber; SDF: soluble dietary fiber. BSP-W: bamboo shoot powder extracted with water; BSP-CA: bamboo shoot powder extracted with citric acid; BSP-EAA: bamboo shoot powder extracted with ethanol, acid and alkali solution; BSP-EN: bamboo shoot powder extracted with enzymes. Mean ± SD (standard deviation) of triplicate analyses. Different letters within the same column are significantly different at $p < 0.05$.

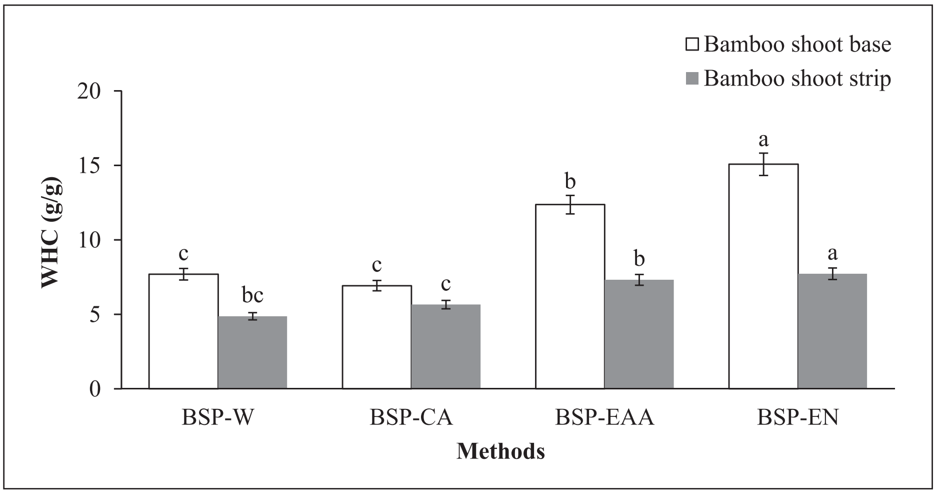

Fig. 1. Water holding capacity (WHC) of bamboo shoots powder. BSP-W: bamboo shoot powder extracted with water; BSP-CA: bamboo shoot powder extracted with citric acid; BSP-EAA: bamboo shoot powder extracted with ethanol, acid and alkali solution; BSP-EN: bamboo shoot powder extracted with enzymes. Bars represent mean values ± SD of triplicate analyses. Different letters above bars with the same color show significant differences ($p < 0.05$).

SDF (34.72 ± 0.95%). This result indicated that the enzymes hydrolyzed dietary fiber, which may contribute to the release of trapped soluble fiber, thus influencing the ratio between IDF and SDF (Zhang *et al*., 2018). The same trend was also found in the bamboo shoot strip.

Physicochemical properties

Water holding capacity (WHC)

The water holding capacity is defined as a moist material to hold water when subjected to an external force (Luo *et al.,* 2017). As shown in Figure 1. The highest WHC was found in BSP-EN obtained from bamboo shoot base (15.08 g/g), which was significantly higher than BSP extracted by other solvents ($p < 0.05$). For bamboo shoot strip, BSP-EN had the highest WHC (7.73 g/g) compared with other treatments ($p < 0.05$). WHC of BSP-EN was higher than those of cumin (6.26 g/g), foxtail millet bran (3.24 g/g), coconut kernels (10.71 g/g) and mango peel (11.40 g/g) (Ma & Mu, 2016; Zhu *et al.,* 2018; Chau *et al.,* 2007). WHC depended on particle size, processing condition, and surface characteristics, such as porosity, charge density, surface, and microstructure. Besides, WHC is also related to the content of SDF (especially of pectin). Therefore, the higher the content of SDF, the higher the WHC value (Ma & Mu, 2016).

Swelling capacity (SC)

The swelling capacity is defined as the volume of water occupied by a hydrated sample immersed in an excess of water (Luo *et al.,* 2017). The highest SC was found in BSP-EN obtained from bamboo shoot base (7.23 mL/g), followed by BSP-W, BSP-EAA and BSP-CA, respectively (Figure 2). For bamboo shoot strip, BSP-EN had the highest SC (5.05 mL/g), which was significantly higher than other treatments. SC of BSP-EN from bamboo shoot waste was similar to that of TDF from bamboo shoot shell (7.16 mL/g) (Luo *et al.,* 2017). The SC is related to structural characteristics (particle size distribution, surface area and bulk density) and chemical composition, which may be manipulated by pretreatments and extraction methods (Yalegama *et al.,* 2013; Lan *et al.,* 2012; Wuttipalakorn *et al.,* 2009). Higher SC is associated with lower bulk density, smaller particle size and larger surface area, which was positively correlated with TDF and SDF contents of the fibers (López-Marcos *et al.,* 2015).

WHC and SC of fiber obtained from enzymatic extraction of bamboo shoot base were higher than those obtained from bamboo shoot strip. These might be due to the preparation of raw material before processing. Bamboo shoot base was blanched only once after harvest, while bamboo shoot strip was further cut into strips and blanched again. This size reduction and heat treatment caused a higher loss of SDF in bamboo shoot strip, which influenced hydration properties of dietary fiber.

Oil binding capacity (OBC)

OBC of dietary fibers is an important factor for preventing oil/fat loss during food processing and reducing oil/fat absorption during digestion in the human intestine (Luo *et al.,* 2018). As shown in Figure 3, OBC of BSP from bamboo shoot base was higher than that of bamboo shoot strip ($p < 0.05$). However, OBC values were not different between BSP from bamboo shoot strip extracted by different methods. For bamboo shoot base, the highest OBC was found in BSP-W (1.56 g/g), which was not significant when compared with BSP-CA (1.48 g/g), but significantly higher than BSP-EN (1.43 g/g) and BSP-EAA (1.19 g/g). The values obtained from this study were lower than that of dietary fibers extracted from bamboo shoot shell (4.74 g/g) (Luo *et al*., 2017). Navarro-González *et al*. (2011), reported that low OBC values might be due to the absence or slight presence of lignin in tomato DFs. This could also be explained that the lower OBC values of BSP extracted from bamboo shoot strip were because the tip of the bamboo shoots has low lignin content compared to the bamboo shoots base and shell.

Color values

Color is an important attribute of the foods affecting consumer acceptability (Ullah *et al*., 2019). The CIE values (L^*, a^*, b^*) of dietary fiber from all four methods are shown in Figure 4. The highest whiteness was found in BSP-EAA obtained from bamboo shoot strip (74.53 ± 0.47). For bamboo shoot base, BSP from different extraction method has no significant difference in whiteness values ($p < 0.05$). The samples with low whiteness value could be due to occurrence of brown color by Maillard reaction and oxidation process from contact between fiber and oxygen in air under extraction treatment (Zhang *et al*., 2018).

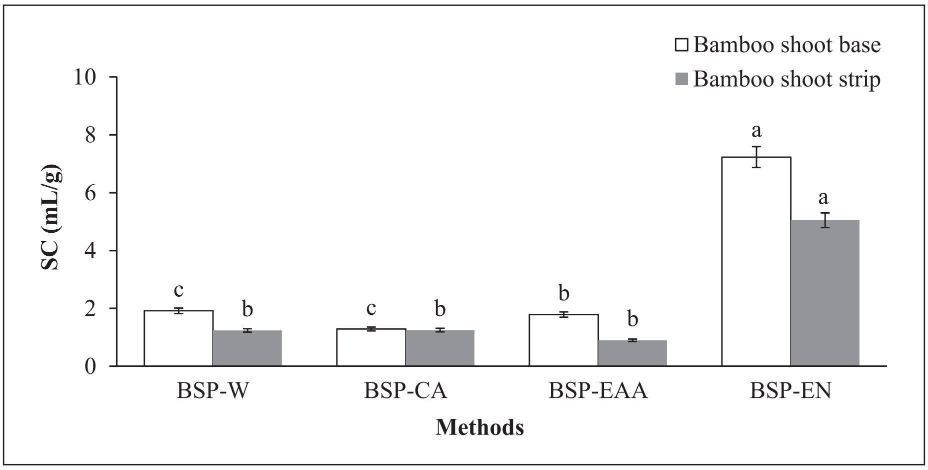

Fig. 2. Swelling capacity (SC) of bamboo shoots powder. BSP-W: bamboo shoot powder extracted with water; BSP-CA: bamboo shoot powder extracted with citric acid; BSP-EAA: bamboo shoot powder extracted with ethanol, acid and alkali; BSP-EN: bamboo shoot powder extracted with enzymes. Bars represent mean values ± SD of triplicate analyses. Different letters above bars with the same color show significant differences ($p < 0.05$).

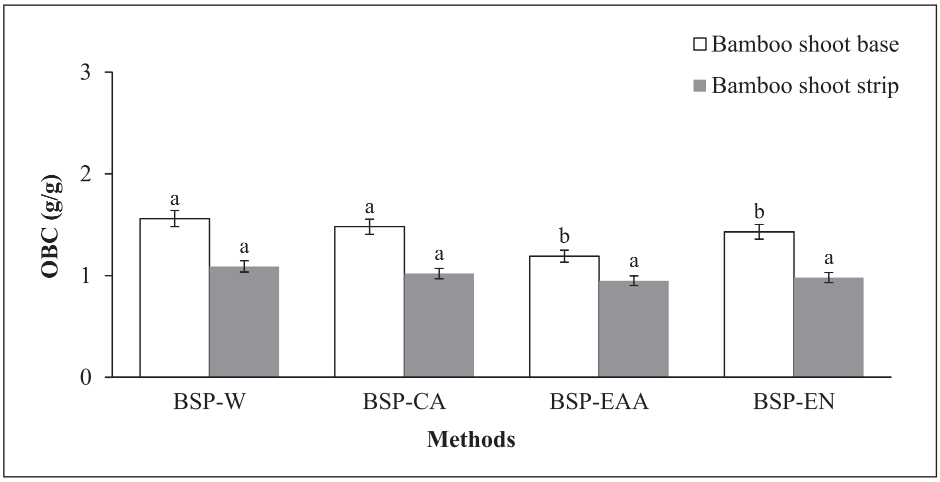

Fig. 3. Oil binding capacity (OBC) of bamboo shoots powder. BSP-W: bamboo shoot powder extracted with water; BSP-CA: bamboo shoot powder extracted with citric acid; BSP-EAA: bamboo shoot powder extracted with ethanol, acid and alkali; BSP-EN: bamboo shoot powder extracted with enzymes. Bars represent mean values ± SD of triplicate analyses. Different letters above bars with the same color show significant differences ($p < 0.05$).

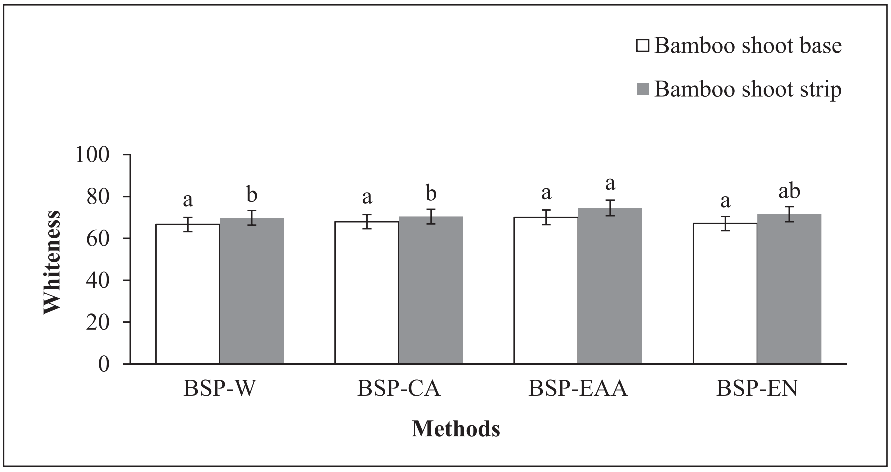

Fig. 4. Whiteness of bamboo shoots powder. BSP-W: bamboo shoot powder extracted with water; BSP-CA: bamboo shoot powder extracted with citric acid; BSP-EAA: bamboo shoot powder extracted with ethanol, acid and alkali; BSP-EN: bamboo shoot powder extracted with enzymes. Bars represent mean values ± SD of triplicate analyses. Different letters above bars with the same color show significant differences ($p < 0.05$).

CONCLUSION

The proximate composition analysis confirmed that bamboo shoots waste as a rich source of dietary fiber. Enzymatic extraction methods provided the highest yield of dietary fiber especially for bamboo shoot base, might be related to the structure and content of dietary fiber remaining from the process. Moreover, enzymatic extraction also provided dietary fiber with high water holding capacity and swelling capacity. Therefore, dietary fiber from bamboo shoots waste obtained by enzymatic extraction had the highest functional properties that can be used in food and health products as a functional ingredient.

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