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Optimization of dietary fiber extraction from corn stalks and product characterization

Abstract: This research optimizes dietary fiber extraction from corn stalks and addresses its potential use in processed meat and fish products. The research aims to optimize dietary fiber extraction from corn stalk and characterize its potential as a food ingredient. Corn stalks were extracted using NaOH for dietary fiber, the procedure involved cleaning, drying, extraction, bleaching, and drying. RSM optimization using Design-Expert software determined optimal NaOH concentration and extraction time for dietary fiber yield. Products were characterized by FTIR, SEM, and BET, as well as determining WHC and OHC. This study optimized the extraction of dietary fiber from corn stalk using NaOH. RSM identified optimal conditions, i.e., NaOH concentration (A) = 25.96% and extraction time (B) = 65.39 min, yielding 34.47% dietary fiber. Validation trials resulted in a 34.38 ± 0.04% yield. Product characterization (FT-IR, SEM, BET), as well as assessments of WHC and OHC demonstrate the potential of corn stalk as a dietary fiber source and its use as a filler for processed meat and fish products. Optimization of dietary fiber extraction from corn stalks, achieved a yield of 34.47%. The findings highlight the feasibility of corn stalks as a source of dietary fiber in processed foods and the use of NaOH in extraction for large-scale production.
Key words: chemical extraction, corn stalks, dietary fiber, Response Surface Methodology, sodium hydroxide.

Introduction

Food crops, such as corn, are cultivated year-round, but only the fruit is consumed, leaving a significant amount of waste. The yearly yield of corn stalks is projected to be close to 1 billion tons [1]. In the stem part, there are about 30-50% of the total weight of the plant, depending on the variety, growth conditions, and cultivation methods. Corn stalks contain cellulose fiber, which has potential as a source of dietary fiber and fillers in the processing of fishery products, such as meatballs and nuggets. This potential is particularly feasible, as the current filler-wheat flour is an imported product, which adds to production costs. Moreover, the availability of corn stalks is abundant, renewable, and sustainable, making them an ideal alternative.

In the processing of fishery products, fillers are essential to the role in product quality, improving emulsion properties, enhancing characteristics and sensory attributes, reducing cooking shrinkage, increasing water and oil-holding capacities, and lowering production costs. Additionally, processed fishery products often fall short of meeting dietary fiber requirements. The recommended daily intake is 25 g per 2.000 calories or 30 g per 2,500 calories, while meatballs on the market typically contain only 0.5% fiber per serving. Long-term consumption of synthetic fibers can have detrimental effects on both health and environmental sustainability [2].

Dietary fiber plays a crucial role in the diet by supporting the digestive system, aiding the movement of food through the intestines, and facilitating the removal of waste from the body. Adults need 25-30 g of fiber per day, which should be obtained from food rather than supplements. A meta-analysis conducted by the World Health Organization (WHO) found that consuming at least 25 to 29 g of fiber per day can help protect against various diseases [3].

The addition of dietary fiber to food products is one way to increase human fiber intake [4, 5]. Interest in adding dietary fiber to animal products is increasing because of its possible health benefits [6]. In the meat processing industry, meeting the nutri-

tional claim standards of "source of dietary fiber" and "high fiber food" requires a minimum of 3 g or 6 g of dietary fiber per 100 g of product. These claims can enhance the market potential of dietary fiber-rich meat and fish products and provide consumers with healthier food choices. The concentration of dietary fiber in meatballs is of industrial significance because it meets the nutritional criteria for these claims. Adding up to 6 g of dietary fiber per 100 g can also affect the sensory quality of meatball products [7].

The flour is a versatile food ingredient extensively used in the production of emulsified meat products, such as meatballs [8]. The flour acts as an active filler in the meat protein matrix, improving gel properties and increasing the firmness and cutting ability of emulsified meat products [9]. Flour, when combined with dietary fiber, can further enhance the quality of these products to meet dietary fiber needs.

Cellulose in nature is not found in its pure form but rather as part of lignocellulose, a complex of cellulose, hemicellulose, and lignin. Since cellulose and lignin are bound together, a method is needed to separate cellulose from lignin; this process is known as "delignification". Delignification breaks down the lignocellulose structure, making cellulose more accessible and dissolving the lignin content, which facilitates the separation of lignin from the fiber.

The use of NaOH in the delignification process can break the ether bonds connecting lignin to cellulose, remove lignin, and increase biomass porosity [9]. In addition, the bleaching process can use several chemicals, such as sodium hypochlorite, alkali compounds, and acids, these chemicals can hydrolyze and bleach the product. The application of this process in industry is very feasible to apply, because the methods and equipment needed are relatively simple. However, process control is important to be carried out carefully because cellulose can be degraded under certain process conditions. Therefore, the optimum extraction process conditions are important to know to produce high-quality products and achieve high efficiency in order to save production costs.

Some research has focused on modeling and optimizing cellulose extraction. For example, from orange peels, palm trees, wheat straw, and corn cobs [8, 9, 11]. However, modeling and optimization of cellulose extraction from corn stalks, which has the potential to be used as dietary fiber, have not been discussed. This study aims to determine the optimal conditions for dietary fiber extraction from corn stalks, characterize the product, and explore the potential of dietary fiber from corn stalks as a food ingredient.

Materials and methods

NASA 29 variety hybrid corn stalks as samples were obtained from Maros Regency, South Sulawesi, Indonesia. Sodium hydroxide (NaOH) (Merck, Germany) and sodium metabisulfite ($Na_2S_2O_5$) (Aditya Birla) were purchased from a local chemical shop.

Cellulose fiber extraction: Corn stalk samples were cleaned, washed, and chopped using a disk mill and dried to a water content of 6%. The extraction process used a stainless steel vessel equipped with a stirrer and a gas stove as a heater. Dietary fibers were extracted using chemical methods. Each experimental unit used 100 g of sample and 1000 mL of NaOH solution, the extraction process takes place at 90°C. After the extraction, the samples were washed with clean running water until the pH of the water reached 7. Then, bleaching was performed by soaking the samples in a 5% $Na_2S_2O_5$ solution for 60 min, followed by filtration using a nylon filter cloth. The samples were dried to a water content of about 4 to 5%, then packed in plastic bags and weighed to calculate the dietary fiber yield (Equation 1). The samples were then placed in a cooling room for further analysis and characterization.

$$\text{Yield (\%)} = \frac{\text{dietary fiber (g)}}{\text{corn stalk (g)}} \times 100 \qquad (1)$$

Optimization and modeling using Response Surface Methodology (RSM). The parameters monitored were the NaOH concentration (%), which was labeled A, and the processing time (min), which was labeled B. To determine the impact of A and B as process parameters on dietary fiber yield (Y), optimization and modeling were carried out using RSM, the experimental data was acquired via Design Expert Version 13 (Stat-Ease, Inc., USA), and used to optimize and model the process. Two central composite design (CCD) factors were used to monitor the optimal A (%) and B (min) to achieve a high dietary fiber yield (Y) as responses. The midpoint of the process was set at 25% for variable A and 60 min for variable B (Table 1).

Table 1 – Parameters considered, range and levels of independent variables

Independent variables	Range and levels of independent variables				
	-α	-1	0	1	+α
A (%)	10.86	15	25	35	45.86
B (min)	39.14	50	60	70	74.14

Product characterization: The obtained dietary fiber products were then characterized using Fourier transform infrared spectroscopy (FT-IR), scanning electron microscopy (SEM), and Brunauer-Emmett-Teller (BET). Determining the water-holding capacity (WHC) and oil-holding capacity (OHC) has also been carried out. SEM analysis used instrument SEM, Hitachi SU1000, and FlexSEM 1000 II. Double-sided adhesive carbon tape was used to secure the dried sample to a specimen stub, and a spray of air was used to remove any extra fiber. Using a SCD500 vacuum turbo evaporator system, a platinum coating with a thickness of 10-20 nm was deposited on the sample surface. A Quanta 250 FEG scanning electron microscope (Hitachi SU1000, Flex SEM 1000 II) was used to take micrographs of the sample surfaces at 500× magnification and a voltage of 5.00 kV. FT-IR spectroscopy analysis (the ALPHA FTIR spectrometer Bruker Optics GmbH & Co. KG, Germany), was used to obtain FT-IR spectra of samples. The dried samples were analyzed from 4000 to 500 cm^{-1}, slit number 4 cm^{-1}, and 24 scans were conducted for each sample.

For analysis of BET, the sample was analyzed on the Anton Paar Nova Touch instrument. Samples with appropriate particle size are selected, and it was ensured that the sample was dried and free from contamination. The sample cell was filled with the correct amount according to the analysis requirements. The degassing profile was set according to the sample type. This process removes adsorbates present on the sample surface prior to BET analysis. The sample cell was placed on the degassing station, and the process was started according to the specified profile. The dewar was filled with liquid nitrogen to the specified level indicator, and the degassed sample cell was installed on the appropriate analysis station. The analysis profile was selected according to the sample type, the analysis process was started, and the instrument was allowed to run until completion.

WHC was determined using a modified procedure from Jia et al. [12]. A sample weighing 1.0 g was mixed with 70 mL of aquadest and stirred for 4 h. The resulting turbid liquid was then centrifuged at 3000 rpm for 15 min, the surplus water was then meticulously eliminated. The weight of the wet sample was recorded and then placed in an oven at 105°C until it reached a constant weight. The sample was weighed to calculate the WHC of the obtained dietary fiber (Equation 2).

$$\text{WHC (g/g)} = \frac{(wet\ weight - dry\ weight)}{dry\ weight} \qquad (2)$$

The method adapted from Abdul-Hamid and Luan [13] was used to evaluate OHC using a 1.0 g sample. The sample was placed in a centrifuge tube and mixed with excess corn oil. The centrifuge tube was stirred for 30 seconds every 5 min, and after 30 min, the tube was centrifuged at 1600 rpm for 20 min. The oil and water attached to the inside of the tube were cleaned after the excess oil was carefully separated, and the tube was weighed to calculate the OHC of the obtained dietary fibers (Equation 3).

$$\text{OHC (g/g)}\ \frac{Oil\ retained}{Original\ dried\ fiber\ sample} \qquad (3)$$

Results and discussion

The 2^2 factorial design including the appropriate responses as the yield of dietary fibers extracted from corn stalks through a chemical process using NaOH, is shown in Table 2. The effects of variables A and B on the response Y of dietary fiber were studied during experimentation. The data showed that the response Y ranged from 31.12 to 34.53%. The main purpose of this chemical extraction process is to produce as much dietary fiber as possible from the corn stalks. For the selected models, the sum of squares sequential model was run for the Y as shown in Table 3.

Table 2 – 2^2 Factorial design of CCD, A (%), B (min), and Y (%) as responses

A (%)	B (min)	Y (%)
15	50	31.65
35	50	31.27
15	70	32.44
35	70	33.44
10.86	60	31.25
39.14	60	32.56
25	45.86	31.12
25	74.14	33.86
25	60	34.53
25	60	34.12
25	60	34.23
25	60	34.15
25	60	34.05

Table 3 – Sequential model sum of squares

Source	Sum of squares	DF	Mean square	*F*-value	*p*-value
Total vs. Mean	14135.23	1	14135.23	-	-
Mean vs. Linear	6.6	2	3.3	2.4	0.1411
Linear vs. 2FI	0.4761	1	0.4761	0.3222	0.5842
2FI vs. Quadratic	12.86	2	6.43	103.62	< 0.0001[a]
Quadratic vs. Cubic	0.2946	2	0.1473	5.26	0.0589[b]
Residual	0.1399	5	0.028	-	-
Total	14155.61	13	1088.89		
Note: [a]Suggested; [b]Aliased					

The effects of variables A and B on the response Y were studied during experimentation. The quadratic response surface model can be seen in the analysis of variance at Table 4. According to CCD of RSM utilizing Design-Expert version 13 software, the maximum Y was achieved under the experimental conditions of A = 25.96% for B = 63.47 min. Under these process conditions, the maximum response (Y) was 34.47%.

Numerical optimization and modeling of the extraction process: A model that is defined in terms of real variables can accurately depict the percentage of dietary fiber that is extracted from corn stalks, as in Equation 4.

Table 4 – Response surface quadratic model of analysis of variance

Response: Dietary fiber yield					
Source	Sum of Squares	DF	Mean square	*F*- value	*p*-value
Model	19.94	5	3.99	64.26	< 0.0001*
A	0.7642	1	0.7642	12.31	0.0099
B	5.84	1	5.84	94.08	< 0.0001

Continuation of the table

Response: Dietary fiber yield					
Source	Sum of Squares	DF	Mean square	*F*- value	*p*-value
A^2	0.4761	1	0.4761	7.67	0.0277
B^2	9.28	1	9.28	149.48	< 0.0001
AB	5.17	1	5.17	83.35	< 0.0001
Residual	0.4345	7	0.0621	-	-
Lack of Fit	0.2946	3	0.0982	2.81	0.1721^{ns}
Mean	32.97		R^2	0.9787	
Std. Dev.	0.2491		Expected R^2	0.8865	
C.V. %	0.7555		Adjusted R^2	0.9634	
Note: * Significant; ns Not significant					

$$Y\,(\%) = -4.77137 + 0.401345A + 1.03404B + 0.003450AB - 0.011549A^2 - 0.008624B^2 \quad (4)$$

where A = NaOH concentration (%) and B = extraction time (min).

The models are significant for Y according to the analysis of variance (Anova). The correlation coefficient value was used to assess the quality of the models that were created. The coefficient of determination (R^2) value of 0.97 shows that the models adequately represent the true connection between the selected variables (A and B). The *F*-value and *p*-value were used to assess the importance of the various terms in each coefficient. A small *p*-value and a large *F*-value would suggest a more significant effect on the related response variable [14].

The model terms are considered significant if the *p*-value is less than 0.05. A, B, AB, A^2, and B^2 are important model terms in this instance. The lack of fit is not significant in relation to the pure error, according to the lack of fit *F*-value of 2.81. A *F*-value of this magnitude has a 17.21% probability of being the result of noise. A good fit is indicated by a lack of fit that is not statistically significant.

Figure 1 is a 2D and 3D graphical representation of the variable A and variable B model on the Y. A higher yield of dietary fiber will result from raising the NaOH concentration and lengthening the extraction period. The 2D and 3D contour plots play an important role in visualizing and gaining a better understanding of the relationships between variables A and B and the measured response Y. 2D and 3D contour plots are essential in this study because they offer a visual approach to analyzing and optimizing processes by directly observing the relationships between variables A and B and response Y.

A 2D contour plot shows the independent variables A and B affecting Y in two dimensions. The contour plot depicts the areas where the response value remains constant. This helps identify patterns or trends in the experimental data, while a 3D contour plot provides a three-dimensional representation of the relationship between the two independent variables, in this case A and B, with respect to Y as the response. A 3D contour plot is helpful in visualizing more complex interactions between the variables and the response. The 2D contour plot shows the independent variables A and B which affect Y in two dimensions. The contour plot describes the area where the response value remains constant. This helps identify patterns or trends in experimental data, while 3D contour plots give three dimensional representations of the relationship between two independent variables, in this case A and B, in connection with Y in response. 3D contour plot helps in visualizing more complex interactions between variables and responses.

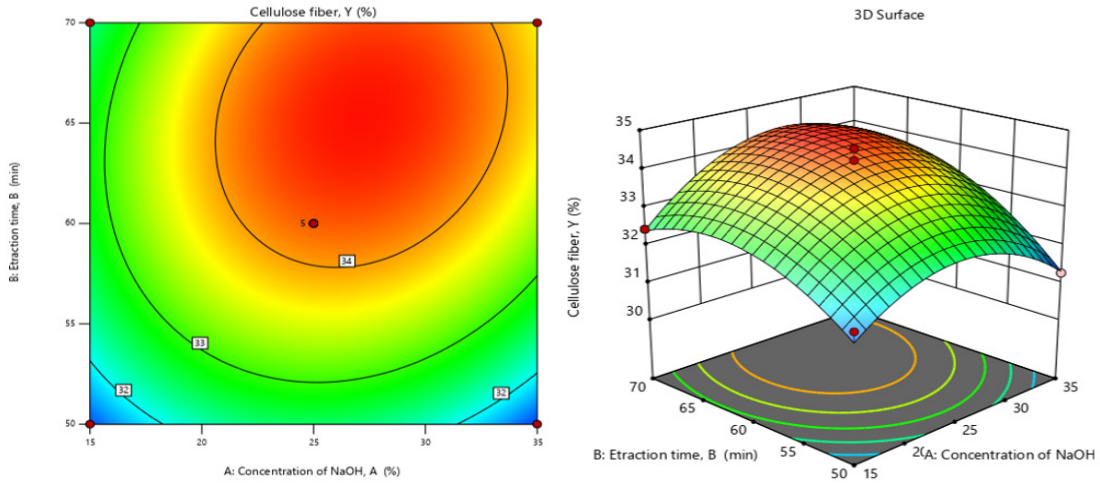

Figure 1 – Contour 2D and 3D surface curves of A and B

The 2D and 3D contour plots visualize the location of the optimum response point area, so that the process conditions can be determined that produces the best performance. In the 2D contour plot, researchers can comprehensively understand how changes in one variable can affect the response when other variables are kept constant, so that the direct effect of a single variable to the response can be well understood. In the 3D contour plot, we can understand the effect of two variable interactions on the response when the other variables are kept constant. Based on the comprehensive understanding of the contour plot viasualization, researchers can design advanced optimization research by focusing on a significant variable affecting the process to produce high -quality products and achieve the effectiveness and efficiency of a chemical process. The next step is verification and validation of the RSM results on a laboratory scale to ensure feasibly methods and models are applied in the industry.

Related to Figure 1, it can be explained that the maximum Y is achieved when using A = 25.96% and B = 65.39 min. If variables A and B are smaller or larger than these values, then the Y is not maximum. Based on the coefficient value of the regression model (Equation 2), where the coefficient B > A, it can be explained that the influence of variable B is greater in obtaining the maximum Y compared to the influence of variable A. This can also be proven from the estimated coefficient value, where the value of B > A, or the value of B = 0.8544, and the value of A = 0.3091.

More about dietary fiber extraction, the alkaline hydrolysis breaks the bonds between the lignin and hemicellulose's ester groups, aryl-ether, carbon-carbon, and aryl-aryl groups, reducing the amount of lignin and hemicellulose [14]. Increasing the concentration of NaOH, on the other hand, will result in the uncontrolled hydrolysis of cellulose's functional groups, lowering the product's cellulose content. The recovery of cellulose fibers is positively impacted by longer extraction times as well; however, prolonged extraction leads to cellulose degradation and a reduction in cellulose yield.

Alkali treatment with NaOH is very effective in achieving complete biomass hydrolysis. This method effectively dissolves lignin and hemicellulose fractions while causing minimal cellulose dissolution. It works by breaking down the biomass cell walls, dissolving matrix hemicellulose and lignin, as well as breaking the α-ether bonds between these components, as well as the ester bonds associated with them [11]. The impact on hemicellulose can vary depending on the processing conditions [15]. The efficiency of this treatment is influenced by several factors, including temperature, concentration, duration, type of raw material used, and lignin content in the material [16].

In RSM, desirability and predicted response Y are also visualized as in Figure 2. The desirability value helps guide decisions and provides a clear figure of how well an experimental condition meets the desired objectives. The NaOH concentration and extraction duration were tuned to "within range" in order to maximize the dietary fiber extraction process. The "maximize" dietary fiber content was selected. The results indicate that the extraction of dietary fiber can be finished in a comparatively short amount of time. In addition, the analysis confirmed that corn

stalks contain a significant amount of cellulose, supporting their potential as a source of dietary fiber and as a food ingredient. The composition variation is influenced by factors such as species, geographic location, age, and climate, as noted in previous studies [17].

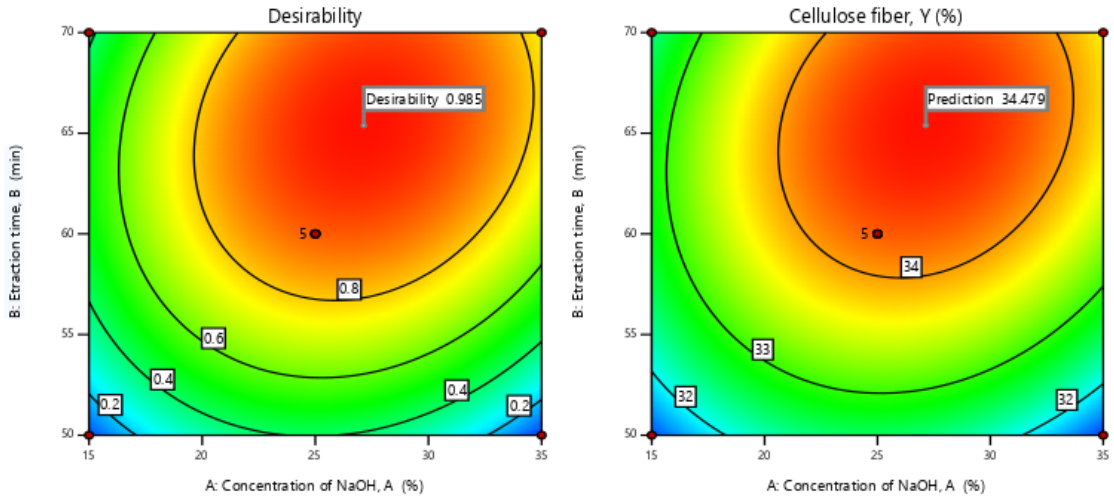

Figure 2 – Desirability and response Y prediction, show the ideal set of process variables that will yield the maximum dietary fiber content response

In chemical process optimization, "desirability" refers to a systematic approach used to evaluate and improve the performance of a process based on multiple criteria or objectives. The concept is often implemented through a "desirability function," which helps combine multiple responses into a single metric for optimization. The desirability function measures how desirable a particular outcome is, typically ranging from 0 (not desirable) to 1 (very desirable). Different responses, in this case dietary fiber yield, can be converted into a desirability score, allowing for a comprehensive evaluation.

The application of RSM in chemical process research can help researchers to explore the influence of several variables on the intended response and achieve optimum process conditions. Overall desirability can be known from the desirability value of each intended response so that researchers can make decisions regarding the optimum chemical process conditions appropriately. Desirability considers several factors, identifying optimum process conditions by balancing all factors involved in a chemical process. Thus, decision-making on a chemical process can be more effective, efficient, and feasible.

Verification model: Verification of optimal dietary fiber extraction conditions was carried out using optimized parameters. For model verification, triplicate experiments were used. This was to show that the optimal extraction condition solution recommended by the RSM produced dietary fibers according to the predicted values. The average yield, according to the data, was 34.47%, which was close to the verification value of 34.38 ± 0.04%. The average yield value of dietary fibers produced during the verification procedure was slightly less than the prediction but not significantly different, so the model created can be used to maximize the extraction of dietary fibers from corn stalks and is reliable and adequate in its predictions. These results indicate that the dietary fiber extraction model from corn stalks obtained from the verification process can be applied to actual applications.

Characteristics of the product. Cellulose fiber is needed in food processing as a dietary fiber and as a filler in processed meat and fishery products such as meatballs or fish balls. The filler and source of dietary fiber currently used is wheat flour, but additional dietary fiber from other sources is still needed. The ability of flour to absorb high water is needed in this case because it has an impact on the texture, taste, and consistency of the final product. Flour with good water absorption capacity can produce a softer and chewier product texture, the quantity of water that the flour absorbs determines the elasticity and density of the dough. Flour that absorbs water well can help bind other ingredients so that the final product is more stable and does not easily crumble. In products

that require fermentation, such as bread, the ability of flour to absorb water affects the gas formation process needed for dough development, flour with good water absorption capacity tends to be more durable because it can control the water content in the dough.

Highly porous cellulose fibers usually have good WHC because their porous structure allows for greater water retention. This makes it suitable for applications in products that require moisture, such as in wet food products or as a binder. The WHC value of corn stalks dietary fiber was found to be 5.1 ± 0.04 (g/g), this value can explain the great potential of corn stalks dietary fiber as a food ingredient. In this case, corn stalks dietary fiber can be combined with wheat flour or rice flour as a source of fiber and filler in the processing of meat and other fishery products that require flour for dough. Corn stalks dietary fiber has the potential to be combined with wheat flour because wheat flour has a low WHC of 1.85 g/g [18].

In line with WHC, OHC is also important in food processing and has several significant impacts, namely that flour that is able to absorb oil well can provide a crispier and softer texture to products, such as cakes and pastries. Good oil absorbers can help bind flavors and aromas and provide a more specific taste to food products. Related to product stability, the ability of flour to absorb oil can increase product stability, help prevent fat separation from dough or mixtures, and provide moisture. Flour that absorbs oil can also help maintain moisture in food products, which is important for maintaining freshness. In the baking process, flour that absorbs oil can contribute to the formation of the desired crust and color. The OHC value of good flour ranges from 1.0 to 2.0 g oil/g flour [19]. Wheat flour has an OHC value of 1.05 (g/g) [20]. Related to OHC, dietary fiber tends to have a lower value, often ranging from 1 to 2 g oil/g fiber. This is because dietary fiber absorbs more water than oil. The OHC value of corn stalks dietary fiber in this study was found to be 1.2 ± 0.03 (g/g).

Dietary fiber products were further characterized by FTIR, SEM, and BET instruments. Spectral analysis of the functional group of dietary fibers before and after treatment with NaOH has been carried out using FT-IR infrared spectroscopy. Figure 3 shows that there are two main regions of absorption, namely the region with a wavenumber range from 500 to 1600 cm^{-1}. The absorption bands near 3303 and 2907 shifted slightly to 2864 cm^{-1} for the -CH_2 group of dietary fibers, the treated stalks are linked to asymmetric stretching of C-H bonds and hydrogen-bonded OH groups [21]. The characteristic signals at 1358 cm^{-1} correspond to the deformation vibrations of CH_2 and CH groups [22, 23]. The peak located at 1145 cm^{-1} is linked to asymmetric C-O-C stretching. After hemicellulose, lignin, and pectin were removed, the broad peak at about 1013 cm^{-1} represents the C-O stretching vibrations in cellulose that varied little. The C-O group connected to the β-glycosidic link was also identified as the source of the peak at 883 and 891 cm^{-1} [24, 25].

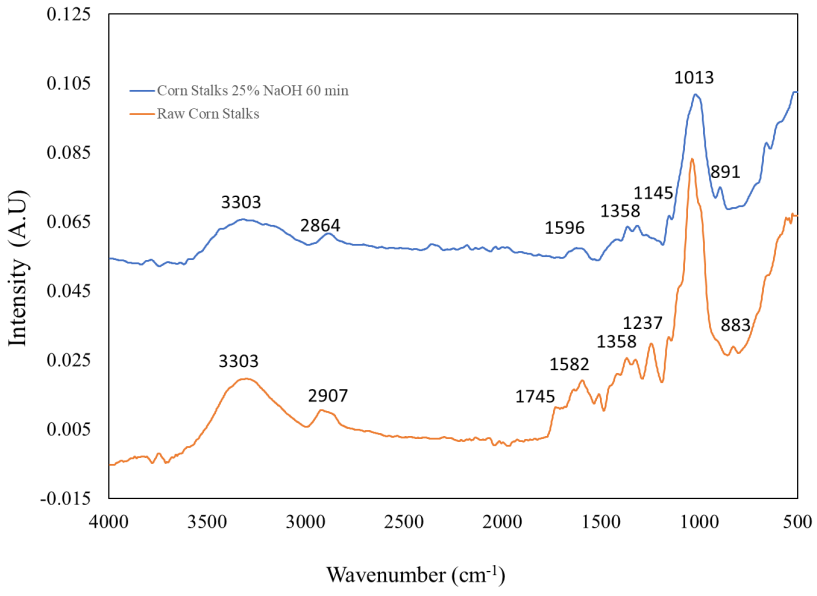

Figure 3 – FT-IR spectra of corn stalks as the sample and dietary fiber extracted from corn stalks as the product

Furthermore, the carbonyl group of aromatic acids present in lignin and hemicellulose in raw maize stalks was identified as the cause of the shoulder peak at 1582 and 1596 cm^{-1}. The FTIR bands at 1745 and 1237 cm^{-1} in corn stalks are associated with the carbonyl (C=O) stretching and C-O stretching vibration, respectively, primarily from ester groups present in hemicellulose. These peaks often indicate the presence of acetyl or ester linkages within hemicellulose, which are responsible for its structural role in the plant cell wall. The intensity of this band can decrease after chemical treatments, such as alkaline processing, as hemicellulose and associated esters are removed [25].

SEM was used to analyze the raw material's microstructure (Figure 4). The surface of the raw corn stalks displays a rough, uneven, filamentous structure. This filamentous nature results from the presence of wax layers, pectin, and other impurities, such as lignin and hemicellulose, which bind the cell walls of the corn stalks together. However, after treatment with 25% NaOH for 60 min, the rough, filamentous surface breaks down, revealing a fibrous structure. The NaOH dissolves the wax, pectin, hemicellulose, and lignin, leaving behind only cellulose fibers.

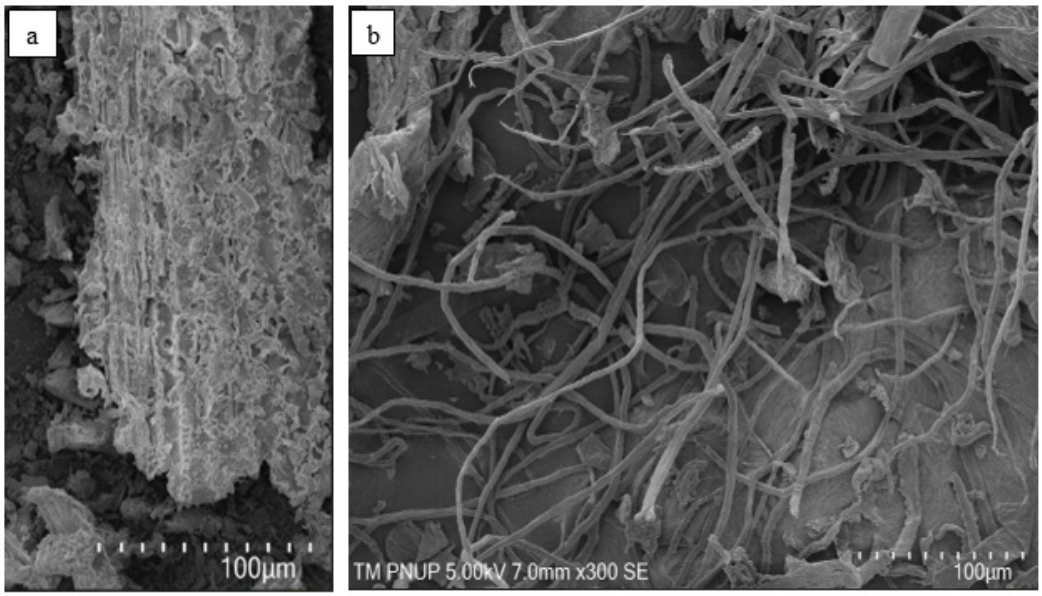

Figure 4 – SEM analysis of corn stalks (a) and dietary fiber extracted from corn stalks after 60 min treatment with 25% NaOH (b)

Analysis of corn stalks dietary fiber products using the BET can be seen in Figure 5. The graph shows that most of the pores are >2 nm in size, this value indicates that the existing pores are mesopores. This fairly large pore size correlates with the large absorption capacity of dietary fiber products for water and oil. Figure 5 shows the adsorption and desorption capabilities of dietary fiber products, which are almost comparable. This means that the product has almost the same absorption capacity in absorbing (adsorption) and releasing (desorption) water and oil. In this result, adsorption refers to the ability of water molecules to adhere to the surface of dietary fiber products, while desorption is the ability of water and oil molecules to be released back into the environment. These two abilities are almost the same, so that corn stalks dietary fiber products have a good balance between water absorption and release, which can impact the quality, texture, and shelf life of the product in its application in the food sector or other industries. This balance is especially important in the context of the storage and use of dietary fiber products because it can impact the physical and chemical properties of the processed products.

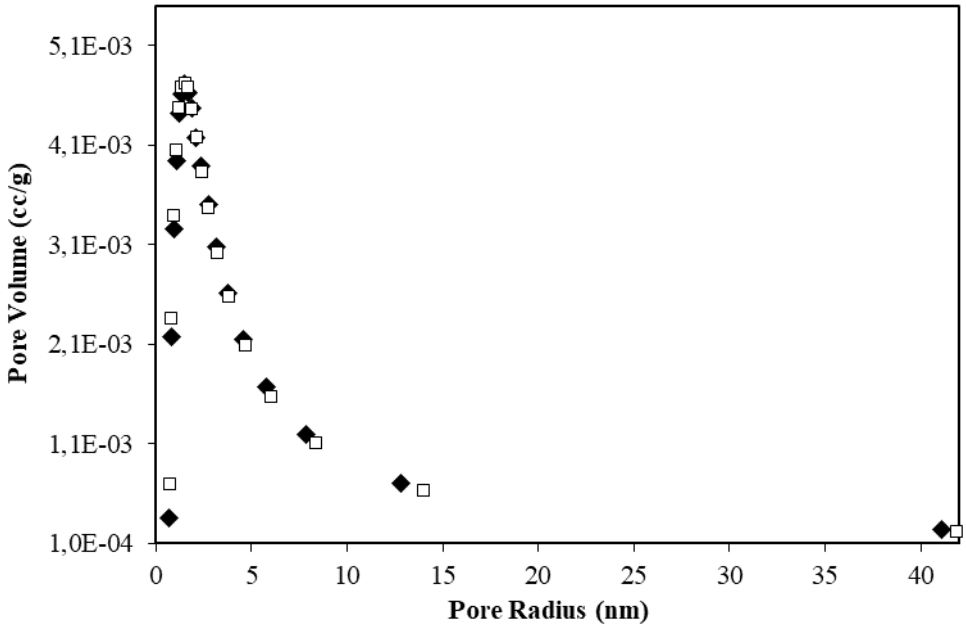

Figure 5 – Analysis of dietary fiber products from corn stalks using the BET instrument (♦ Adsorption and □ Desorption)

The pore surface area obtained was 3.07 m^2/g, pore size = 0.7-41 nm, adsorption pore volume = 3.58E-03 cc/g, desorption pore volume = 3.60E-03 cc/g. The adsorption and desorption abilities of dietary fiber products that are almost the same are considered good in several ways, including: 1) Moisture balance: Products with balanced adsorption and desorption abilities can maintain optimal humidity so that these conditions can prevent the product from becoming too dry or too humid, which can affect its quality; 2) Product stability: This balance can help maintain the stability of dietary fiber products during storage, reducing the risk of lump formation or mold growth due to excessive moisture; and 3) Performance in the processing: In the food processing, dietary fibers that can absorb and release water well can provide better texture and consistency in the final product.

This study provides a model of the optimum conditions for the process of extracting dietary fiber from corn stalks. The effect of the interaction NaOH concentration and extraction time was achieved at 25.96% NaOH for 65.39 min and produced a yield of dietary fiber of 34.47%, and at the laboratory scale verification stage, a yield of 34.38% was produced. These results promise the feasibility of this method for industrial-scale applications. An important result of this study is that the optimum conditions for the process of extracting dietary fiber from corn stalks were achieved at a NaOH concentration of 25.96% and an extraction time of 65.39 min, producing dietary fiber of 34.38%.

Based on the results of product characterization, namely WHC and OHC analysis, as well as analysis using FT-IR, SEM, and BET instruments, it provides scientific evidence of the product's feasibility as a source of dietary fiber that supports the potential use of the product as a food ingredient. The implication of this study is the availability of an effective and efficient method for extracting dietary fiber from corn stalks. In addition, the results of this study offer an alternative source of dietary fiber that is abundant, renewable, and sustainable as a filler, especially in meat and fish processing. Recommendations for further research include exploring the application of corn stalk fiber in various food matrices and investigating the long-term stability and sensory properties of products containing this dietary fiber.

Conclusion

This study provides a model of optimal conditions for the process of extracting dietary fiber from corn stalks. The optimum conditions in relation to NaOH concentration and extraction time were achieved at 25.96% NaOH for 65.39 min. Under these conditions, the yield of dietary fiber obtained was 34.47%, and at the laboratory scale verification stage, it was

produced as much as 34.38%. These results confirm the feasibility of this method to be applied on a larger scale. Product characterization based on FT-IR, SEM, BET, WHC, and OHC analyses illustrates the feasibility of the product as a source of dietary fiber and filler in food processing. The implication of this study is the availability of an effective, efficient, and feasible method for extracting dietary fiber from corn stalks that can be applied in industry. In addition, the results of this study inform the existence of an alternative source of dietary fiber that is abundant, renewable, and sustainable to be applied as a filler, especially in meat and fish processing. Recommendations for further research include an exploratory study of the application of corn stalk fiber in various food preparations such as bread, cakes, and noodles/pasta. In addition, research related to the long-term stability and sensory properties of products containing this dietary fiber.

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Conflict of Interest

The authors declare no conflicts of interest or personal relationships with other people or organizations that can inappropriately influence this work.

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