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Effect of Particle Size on Physico-Chemical and Antioxidant Activity of Insoluble Dietary Fiber Powder from Corncob (*Zea mays* L.)

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Effects of particles size of dietary fiber powder on the physico-chemical properties and antioxidant activity of corncob were investigated. Corncob was grounded in a regularly mill and grinding characteristics and the particles size were evaluated by particle size analyzer (PSA) using laser diffraction method and Fourier transform infrared (FTIR). The results showed that the insoluble dietary fiber (IDF) powder from corncob had the highest crude fiber content (32.31%) and carbohydrates (55.07%). Spectral analysis shows that the IDF matrix structure does not change after grinding and has three characteristics of absorption spectra at 3433-3425 cm^{-1} (O-H); 2920 cm^{-1} (C-H) and 1635 cm^{-1} (aromatic) in presence of the special structures of polysaccharide and lignin compounds. Particle size analyzer (PSA) results showed that the size of IDF 200 mesh and 80 mesh powder were 63.13 and 260.89 µm, respectively. The insoluble dietary fiber (IDF) significantly shows a decrease in dietary fiber content in line with the reduction in particle size. The IDF powder with a particle size of 63.13 µm showed that highest total phenolic content accompanied with the best antioxidant activity through all antioxidant assays ($p < 0.05$). This study concluded that the IDF micro-powder particle size exerted influence on physico-chemical properties, dietary fiber, total phenolic and antioxidant activity.

Keywords: Corncobs, Particle size, Dietary fiber, Antioxidant activity, Phytochemicals.

INTRODUCTION

Corncobs, which are influenced by corn varieties and contribute up to 30% of corn, are the main byproducts of corn processing. Due to their abundance, corncobs can be utilized as the source of phytochemicals and dietary fibres [1]. Corncobs are currently used as fertilizers and animal feed. If corncobs are not processed appropriately, large quantities of corncobs become waste and lead to environmental problems. Dietary fibres are the complex components of natural carbohydrate polymers. These polymers comprise various non-starch based polysaccharides including hemicelluloses, cellulose, pectin, and lignin and are biosynthesised using hexose, pentose, and uronic acid [2]. Lignin is acquired from a phenylpropane unit, including couramyl and cinamyl alcohols [3]. Corncobs constitutes hemicellulose (36%), cellulose (41%), pectin (3%), and lignin (6%). These components render its use as the source of antioxidant phytochemicals and dietary fibres, *etc*. [1,4]. In corncobs, the phenol content is approximately 22.35-162.14 because gallic acid is equivalent to microgram per millilitre of the extract. Due to the presence of dietary fibre associated phenolic compounds in corncobs, they are more beneficial than other sources of dietary fibres.

Corncobs, which are rich in polyphenols and dietary fibres, are a promising source of antioxidant dietary fibres. According to studies, plants comprising natural antioxidants and dietary fibres may be associated with health promotion and disease prevention activities, such as laxative effects, the attenuation of glucose, blood cholesterol and reduction of risk of heart disease, colon cancer, obesity, diabetes, artherosclerosis, inflammation, osteoporosis, hypertension and neurodegenerative diseases related to oxidative stress [5-10].

Recently, the use of micro-technology and nanotechnology in the food industry has attracted considerable attention and has emerged as the research focus in numerous countries [11]. Micronization is effective for enhancing the physical and

functional properties of a food ingredient [12]. Ultrafine grinding can be employed to reduce the particle size of these ingredients to a range of 1 nm-100 μm [13]. According to previous studies, the micronization of antioxidant dietary fibres improves the water holding capacity, solubility, oil holding capacity and swelling capacity of the food [11,14-16]. Moreover, through ultrafine grinding, phenolic compound extraction from antioxidant dietary fibre (insoluble) acquired from citrus pomace can be improve and the antioxidant capacities of the resultant powder and free phenols can be increased [16]. This study aimed to evaluate the effects of micronization on the antioxidant and physico-chemical properties of insoluble dietary fibres acquired from corncobs and characterize the microparticle dietary fibres of corncobs.

EXPERIMENTAL

The sample used was corncobs variety Manado kuning obtained from Tompaso, Minahasa, Indonesia. The chemicals used were ethanol, petroleum ether hydrochloric acid, sodium hydroxide, sodium acetate, iron(II) sulfate, iron(III) chloride, potassium ferricyanide, trichloroacetic acid, sodium carbonate, Folin-Ciocalteou reagent from Merck (Darmstadt, Germany). Gallic acid, 2,4,6-tris(2-pyridyl)-1,3,5-triazine (TPTZ), 1,1-diphenyl-2-picrylhydrazyl (DPPH), α-amylase, protease and amyloglucosidase were obtained from Sigma-Aldrich Chemical Co. (St. Louis, USA).

Preparation of corncob with regular milling: Dry corncob was shredded and cut into small slice and uniform size of 3-5 cm^2 and immediately blended with distilled water in solid-liquid ratio of 1:10 for 5 min with the working frequency was set at 50-60 Hz. Then mixture was filtered, dried at 55-60 ºC for 48 h, ground by a regular laboratory mill (Philips) and passed through a 40 mesh (0.42 mm) screen.

Preparation of corncob insoluble dietary fiber: The corncob pulp was then heated with 1000 mL of distilled water for 1 h under constant stirring of 200 rpm and filtered to separate insoluble fraction. Insoluble dietary fiber (IDF) fraction was dried in the oven at 55-60 ºC for 48 h, ground by a regular laboratory mill (Philips) and passed through a 80 mesh (0.42 mm) screen. The IDF powder was further grinded by using mill Fomac type FCT-Z200 for 2 min. The working rotating speed was set at 28,000 rpm, while the working frequency was set at 50-60 Hz. The IDF powders after grinding were separated into different particle size fraction using standard screens (200 mesh). All the powders were hermetically packaged in plastic bags and stored at room temperature in a desiccator for further analysis.

Physico-chemical properties: The physico-chemical properties of IDF powder include FTIR spectra using a FTIR spectrometer (Shimadzu FTIR 8201 PC) over the range 4000-400 cm^{-1} by KBr pellet method. The particle size of the IDF powder was determined using a laser particle size analyzer (LA-960, Horiba Limited, Japan). The proximate chemical composition of the samples was determined using the standard methods of analysis of AOAC method [17]. Total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF) were analyzed in IDF powders by AOAC methods [17]. The ultraviolet (UV) spectra of the ethanol extracts were recorded using spectrophotometer (Shimadzu 1800, Japan).

Extraction of phytochemicals of IDF powder: The dried IDF powder (10 g) was extracted with 50 mL of ethanol-water (80:20, v/v). The mixture was homogenized by vortexing for 2 min, placed in an ultrasonic bath with a frequency of 40 kHz for 30 s at room temperature and then filtered through filter paper to separate solvent extracts and residual material. After that, the resulting extracts were evaporasted to dryness using vacuum rotary evaporator at 50 ºC. The extract stored at 5 ºC for the further phytochemical analysis and antioxidant activity.

Determination of total phenolic content: Total phenolic content (TPC) of ethanol extracts was estimated using the Folin-Ciocalteu reagent based colorimetric assay [18]. Each sample solution (0.1 mL, 1 mg/mL) was added to Folin-Ciocalteu reagent (0.1 mL, 50%) in a test tube and then this mixture was vortexed for 3 min. After intervals of 3 min, 2 mL of Na_2CO_3 2% solution was added. After the incubation at room temperature for 30 min, the mixture was kept in the dark for 30 min. The supernatant was measured using a spectrophotometer at 760 nm. The standard curve was prepared using different concentrations of gallic acid and the results were expressed as gallic acid equivalents in milligrams per milligram extract.

Determination of free radical scavenger: DPPH radical scavenging activity of ethanol extracts was evaluated according to the method of Li *et al*. [18] with slightly modifications. A total of 2 mL solution of 92 μM 1,1-diphenyl-2picrylhydrazyl (DPPH) in ethanol was added 0.5 mL ethanol extract and a solvent fraction. A level of colour reduction of the solution shows the efficiency of radical scavenger. The last five minutes of the 30 min, the absorbance was measured using a spectrophotometer at 517 nm. Free radical scavenger activity was calculated as a percentage reduction of DPPH color using the equation:

$$\text{Free radical scavenging activity (\%)} = \left(1 - \frac{\text{Sample absorbance}}{\text{Control absorbance}}\right) \times 100$$

Determination of total antioxidant: Determination of total antioxidant determined using ferric reducing ability of plasma (FRAP) method [19]. Measurements were carried out by taking 0.1 mL IDF powder dissolved in ethanol was mixed with 3 mL reagent FRAP in a fresh state. Then the mixture was shaken with a vortex instrument and thereafter, immediately measured the absorbance at 593 nm. The FRAP reagent was always prepared in a fresh state by mixing 2.5 mL, 10 mM solution of 2,4,6-tris(2-pyridyl)-1,3,5-triazine in 40 mM HCl with 2.5 mL, 20 mL solution of $FeCl_3 \cdot 6H_2O$ and 2.5 mL, 0.3 M acetate buffer at pH 3.6. The total content was expressed as equivalent antioxidant Fe^{3+} to Fe^{2+} in mol/L extract. A standard curve was prepared in the same way using $FeSO_4$ solution with a concentration of between 100-1000 mol L^{-1}.

Determination of reducing power: The reducing power of ethanol extracts was determined according to Yen & Chen method [20]. Ethanolic extracts of IDF powder (1000 μg/mL) in 1 mL ethanol were mixed with phosphate buffer (2.5 mL, 0.2 M, pH 6,6) and potassium ferricyanide (2.5 mL, 1 %), the mixture was incubated at 50 ºC for 20 min. A portion of trichloroacetic acid (10%, 2.5 mL) was added to the mixture and centrifuged at 3000 rpm for 10 min. The upper layer of

solution (2.5 mL) was mixed with distilled water (2.5 mL), ferric chloride (0.5 mL, 0.1%) and finally the absorbance was measured at 700 nm. Increased absorbance of the reaction mixture indicated the increased reducing power.

Statistical analysis: Data were analyzed with computer software, SPSS version 18 (Illinois, USA) using ANOVA analysis followed by Duncan's multiple range test to determine the significant differences between the carrying by ±5%.

RESULTS AND DISCUSSION

Chemical composition of IDF powder: Table-1 presents the proximate composition of the powder of insoluble dietary fibres obtained from corncob. The insoluble dietary fiber (IDF) powder has a higher percentage of carbohydrates and crude fibre than other components. The results showed that the obtained crude fibre content was 31.05% and that acquired in other studies was 33.33% [21]. This content variation resulted from differences in corncobs and raw material types, corncob age and humidity. The amount of crude fibre, the main component of the cell wall, increases with the synthesis of structural carbohydrates, including hemicellulose and cellulose [22,23]. Non-starchy vegetables, which are used for the treatment of diseases such as diabetes, obesity and gastrointestinal disorders [24] are the richest sources of dietary fibres [25].

TABLE-1
PROXIMATE COMPOSITION IN INSOLUBLE DIETARY FIBER (IDF) POWDERS FROM CORNCOBS

Parameter	Percentage
Moisture	9.07 ± 0.71
Ash	0.82 ± 0.04
Protein	2.35 ± 0.06
Crude fiber	31.05 ± 0.04
Fat	1.04 ± 0.03
Carbohydrates	55.67 ± 0.73

Particle size: Table-2 presents the particle size distribution obtained using various screen methods for the IDF fraction powder. Particles size distribution was analyzed using $D_{0.1}$, $D_{0.5}$ and $D_{0.9}$ values [26]. Zhang *et al*. [16] considered D_{50} the average median diameter representing the powder cohesiveness degree. The D_{50} of 200 and 80 mesh screens were 63.13 and 260.89 µm, respectively. The particles size for the 200 mesh screen was 63.13 µm, indicating the fine or micron-size particles. The finer are the particles, the higher is the number of particles per unit weight and the higher are their solubility and dispersibility in food systems [27].

TABLE-2
EFFECTS OF GRINDING ON PARTICLE SIZE AND DISTRIBUTION OF IDF POWDERS FROM CORNCOB

Characteristic parameter	IDF (80 mesh)	IDF (200 mesh)
$D_{0.1}$ (µm)[a]	125.20 ± 0.36	8.43 ± 0.01
$D_{0.5}$ (µm)	260.89 ± 0.12	63.13 ± 0.45
$D_{0.9}$ (µm)	426.30 ± 1.60	117.41 ± 0.91
Span[b]	1.15 ± 0.00	1.73 ± 0.01

$D_{0.1}$, $D_{0.5}$, $D_{0.9}$ are the equivalent volume diameter at 10, 50 and 90% volume cumulative, respectively. [b]The width of particle size distribution. Span = $(D_{0.9}-D_{0.1})/D_{0.5}$.

The particle size distribution width was estimated with span by following the British Standards. According to Zhang *et al*. [16], the smaller is the span value, the narrower is the particle size distribution and more uniform is the size. The span value of the 80 mesh screen powder (1.15) was higher than that of the 200 mesh screen powder (1.73), *i.e.* the powder obtained with the 200 mesh screen was more homogeneous than that acquired with the 80 mesh screen, which indicated the wide distribution of particle size for the IDF powder. The particle size of 63.13 µm belonged to the fine particle category. Fine particles showed more particles per unit weight, revealing a higher potential for homogeneity in combination with other powder additives [28]. The ultrafine IDF powder with high dispersibility as a food processing additive can easily enter into the food structure [27].

IR spectra: Two characteristic absorption peaks were obtained for both the samples at 2924 cm^{-1} (C-H *str.* vibration of methyl and methylene) and 3433-3425 cm^{-1} (O-H *str.* vibration of the hydroxyl group) (Fig. 1). These peaks revealed the existence of a typical polysaccharide structure [29]. The characteristic peaks appearing at 1720 cm^{-1} was assigned to the carbonyl group stretching vibration of the ester group that obtained at 1647 cm^{-1} corresponded to the aromatic benzene of lignin. These two peaks appeared for both the samples [30]. The absorption peaks of FTIR spectra for the IDF powder did not change, *i.e.* grinding caused no change in the FTIR spectra. Liu *et al*. [31] reported that the effect of grinding on the main components and ensured that the active ingredients of dietary fibres were not destroyed. Furthermore, compared with the FTIR spectra of standard microcellulose (Fig. 1), those of both the IDF powders shifted from 3433 to 3371 cm^{-1} revealing the change in other absorption peaks, which might be related to the change in or degradation of the chemical structure of the IDF powder. From a study, during milling, mechanical force can break intramolecular hydrogen bonds, thereby contributing to cellulose degradation [30,32]. The absorption peaks of both the IDF powders did not change, indicating the presence of impurities causing different wavelengths.

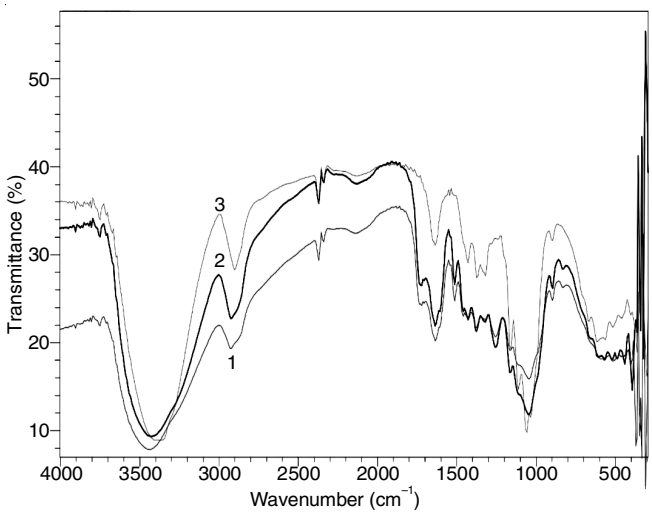

Fig. 1. FTIR spectra of the corncob IDF powder obtained by different screen methods. (1) IDF (80 mesh), (2) IDF (200 mesh) and (3) cellulose mikrokristallin

TABLE-3
DIETARY FIBER CONTENT OF INSOLUBLE DIETARY FIBER (IDF) POWDER FROM CORNCOB

Sample	IDF (%)	SDF (%)	TDF (%)	IDF:SDF
Corncob IDF (80 mesh)	62.82 ± 0.11	2.20 ± 0.02	64.36 ± 0.23	20.58 ± 0.46
Corncob IDF (200 mesh)	57.10 ± 0.07	1.39 ± 0.24	58.59 ± 0.17	15.72 ± 0.23

Dietary fiber content: The insoluble dietary fibre (IDF), total dietary fibre (TDF) and soluble dietary fibre (SDF) contents of the 200 mesh screen were lower than those of 80 mesh screen for the IDF powder (Table-3). The IDF contents decreased from 62.82% to 57.10% when the particle size of the dietary fibre powder decreased and the SDF content decreased from 2.20% to 1.39%. After grinding, the TDF content significantly decreased ($p < 0.05$), may be due to the redistribution of fibre components in the IDF powder and due to various materials, grinding degree (fine, superfine, and ultrafine), treatments and physical structures of the fibre. Zhu *et al*. [11] stated that after grinding, the decrease in the TDF and IDF contents might be caused by the degradation of cellulose, hemicellulose and lignin, which transformed into some other small molecules and the SDF fraction. Another study revealed that after ultrafine grinding, IDF content decreased because of the mechano-chemical degradation of cellulose, hemicellulose and lignin, which transformed into soluble components [33]. Soluble dietary fibers (SDFs) include gums, pectic substances, some hemicelluloses and mucilage, while IDFs include cellulose and other types of lignin and hemicelluloses [34].

For comparison, dietary fibre acquired from sources such as potato (34.40%), carrot (34.40%), apple (10.8%), orange (6.7%), banana (6.70%) and coconut (58.72%) or (56.80%) were analyzed. The IDF contents of the IDF powder from corncob was higher than that of potato, carrot, apple, orange and banana and similar to that of coconut [35,36]. The IDF powders are highly rich sources of insoluble dietary fibres to be used as a functional ingredient for food industry and positively influence metabolic disease prevention.

Total phenolic content: Phenolic compounds were extracted from the IDF powder by employing the ultrasound assisted extraction method and ethanol solvent (Table-4). Sonication extraction is a rapid process because the cell wall of the IDF powder disintegrates through ultrasonic vibrations and thus the solvent easily enters the active component containing cell cavity. Phenolic components present in the cell can be extracted because of different active component concentrations inside and outside the cell. The total phenolic content in the corncob powder of 200 mesh screen, IDF powder of 80 and 200 mesh screen.

TABLE-4
TOTAL PHENOLIC CONTENT OF VARIOUS PARTICLE SIZES OF CORNCOBS POWDER

Powder particle size	Phenolic total content
Corncob powder (CCP)	57.35 ± 0.08
Corncob IDF (80 mesh)	81.33 ± 0.06
Corncob IDF (200 mesh)	116.73 ± 0.02

The total phenol content of IDF (200 mesh) was higher than that of corncob powder (CCP) (200 mesh) and IDF (80 mesh) may be due to its particles size, which led to solvent extraction solubility in ethanol, thereby facilitating the penetration into the IDF powder cell wall. Coulson *et al*. [37] reported that several factors can affect the extraction results, such as type of solvent, particle size, temperature, solvent polarity and stirring. The smaller is the sample size, the larger is the surface area; thus, it affects interactions between the sample and solvent during extraction that occurs optimally and generates the maximum phenolic extract. Naczk & Shahidi [38] reported that the total phenol content results from the sum of phenolic compounds, including non-tannin flavans (catechins, anthocyanins and leuco-anthocyanins), simple phenolics (derivatives of hydroxycinnamic and hydroxybenzoic acid), hydrolyzable tannins (ellagic and gallic acid), condensed tannins (copolymers and polymers of leucoanthocyanins and catechins).

Ultraviolet studies: Fig. 2 shows the UV spectra of corncob IDFs for the phenolic component in the 200-400 nm with different sizes. The corncob IDF (200 mesh) and IDF (80 mesh) extracts exhibited the highest and lowest absorbance, respectively, at 316 nm (abs, 0.539) 315 nm (abs, 0.289), respectively. However, corncob powder obtained from the ethanol extract showed UV spectra with the highest absorbance at 313 nm (abs, 0.276). A similar result was observed for the ethyl acetate fractions [1] and corncob extract may be due to the existence of many simple flavonoids and phenolic compounds, which are highly soluble in an ethanol:water mixture (80:20). Each phenolic compound group is exhibited one or more UV light absorption maxima. Simple phenolic compounds showed the absorption maxima in 220-280 nm [9], which indicated the existence of phenolic acid compounds appearing between 220 and 320 nm.

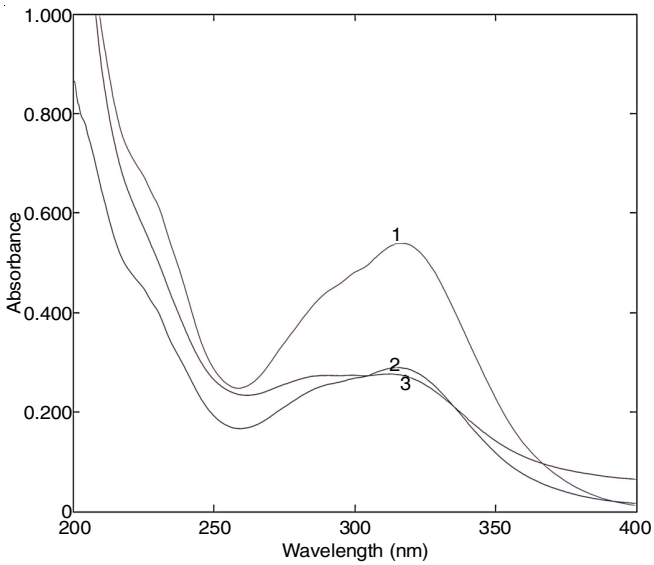

Fig. 2. UV spectra of ethanol extract of IDF powder, (1) corncob IDF 200 mesh, (2) corncob IDF 80 mesh and (3) corncob powder

A decrease in the particle size significantly affected the UV spectra of the corncob IDF extract. This decrease corresponded to phenolic component present in ethanolic extracts. For different particle sizes of the corncob IDF extract, the UV spectra were studied. The particle size decrease from 260.89 to 63.13 μm led to an increase in the absorbance value. The highest spectra appears in spectrum 1 followed by spectrum 2 and 3 (Fig. 2). This may make the particles size of corncobs IDF (200 mesh) smaller than that of corncobs IDF (80 mesh). When particle size decreases, the surface area increases; thus, it influences the particle size and interactions between the corncob IDF powder and solvents during extraction. It can also increase the surface area of contact between the solvent and particles; thus, phenolics can be extracted with the optimal efficiency. According to Zhu *et al.* [39], ultrafine grinding changed or damaged the fibre matrix, thereby causing liked or embedded phenolics to be related or exposed in the matrix.

Free radical scavenging activity: DPPH$^{\bullet}$ accepts an hydrogen or electron radical to become stable, is a stable free radical and is a reagent used to estimate the free radical scavenging activity of antioxidants. The influence of the IDF powder extract on DPPH$^{\bullet}$ free radical was studied. For comparison, α-tocopherol was used as the control positive (Fig. 3). The examined IDF extracts exhibited DPPH-scavenging activity, which indicated that these three phenolic compound extracts can be employed as the most potent DPPH scavengers (Fig. 3). In DPPH, the free radical scavenging of the three extracts exhibited the order of CCP > IDF powder (80 mesh) > IDF powder (200 mesh) with the activity of > 50% at 1000 μg/mL. The 200 mesh IDF powder exhibited higher free radical scavenging activity than CCP and IDF powder (80 mesh) ($p < 0.05$). The radical scavenging activity increased with the increase in the particle size. Various particle sizes of the IDF powder led to different particle surface areas for contact with the solvent; thus, some phenolic components acting as free radical scavengers can easily be released from the fibre matrix. This matrix easily dissolves in a polar solvent, including ethanol. The decrease in particle sizes can increase the solubility of the IDF powder (200 mesh screen) or can cause the release of a few antioxidants. The antioxidant effect can be proven, especially due to the hydroxyl groups in phenol components. Du *et al.* [40] reported that the antioxidant activity may increase because of ultrafine grinding, which leads to changes in the fibre matrix, thereby causing some linked or embedded phenolic components to be related or exposed in a compact structure. Some studies reported an increase in the DPPH radical scavenging activity and total phenolic content of buckwheat hull, wheat bran, and Qingke (hull-less barley) after ultrafine grinding [11,39,40]. By contrast, in the pomace dietary fibre and wine wheat brain grape, the DPPH radical scavenging activity decreased after grinding, which is not associated with the total phenolic content [11,41,42].

All the examined extracts exhibited good DPPH scavenging activity (Fig. 3); thus, three extracts presented a positive relationship between the free radical scavenger activity and total phenol content. All the IDF powder extract were compared with α-tocopherol (positive control). Three extracts exhibited

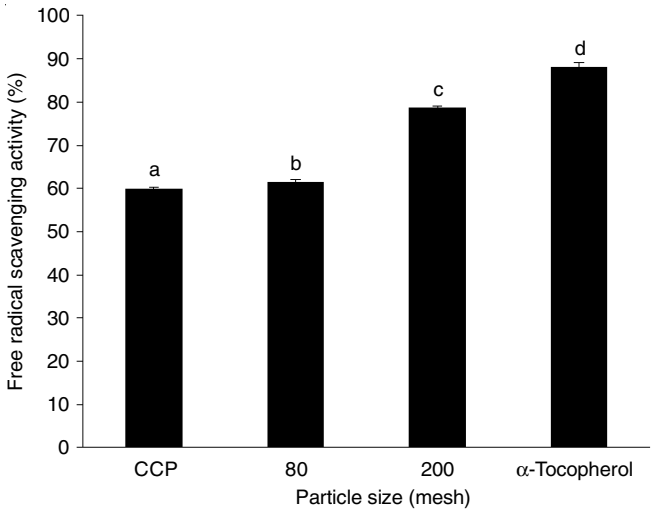

Fig. 3. DPPH free radical scavenging activity of IDF powder from corncob

lower radical scavenging activity than α-tocopherol. However, plants containing natural antioxidants and dietary fibre exhibit an advantage over other sources, such as ascorbate acid, α-tocopherol and pure antioxidant. Thus, corncobs are the rich source of insoluble antioxidant dietary fibre.

Total antioxidant: On the basis of capacity of a compound to reduce Fe^{3+} ions into Fe^{2+}, the FRAP method can be used to determine the total antioxidant concentration of bioextract materials. The blue intensity of the TPTZ-Fe^{2+} complex, used to determine the total antioxidant available in the FRAP method, presents the highest absorbance at 596 nm. The total antioxidant content in the CCP and IDF powders were interpreted by increasing the absorbance at 596 nm and are summarized as the Fe^{2+} amount equivalent to the standard antioxidant [43]. Fig. 4 shows the total antioxidant content for several particle sizes.

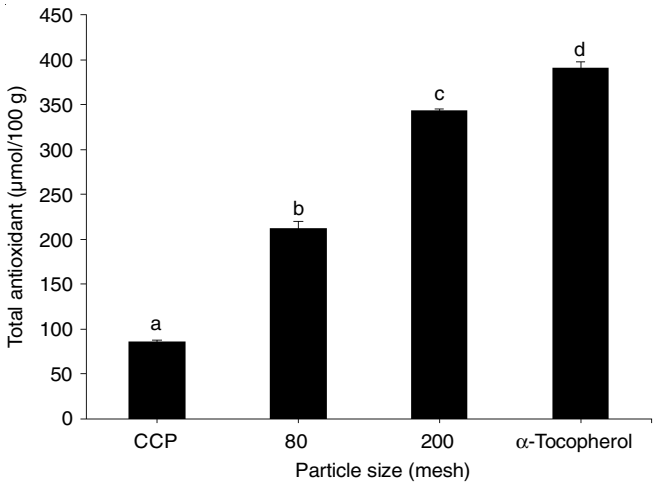

Fig. 4. Total antioxidant activity (FRAP) of IDF powder from corncob

A 200 mesh size showed a considerably higher total antioxidant content than the particle 80 mesh size for IDF and CCP. In the 200 mesh size, total antioxidant content was higher than that in the 80 mesh size. These antioxidants can reduce Fe^{3+} to Fe^{2+} ions. These contents of two particle sizes increased

with the particle size increase. There is a tendency for reduction of particle sizes exhibited the greater the total antioxidant content. Therefore, phenolic compounds with different particle sizes can serve as electron donors, which end the radical chain reaction through the conversion of free radicals into highly stable products. The FRAP of buckwheat hull, wheat bran, and hull-less barley (Qingke) dietary fibre increased after ultrafine grinding [11,39,40]. This study concluded that phytochemical antioxidants with the maximum free radical scavenging activity and total phenolic content have a positive relationship with FRAP values.

Reducing power: The reduction capacity of three extracts was estimated by studying the reduction of Fe^{3+}/ferricyanide complex into ferrous. According to Lai *et al*. [44], an increase in absorbance at 700 nm represents the increase in reduction capacity. The reduction and antioxidant capacities of bioactive compounds are associated. The reduction capacity of IDF (80 mesh), IDF (200 mesh) and CCP powder extracts were 0.59, 0.77 and 0.36 at 1000 µg/mL, respectively (Fig. 5). The results indicated that the IDF (200 mesh) extract exhibited a higher reduction capacity than the IDF (80 mesh) and CCP powder extract. The reduction capacity increased with the increase in the particle size.

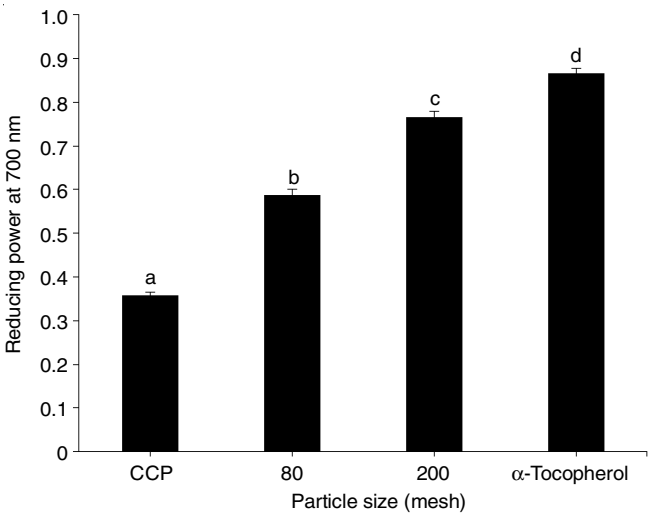

Fig. 5. Reducing power of IDF powder from corncob

The reduction capacity of the IDF (80 mesh) and IDF (200 mesh) extracts was compared with that of α-tocopherol by using the same concentration. The IDF extracts exhibited a lower reduction capacity than α-tocopherol. Thus, phenolic compounds present in the IDF powder extracts are excellent electron donors and can converting free radicals into more stable products by reacting with them or have the ability to reduce the phenolic antioxidant to Fe^{3+} (potassium ferrycianide complex $[K_3Fe(CN)_6]$) to Fe^{2+} (ferro form). The reduction capacities, DPPH radical scavenging activity, FRAP, of the IDF 80 mesh, IDF 200 mesh and CCP extracts exhibited the same order in accordance with their total phenolic amounts. Thus, according to all the antioxidant assays, the antioxidant activity was correlated with the amount of phenolic compounds, which were reported earlier [11,18,45,46].

Conclusion

This study showed that grinding with mill Fomac type FCT-Z200 an effectively minimize the particle size of the insoluble dietary fiber (IDF) powder to micro-size or fine size. FTIR spectra indicated that the IDF (200 and 80 mesh) matrix structure did not change after micronization. The average particle size was significantly decreased and also its uniform particle size distribution. The soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) contents of the micropowder decreased after the particle size decrease of the dietary fibre powder. The UV spectra of phenolic compounds of the corncob IDF extracts exhibited the highest absorbance at 316 nm. The DPPH scavenging activity, total phenolic content, reduction capacity and ferric reducing antioxidant power increased after micronization. The antioxidant assay results of micro-powder 200 mesh were the optimum among all the samples. The DPPH radical scavenging activity, reduction capacity and FRAP were positively correlated with amount of the total phenolic content. The results indicated that micronize processing can improve some antioxidant and physicochemical properties of IDF of micro-powder obtained from corncob.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

REFERENCES

1. A. Ashour, M. Amer, A. Marzouk, K. Shimizu, R. Kondo and S. El-Sharkawy, *Molecules*, **18**, 13823 (2013); https://doi.org/10.3390/molecules181113823
2. A. Abirami, G. Nagarani and P. Siddhuraju, *Bioact. Carbohydr. Diet. Fibre*, **4**, 16 (2014); https://doi.org/10.1016/j.bcdf.2014.06.001
3. A. Idouraine, M.J. Khan and C.W. Weber, *J. Agric. Food Chem.*, **44**, 2067 (1996); https://doi.org/10.1021/jf960151e
4. K.J. Lorenz and K. Kulp, Cereal Science and Technology, Marcel Dekker: New York (1991).
5. Y.L. Huang, F. Sheu, M.H. Lee and C.F. Chau, *J. Sci. Food Agric.*, **88**, 435 (2008); https://doi.org/10.1002/jsfa.3104
6. G.H. Mcintosh, *Prev. Med.*, **22**, 767 (1993); https://doi.org/10.1006/pmed.1993.1070
7. J.W. van der Kamp, J. Jones, B. MacCleary and D. Topping, Dietary Fibre: New Frontiers for Food and Health, Wageningen Academic Publishers: Wageningen, The Netherlands, pp. 1-586 (2010).
8. B.N. Ames and M.K. Shigenaga, Eds.: B. Haliwell and O.I. Aruoma, Oxidants are a Major Contributor in Cancer and Aging, In: DNA and Free Radicals, Ellis Horwoosd Ltd.: West Sussex, U.K. (1993).
9. F. Shahidi and M. Naczk, Food Phenolics: Sources, Chemistry, Effects and Applications. Technomic Publication Company, Inc.: Lancaster (1995).
10. B. Halliwel and J.M.C. Gutteridge, Free Radicals in Biology and Medicine, Oxford University Press: London (2001).
11. K.X. Zhu, S. Huang, W. Peng, H.F. Qian and H.M. Zhou, *Food Res. Int.*, **43**, 943 (2010); https://doi.org/10.1016/j.foodres.2010.01.005

12. C.F. Chau, Y.T. Wang and Y.L. Wen, *Food Chem.*, **100**, 1402 (2007); https://doi.org/10.1016/j.foodchem.2005.11.034
13. X.Y. Zhao, Z.B. Yang, G.S. Gai and Y. Yang, *J. Food Eng.*, **91**, 217 (2009); https://doi.org/10.1016/j.jfoodeng.2008.08.024
14. M. Senevirathne, Y.J. Jeon, J.H. Ha and S.-H. Kim, *J. Food Eng.*, **92**, 157 (2009); https://doi.org/10.1016/j.jfoodeng.2008.10.033
15. C.C.R. Wang, J.Y. Ciou and P.Y. Chiang, *Food Chem.*, **113**, 970 (2009); https://doi.org/10.1016/j.foodchem.2008.08.048
16. B. Tao, F. Ye, H. Li, Q. Hu, S. Xue and G. Zhao, *J. Agric. Food Chem.*, **62**, 7166 (2014); https://doi.org/10.1021/jf501646b
17. AOAC, Official Methods of Analysis, Ed. 16 (1995).
18. X. Li, J. Lin, W. Han, W. Mai, L. Wang, Q. Li, M. Lin, M. Bai, L. Zhang and D. Chen, *Molecules*, **17**, 13457 (2012); https://doi.org/10.3390/molecules171113457
19. A. Szydlowska-Czerniak, C. Dianoczki, K. Recseg, G. Karlovits and E. Szlyk, *Talanta*, **76**, 899 (2008); https://doi.org/10.1016/j.talanta.2008.04.055
20. G.C. Yen and H.Y. Chen, *J. Agric. Food Chem.*, **43**, 27 (1995); https://doi.org/10.1021/jf00049a007
21. U.S. Abubakar, K.M. Yusuf, I. Safiyanu, S. Abdullahi, S.R. Saidu, G.T. Abdu and A.M. Indee, *Int. J. Food Sci. Nutr.*, **1**, 25 (2016).
22. D.J. Peer and S. Leeson, *Anim. Feed Sci. Technol.*, **13**, 191 (1985); https://doi.org/10.1016/0377-8401(85)90022-7
23. D. Cuddeford, *In Pract.*, **11**, 211 (1989); https://doi.org/10.1136/inpract.11.5.211
25. L.G. Saldanha, *Pediatry*, **96**, 994 (1995).
25. C. Agostoni, R. Riva and M. Giovannini, *Pediatry*, **96**, 1000 (1995).
26. K. Giry, J.M. Pe'an, L. Giraud, S. Marsas, H. Rolland and P. Wüthrich, *Int. J. Pharm.*, **321**, 162 (2006); https://doi.org/10.1016/j.ijpharm.2006.05.009
27. G. Zhao, R. Zhang, L. Dong, F. Huang, X. Tang, Z. Wei and M. Zhang, *LWT-Food Sci. Technol.*, **87**, 450 (2018); https://doi.org/10.1016/j.lwt.2017.09.016
28. C.K. Riley, S.A. Adebayo, A.O. Wheatley and H.N. Asemota, *J. Powder Technol.*, **185**, 280 (2008); https://doi.org/10.1016/j.powtec.2007.10.028
29. X. Yan, R. Ye and Y. Chen, *Food Chem.*, **180**, 106 (2015); https://doi.org/10.1016/j.foodchem.2015.01.127
30. M. Ma and T. Mu, *Carbohydr. Polym.*, **136**, 87 (2016); https://doi.org/10.1016/j.carbpol.2015.09.030
31. Y. Liu, L. Wang, F. Liu and S. Pan, *Int. J. Polym. Sci.*, **2016**, 6269302 (2016); https://doi.org/10.1155/2016/6269302
32. X. Zhao, H. Zhu, G. Zhang and W. Tang, *J. Powder Technol.*, **286**, 838 (2015); https://doi.org/10.1016/j.powtec.2015.09.025
33. F.Y. Ye, B.B. Tao, J. Liu, Y. Zou and G.H. Zhao, *Food Sci. Technol. Int.*, **22**, 246 (2016); https://doi.org/10.1177/1082013215593394
34. M. Elleuch, D. Bedigian, O. Roiseux, S. Besbes, C. Blecker and H. Attia, *Food Chem.*, **124**, 411 (2011); https://doi.org/10.1016/j.foodchem.2010.06.077
35. T.P. Trinidad, D. Valdez, A.C. Mallillin, F.C. Askali, A.S. Maglaya, M.T. Chua, J. Castillo, A.S. Loyola and D.B. Masa, *Indian Coconut J.*, **7**, 45 (2001).
36. S.N. Raghavendra, S.R. Ramachandra-Swamy, N.K. Rastogi, K.S.M.S. Raghavarao, S. Kumar and R.N. Tharanathan, *J. Food Eng.*, **72**, 281 (2006); https://doi.org/10.1016/j.jfoodeng.2004.12.008
37. J.M. Coulson, J.F. Richardson, J.R. Backhurst and J.H. Harker, Fuild Flow Heat Transfer and Mass Transfer, In: Coulson & Richardson's Chemical Engineering, John Francis Richardson, Elsevier, vol. 1 (1999).
38. M. Naczk and F. Shahidi, *J. Pharm. Biomed. Anal.*, **41**, 1523 (2006); https://doi.org/10.1016/j.jpba.2006.04.002
39. F. Zhu, B. Du, R. Li and J. Li, *Biocatal. Agric. Biotechnol.*, **3**, 30 (2014); https://doi.org/10.1016/j.bcab.2013.12.009
40. B. Du, F. Zhu and B. Xu, *Bioact. Carbohydr. Diet. Fiber*, **4**, 170 (2014); https://doi.org/10.1016/j.bcdf.2014.09.003
41. F. Zhu, B. Du and J. Li, *Food Sci. Technol. Int.*, **20**, 55 (2014); https://doi.org/10.1177/1082013212469619
42. L. Yu, S. Haley, J. Perret, M. Harris, J. Wilson and M. Qian, *J. Agric. Food Chem.*, **50**, 1619 (2002); https://doi.org/10.1021/jf010964p
43. M. Antolovich, P.D. Prenzler, E. Patsalides, S. McDonald and K. Robards, *Analyst*, **127**, 183 (2002); https://doi.org/10.1039/b009171p
44. L.S. Lai, S.T. Chou and W.W. Chao, *J. Agric. Food Chem.*, **49**, 963 (2001); https://doi.org/10.1021/jf001146k
45. R.G.O. Rumbaoa, D.F. Cornago and I.M. Geronimo, *J. Food Compos. Anal.*, **22**, 546 (2009); https://doi.org/10.1016/j.jfca.2008.11.004
46. X. Li, X. Wu and L. Huang, *Molecules*, **14**, 5349 (2009); https://doi.org/10.3390/molecules14125349
47. X. Li, D. Chen, Y. Mai, B. Wen and X. Wang, *Nat. Prod. Res.*, **26**, 1050 (2012); https://doi.org/10.1080/14786419.2010.551771