International Journal of PharmTech Research
CODEN (USA): IJPRIF, ISSN: 0974-4304, ISSN(Online): 2455-9563
Vol.9, No.7, pp 130-139, 2016

Utilization of Microcrystalline Cellulose of Sugar Palm Bunches (*Arengapinnata* (Wurmb) Merr.)asExcipients Tablet Direct Compression

Sumaiyah[1]*, Basuki Wirjosentono[2], Karsono[1]

[1] Faculty of Pharmacy University of Sumatera Utara, Indonesia
[2]Faculty of Math and Science University of Sumatera Utara, Indonesia

Abstract : Microcrystalline cellulose is the best in the manufacture of tablet excipients direct compression. This study aims to determine the concentration of α-cellulose contained in the sugar palm bunches, isolate α-cellulose, and change it into microcrystalline cellulose. The microcrystalline cellulose of sugar palm bunches (MCCSPB) was then characterized and compared with commercial MCC (Avicel PH 102). The characteristics of MCCSPB included qualitative identification, pH, drying shrinkage, polymerization degree, functional groups, morphology, particle size, flowability, compressibility, and hydration capacity. Furthermore, MCCSPB were molded into tablets and evaluated weight uniformity, friability, hardness, and disintegration time of tablets. The research results showed that sugar palm bunches had high concentration of α-cellulose of 33.79%. The yields of α-cellulose and microcrystalline cellulose from sugar palm bunches were 20-26% and 16 to 21.33%, respectively. MCCSPB had a functional group that was synonymous with Avicel PH 102, irregular shapes and uneven surfaces, the size of 100-300 μm, the polymerization degree 180.7, good flow properties and compressibility, hydration capacities and swelling respectively for 2.62% and 15.56%. The molded tablets using the MCCSPB had a weight uniformity that is qualified to the Indonesian Pharmacopoeia edition III. Tablet hardness and disintegration time were 7.05 and 0.23 minutes, respectively. Thus, it can be concluded that the MCCSPB could be used as a filler, binder, and a disintegrator in the manufacture of tablet direct compression.
Keywords: *Arengapinnata* (Wurmb) Merr.,α-cellulose, microcrystalline cellulose, characteristics, tablet.

Introduction

Cellulose is a polymer renewable source. Cellulose fiber has been used in the form or its derivatives for about 150 years as a chemical raw material [1]. Cellulose is an unbranched chain macromolecular units of β-D-anhydroglucopiranose connected with 1,4-glycoside bond. Cellulose has the chemical formula $(C_6H_{10}O_5)$ n, which n ~ 500, and 243,000 of the molecular weight [2]. Cellulose presents in the cell walls of all plants. Cellulose pulp describes purified cellulose and still containing other carbohydrates. Cellulose of hair cottonseed, flax fibers, and wood are generally used as the source of pure cellulose [3].

In the tablets manufacturing, microcrystalline cellulose (MCC) MCC also has disintegrant and lubricant properties [4]. MCC has also been regarded as the best excipient in the manufacturing of direct compression tablet [5,6, 7]. Microcrystalline cellulose has been made from several natural sources such as fiber hemp, bagasse, straw, leather cotton, and linen by hydrolyzing α-cellulose and dilute acid solution at high temperature. Hydrolysis of

α-cellulose will shorten the chain, so then the microcrystalline cellulose has the formula $(C_6H_{10}O_5)$ n, where n ~ 220, molecular weight: ~ 36,000[5,8,9, 10, 11].

Plant sugar palm (*Arengapinnata* (Wurmb.) Merr.)or *Arenga saccharifera* Labill.is a species of the genus Arenga and part of Arecaceae (Palmae) family. Aren is a versatile plant. Virtually, all parts of the sugar plant can be utilized. Fruit seed can be processed intosweets and food (kolang-kaling). The bunches of palm tree consist of many stalks whose approximately 2 feet length, all hanging on a larger stalk, all full of fruit that are green when it is young and yellowish brown when ripe [12]. The palm fruit seeds that are going to be processed into kolang-kalingare brought to the mill while it is still attached to their stems. Then, the empty bunches which all fruits been taken to be processed into kolang-kaling are usually left to dry or used as a firewood.

Based on the above description, the authors are interested in examining the content of α-cellulose in the waste palm bunches, isolating α-cellulose, and turn it into microcrystalline cellulose, then use it as a tablet excipients in a direct compression. In this study, the authors also carry out the characterization of MCCSPB that covers functional groups, morphology, particle size, degree of polymerization, flowability, compressibility and hydration capacity. The obtained MCCSPB is molded into a tablet, and evaluated its weight uniformity, friability, hardness, and the time of destruction.

Experimental

Material

Materials used were empty fruit bunches of palm trees, collected from Langkat, North Sumatera. Avicel was obtained from Mingtai Chemical Co. Ltd., and HCl, HNO_3, NaOCl, NaOH, $NaNO_2$, and Na_2SO_3were from Merck pro analysis.

Apparatus

Oven, blender, analytical balance (Mettler Toledo), desiccator, stopwatch, thermometer, waterbath, drying cabinets, sieve, pH meter (Hanna), angle of repose and flow time testers, scanning electron microscopy (SEM) (JSM-35 C Sumandiu), vacuum pump, FTIR (Shimadzu), compressing tablet single punch (Ateliers), strong cobb hardness tester (Erweka), disintegration tester (Erweka), dissolution apparatus, and equipment laboratory glassware.

Preparation of materials

The collected bunches of palm were cut into small pieces with a size of 1-2 cm, dried, pulverized in a blender and filtered through a sieve of 20 and 60 mesh. The filtration result would pass in the sieve 20 mesh and retained on 60 mesh.

Determination of Chemical Components of Sugar Palm Bunches

Determination of the chemical components of sugar palm bunches was determined in accordance with the standards outlined in TAPPI test methods. Lignin content was carried out following the T222 method [13], α-cellulose based by T203 [14], holocellulose was determined by T249[15], moisture was determined by T258[16], and extractive was determined by T-204[17].

Isolation of α-Cellulose Sugar Palm Bunches

75 g of palm bunches powder was inserted into the beaker glass, then added 1L of a mixture of HNO_3 3.5% and 10 mg $NaNO_2$, and immersed in a water bath at 90 °C for 2 hours. Then this was filtered and the residue was washed until the filtrate was neutral. Furthermore, the residue was digested by 750 ml of 2% NaOH solution and 2% sodium sulfite at a temperature of 50 °C for 1 hour. Then residue was filtered. Furthermore, the bleaching was conducted with 250 ml of 1.75% sodium hypochlorite solution at boiling temperature for 0.5 hours. Then residue was filtered and washed until the pH of the filtrate was neutral. Furthermore the purification of α-cellulose of the sample was done by 500 ml of 17.5% NaOH solution at 80 ° C for 0.5 hours. Then this was filtered and washed until the filtrate was neutral. Following to that, the bleaching was performed using 10% hydrogen peroxide solution at a temperature of 60 °C for 15 minutes. Then this was filtered and

washed completely with distilled water, and dried at a temperature of 60 °C in the oven for 1 hour. Subsequently α-cellulose was sieved with 20 mesh sieve[8,18].

Manufacture of Microcrystalline Cellulose

The α-cellulose powder was hydrolyzed with 2N HCl in the ratio of powder: HCl 2N (1:20) and refluxed at 105 $\pm$ 2 ° C for 15 minutes. Then this was washed with distilled water until neutral, then dried in a drying cabinet for 24 hours and ground[8].

Characterization of Microcrystalline Cellulose of Sugar Palm Bunches

The tests were conducted to determine the physicochemical properties of microcrystalline cellulose included qualitative identification, pH, drying shrinkage, analysis of functional groups, morphology, particle size, the degree of polymerization, flow-ability, compressibility and hydration capacity.

Infrared Spectroscopy

The infrared spectroscopy of microcrystalline cellulose palm bunches was determined by Infrared Spectrometer Shimadzu FTIR using KBr pellet technique.

Particle Morphology

MCC particle morphology analysis was done by using Scanning Electron Microscope (SEM) JSM-35 C Sumandiu equipment.

Determination of Polymerization Degree

Determination of alpha cellulose sugar palm bunches was performed based on TAPPI [11]. The MCC was weighed 0.025 g, then was put in a 25 ml flask and dissolved gradually with cupri ethylene diamine (CED) until reach the mark line while it was homogenized. 10 ml of solution put in an Ostwald viscometer. The solution flowing time from the top to the bottom marks were recorded. This treatment was done repeatedly in three times. Then the solution viscosity was compared with CED. Next, the value of the intrinsic viscosity of cellulose was determined bythe Least Square method. After the intrinsic obtained, viscosity molecular weight of MCC was calculated using the Mark-Houwink equation [19]:

$[\eta] = KM\alpha$

Where K, α = Mark-Houwink constant (K = 9.8 x 10-3 and α = 0.9)

[η] = intrinsic viscosity

M = molecular weight cellulose

After the molecular weight of MCC was obtained, the degree of polymerization (DP) was determined by comparing the molecular weight obtained with a molecular weight unit structure.

$$DP = \frac{(\text{molecular weight of cellulose})}{(\text{molecular weight of one unit of glucose})}$$

The same procedure was performed to solution concentration of 0.05 g/25 ml, 0.075 g/25 ml, 0.1 g/25 ml, and 0.25 g/25 ml.

Flow Property

Angle of Repose

Angle of repose (θ),is measured according to the method of the funnel and the cone. A funnel was clamped to the ends on a graph paper was placed on a flat horizontal surface. The powder was poured carefully through the funnel to the top of the cone. The average cone base diameter was determined by powder and the tangent of the angle of repose which was calculated using the following equation:

$\text{Tan } \theta = 2h / D$

Given h is the height of the pile of powder and D is the diameter of the base heap of powder.

Bulk and Tap Density

The microcrystalline cellulose powder were placed in a 100 ml measuring cup which was cleaned and dried without tapping determined (V_0). The tapping then was performed 500 times, and then the volume was measured (V_{500}). Bulk and tap density were calculated as the ratio of weight and volume.

Hausner Index

Hausner index was calculated as the ratio of bulk density to tap density of the sample.

The compressibility index (%)

The compressibility index was calculated using the equation:

$$\text{Compressibility} = \frac{(\text{tap density} - \text{bulk density})}{(\text{tap density})} \times 100\%$$

Hydration capacity

Each of 1.0 g sample was put in four 15 ml centrifuge tubes. Then, 10 ml of distilled water was added into the centrifuge tube, and then closed. Subsequently, a mixing was carried out with vortex for 2 minutes. The mixture was stood for 10 minutes and centrifuged at 1000 rpm for 10 minutes. Supernatant was decanted carefully and the precipitate was weighed. Hydration capacity (HC) was calculated as the weight ratio of sludge to a dry sample weight[8].

Moisture Absorption Capacity

The sample was weighed as much as 2 g and distributed on the surface of a porcelain cup. Then the sample was placed in a desiccator containing water (RH = 100%) at a room temperature and the sample was weighed every day for 7 days[8].

Tablet Compression

Tablets were compressed using the MCCSPB and Avicel PH 102 and then the tablets were evaluated.

Pre-formulation Test

Pre-formulation test was carried out for the repose angle of granules, the flow time of granules and the tap index determination.

Evaluation Tablet

The tablet evaluations were included weight uniformity, tablet hardness, friability and disintegration time.

Weight Uniformity

Determination of weight uniformity was done by following Indonesian Pharmacopoeia Edition III[20].

Hardness of Tablet

The strong Cobb hardness tester was used to determine the hardness of tablets.

Friability

Determination of friability of tablet was used a Roche friabilator.

Disintegration Time

Apparatus: disintegration tester

The equipment consisted of a series of baskets, beaker 1000 ml, a thermostat with a temperature of 36-38 °C and a device that meant to dip a basket with a frequency of 29-32 times per minute. One tablet was inserted into each tube of the basket, put the disc into each tube, and the tool was started. The water was as a medium with a temperature of 36-38°C. The tablet disintegration time was reached at the end of the time limit which was the time that all parts of the tablet had passed through the wire netting. The tests were performed with 5 tablets, which took 15 minutes for the entire tablet to crushed and passed through gauze on the tube[20].

Results and Discussion

The results of the determination of chemical components contained in sugar palm bunches can be seen in Table 1.Lignin is an amorphous polymer chemical structure that is very different from the cellulose and hemicellulose. Lignin is deposited predominantly in the walls of secondarily thickened cells, making them rigid and impervious[21]. Levels of lignin derived from palm bunches was 27.74%. These levels included the medium category because in between 18% - 33%. Holocellulose is composed of the total polysaccharide fraction that consist of cellulose and hemicellulose[22]. Levels of holocellulose palm bunches was 68.11%. Content of α-cellulose indicates the purity of cellulose. Content of α-cellulose from sugar palm bunches was 33.79%. Various cellulose derivatives obtained from the processing of α-cellulose with various chemicals. Extractive levels are the result of secondary metabolic processes of trees that vary according to the type, grow, and climate. Levels of extractive substances palm bunches of 1.80%.

Table 1. The chemical components of sugar palm bunches

No.	Parameter	Content (%)
1.	Lignin	27,74
2.	Holocellulose	68,11
3.	α-cellulose	33,79
4.	Moisture	11,10
5.	Extractive	1,80

(a) (b)

Figure 1.α-celluloseof palm bunches (a) and microcrystalline cellulose of palm bunches (MCCSPB) (b)

The yield of α-cellulose palm bunches (Figure 1a) that was produced from 75 g of powdered sugar palm bunches was 15 to 19.5 g (20-26%). The yield of microcrystalline cellulose palm bunches (MCCSPB) (Figure 1b) that was produced from palm bunches of α-cellulose was about 12-16 g (80-82%). Thus, the yield of the starting material was MCCSPB (16 to 21.33%). These results were obtained after the removal of some substances such as lignin, hemicellulose and others contained in palm bunches. This was happen during purification of α-cellulose bunches of palm, and followed by the partial removal of the structure of amorphous cellulose, after the hydrolysis of α-cellulose, thereby reducing the yield of the MCCSPB.

Physicochemical Properties of MCCSPB

The results of the physicochemical properties of the MCCSPB can be seen in Table 2. The organoleptic quality of the MCCSPB produced was good, odorless, tasteless, white, and in the form of fine granules. The test results indicated that the qualitative identification of microcrystalline cellulose had been produced from palm fruit bunches. The test results showed that the starch iodine solution was not found in the MCCSPB

Table 2. The physicochemical properties of the MCCSPB

Parameter	MCCSPB	Avicel PH 102*
Organoleptic	White, odorless and tasteless	White, odorless and tasteless
Identification	Blue violet with $ZnCl_2$	Blue violet with $ZnCl_2$
Starch	None (not blue with iodine solution)	None (not blue with iodine solution)
Polymerization degrees	180.7	236
pH	7.4	6.3
Drying shrinkage (%)	5.68	4.4

Note: - The value obtained is the average of three repetitions

The values obtained from the testing met the requirements of USP 32-NF 27, including DP <350, drying shrinkage of 5.68%. Total recurring in the chain is called the degree of polymerization (DP). Microcrystalline cellulose that was derived from palm bunches had180.7 degree of polymerization (DP). DP Value accordance with the terms contained in USP 32-NF 27 is <350[23].

The infrared spectrum of the MCCSPB compared to Avicel PH 102 was exhibited in Figure 2. The wave numbers of FTIR spectra was demonstrated in Table 3.

Table 3. Wave number of FTIR

Wave number (cm^{-1})	Group
3377	OH
2889	Hydrogen bond
1421	C-H alkane
1311	C-O ether
1029	C-O alcohol

The wave number of the groups that was contained in the MCCSPBwasidentical to those of the microcrystalline cellulose that had been circulating in the trade of Avicel 102. Thus, it could be said that the microcrystalline cellulose had been isolated from palm bunches.

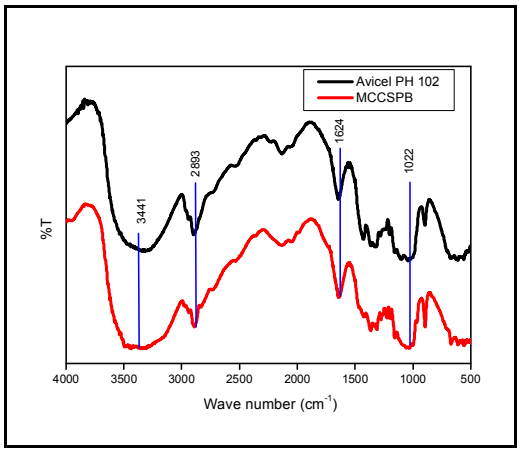
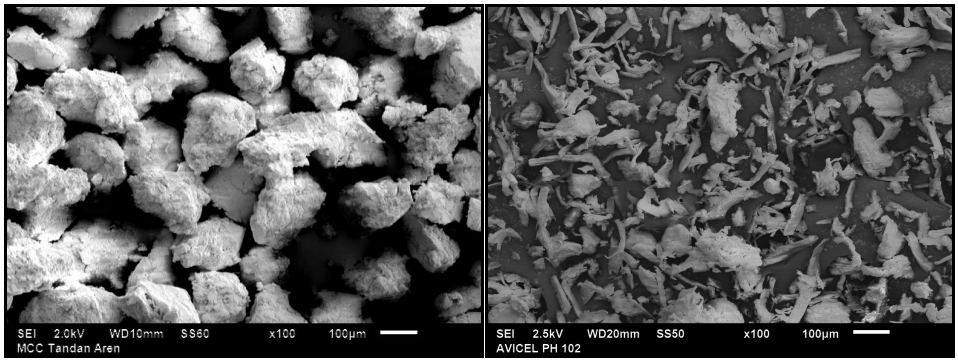


Figure 2. Infrared spectrum of Avicel PH 102 and MCCSPB



(a) (b)

Figure 3. SEM of MCCSPB (a) and Avicel PH 102 (b)

The analysis of microcrystalline cellulose with a scanning electron microscope (SEM) was conducted to determine the particle shape. The results showed that MCCSPB and Avicel PH 102 had an irregular shape and uneven surface texture (Figure 3). The MCCSPB's particle size was about 100-300 µm and theAvicel 102 average size of 100 µm. This was because the MCCSPB granules used were the granules that had passed through 60 mesh and retained on a 100 mesh sieves.

Table 4. Nature of microcrystalline cellulose powder and Avicel PH 102

Parameters	**MCCSPB**	**Avicel PH 102**
True specific gravity (g/ml)	1,47	1,46
Bulk specific gravity (g/ml)	0,43	0,42
Incompressible density (g/ml)	0,51	0,48
Porosity (%)	71,06	71,19
The flow properties : Angle of repose (^{o}) Hausner index Compressibility index	 20,47 1,18 15,79	 30,12 1,14 12,50
Hydration capacity (%)	2,62	2,10
Capacity swelling (%)	15,56	22,50

The MCCSPB flow properties and Avicel PH 102 could be seen in Table 4. The repose angle of MCCSPB measurement results was 20.47^o and Avicel PH 102 30.12^o. This value indicated that the MCCSPB powder had the ability to flow as well as Avicel PH 102. The Hausner Index of MCCSPB and Avicel PH 102 were 1.19 and 1.14 respectively. Both of these materials had an Hausnerindex value of less than 1.25. This meant that the material had good flow properties. The MCCSPB compressibility index value was 15.79 and the Avicel PH 102 was 12.50. This value indicated that the MCCSPB and Avicel PH 102 had good flow properties[5]. The three indicators' value mentioned above showed that the produced MCCSPB had flow properties which was similar to Avicel PH 102. The Avicel PH 102 was already circulating in the market and could be used asa filler in the manufacturing of direct compression tablet.

The enlargement or swelling in general is an indication of the ability of the tablet to rupture. This enlargement could be identified by testing the determination of hydration capacity, swelling capacity and moisture absorption capacity. The MCCSPB's hydration capacity was 2.62% and Avicel PH 102 was 2.11%. This suggested that the ability to absorb water from the MCCSPB and Avicel PH 102 were almost the same which was about two times of the original weight. The swelling capacity of Avicel PH 102 was greater than the MCCSPB. The swelling capacity of the two samples were not significant, this was because the hydrochloric acid had eliminated most of the amorphous cellulose structure that plays an important role in getting water to further inflation.

A moisture absorption capacity is a measurement of the materials sensitivity toward moisture. The profile moisture absorption capacity of the MCCSPB and Avicel PH 102 could be seen in Figure 4. The Avicel PH 102 value was higher than the MCCSPB's. This is due to the size and shape of the Avicel PH 102's particle

was smaller than the MCCSPB's, so the Avicel PH 102's particle had a greater surface area than the MCCSPB's. These results were also important to the stability of tablets made using the MCCSPB or Avicel PH 102 whenever the storage was done in a humid condition. Due to the nature of MCCSPB and Avicel PH 102 were sensitive to the atmospheric humidity, the storage should be done in a tightly closed container.

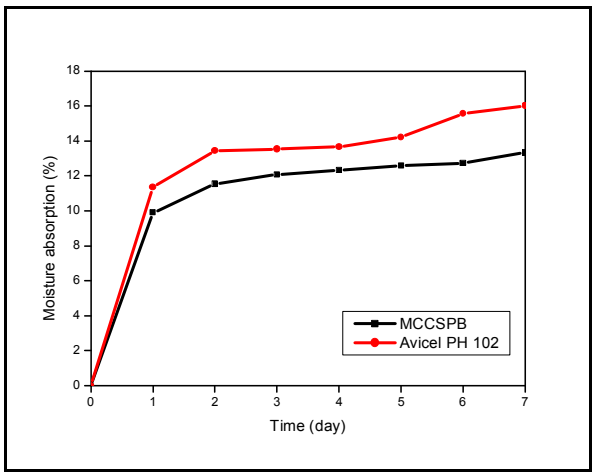


Figure 4. Profile moisture absorption capacity of the MCCSPB and Avicel PH 102

MCCSPB and Avicel PH 102 Tablet

The test results MCCSPB tablet weight uniformity and Avicel PH 102 could be seen in Table 5 below.

Table 5. Results of test weight uniformity tablet MCCSPB and Avicel PH 102

Description	MCCSPB	Avicel PH 102
Average weight (mg)	146	65
A1 (%)	10.96	7.69
A2 (%)	4.11	7.69
B (%)	10.96	7.69

The weight uniformity test results of the MCCSPB's tablet and Avicel PH 102 were consistent to the Indonesian Pharmacopoeia edition III, namely tablets with average weight of 26-150 mg. It had the average weighted deviations which no more than 2 tablets that deviated from the price specified in column A which was equal to 10% and none of the tablet should deviate from the average weighted of the prices set in column B by 20%.

The friability test illustrated the effect of physical impact on the tablet during packaging and distribution. The friability or weight loss was experienced by each type of tablet did not exceed 0.8%. If the friability test requirements were met, then the integrity of the tablet that reaches the consumer could be assured. The MCCSPB and Avicel PH 102 tablets friability test result data can be seen in Table 6. The friability of the tablet formula was not qualified because it was greater than 0.8%. This was influenced by the composition of the tablet that only consists of granule particle size that larger than powder, so there were many voids between particles that caused lack of the tablet power.

Table 6. The results of friability and hardness test from MCCSPB and Avicel PH 102 tablets

Formula	Friability (%)	Tablet Hardness (kg)	Disintegration time	
			With disc (min)	Without disc (min)
MCCSPB	2.02	7.05 ± 0.51	0.23 ± 0.09	0.37 ± 0.05
Avicel PH 102	26.02	1.25 ± 0.25	0.18 ± 0.05	0.36 ± 0.06

The results of hardness test of MCCSPB and Avicel PH 102 tablets could be seen in Table 6 below. Tablet hardness was4-8 kg. It meant tablet hardness could be smaller than 4 or higher than 8 kg. The tablet hardness that was less than 4 kg was acceptable as long as the vulnerability did not exceed the set limit. However, a softer tablet usually will have a fragility that is steeper and more difficult to handle at the time of packaging and transportation. The tablet hardness greater than 10 kg was acceptable as long as they met the requirements of disintegration time and dissolution required.

The disintegration time of MCCSPB and Avicel PH 102 tablets could be seen in Table 6 which the tablet's disintegration time was less than 1 minute. This was due to the tablet formula only consisted of each MCCSPB and Avicel PH 102 granule, which was both hydrophilic and had a gap between the particles [24]. Therefore, the water could easily enter the slits and caused the tablet quickly disintegrated. Both formulas had disintegration time not more than 15 minutes.

Conclusion

The isolation of α-cellulose from sugar palm fruit bunches yield was about 20-26% yield and approximately 16 to 21.33% microcrystalline cellulose. Microcrystalline cellulose was composed of particles with irregular shape, odorless, white, tasteless, with a pH of 7.4, and drying shrinkage of 8.6%. Microcrystalline cellulose powder palm bunches had a good flow properties, with repose angle of 20.47^{o}, Hausner index of 1.19, and a compressibility index of 18.6%. Thus, palm bunches microcrystalline cellulose could be used as a filler, binder, and a disintegrator in the manufacturing of a direct compressed tablet.

Acknowledgement

Sumaiyah would like to acknowledge to home industry of kolang-kaling in Langkat, North Sumatera, Medan, for providing sugar palm bunches.

References:

1. Habibi, Y., Lucia, L.A., and Rojas, O.J., Cellulose Nanocrystals: Chemistry, Self-Assembly, and Applications, Chemical Review, 2010, 110, 3479-3500.
2. Rowe, R.C., Sheskey, P.J., dan Quinn, M.E, Handbook of Pharmaceutical Excipients, Sixth Edition, London, Pharmaceutical Press, 2009, 129-133, 136-138.
3. Zugenmaier, P., Crystalline Cellulose and Derivatives, Heidelberg, Springer-Verlag, 2008, 7-8.
4. Macuja, J.C.O., Ruedas, L.N., and Espana, R.C.N., Utilization of Cellulose from *Luffacylindrica* Fiber as Binder in Acetaminophen Tablets, Advances in Environmental Chemistry, 2015, ID 243785, 1-8.
5. Bhimte N.A and Tayade P.T., Evaluation of Microcrystalline Cellulose Prepared from Sisal Fibers as A Tablet Excipieint: A Technical Note, AAPS PharmSciTech, 2007, 8(1), E1- E7.
6. Formulation Development and Evaluation of Fast Disintegrating Tablets of Salbutamol Sulphate, Cetirizine Hydrochloride in Combined Pharmaceutical Dosage Form: A New Era in Novel Drug Delivery for Pediatrics and Geriatrics, Journal of Drug Delivery, 2015, 2015, 1-10.
7. Pinakin, P., Pandey, N.K., Singh, S. K., and Garg, V., MCC SANAQ® Burst: A Unique Carrier for Formulation of Sublingual Tablets, International Journal of PharmTech Research, 2016, 9(1), 15-22.
8. Ohwoavworhua, F.O., and Adelakun, T.A., Some Physical Characteristics of Microcrystalline Cellulose Obtained from Raw Cotton of *Cochlospermumplanchonii,* Tropical Journal of Pharmaceutical Research, 2005, 4(2), 501-507.
9. Ilindra, A., and Dhake, JD., Microcystalline Cellulose from Bagasse and Rice Straw. Indian Journal of Chemical Technology, 2008, 15, 497-499.
10. Leppanen, K., Andersson, S., Torkkeli, M., et al, Structure of Cellulose and Microcrystalline Cellulose from Various Wood Species, Cotton and Flax Studied by X-Ray Scattering, Cellulose, 2009, 16, 999-1015.
11. Qiang D, Zhang, M., Li, J., Xiu, H., and Liu, Q., Selective Hydrolysis of Cellulose for The Preparation of Microcrystalline Cellulose by Phosphotugstic Acid, Cellulose, 2016, 23(2), 1199-1207.
12. Heyne, K., Useful Plants Indonesia,Vol. 1, Jakarta,SaranaWana Jaya Foundation, 1987, 447-455.

13. Anonymous, Technical Association of the Pulp and Paper Industry: Sampling and Preparing Wood for analysis Technical Association of the Pulp and Paper Industry, TAPPI Standard T222 om-02, Atlanta, USA, 2002.
14. Anonymous, Technical Association of the Pulp and Paper Industry: Sampling and Preparing Wood for Analysis Technical Association of the Pulp and Paper Industry. TAPPI Standard T203 cm-99, Atlanta, USA, 1999.
15. Anonymous, Technical Association of the Pulp and Paper Industry: Sampling and Preparing Wood for Analysis Technical Association of the Pulp and Paper Industry. TAPPI Standard T249, Atlanta, USA, 2000.
16. Anonymous, Technical Association of the Pulp and Paper Industry: Sampling and Preparing Wood for Analysis Technical Association of the Pulp and Paper Industry. TAPPI Standard T258om-02, Atlanta, USA, 2002.
17. Anonymous, Technical Association of the Pulp and Paper Industry: Sampling and Preparing Wood for Analysis Technical Association of the Pulp and Paper Industry. TAPPI Standard T204om-96, Atlanta, USA, 1996.
18. Sumaiyah, Wirjosentono, B., Karsono, Nasution, M.P., and Gea, S., Preparation and Characterization of Nanocrystalline Cellulose from Sugar Palm Bunch (*Arengapinnata* (Wurmb) Merr.), International Journal of PharmTech Research, 2014, 6(2), 814-820.
19. Tomar, M., Singh, A.K., and Sinha, A.R., Physicochemical Parameter of Microcrystalline Cellulose and the Most Acceptability in pharmaceutical Industries, Journal of Innovations in Pharmaceutical and Biological Sciences, 2015.
20. Director General of Food and Drug Administration, Indonesian Pharmacopoeia, Edition III, 1979, Jakarta: Department of Health Republic Indonesia, 7, 774.
21. Vanholme, R., Demedts, B., Morreel, K., Ralph, J., and Boerjan, W, Lignin Biosynthesis and Structure, Plant Physiology, 2010, 153, 895-905.
22. Rabemanolontsoa, H. and Saka, S., Holocellulose Determination in Biomass, Zero Carbon Energy Kyoto 2011, Part II, 135.
23. The USP Convention, The United States Pharmacopoeia 32-The National Formulatory 27, 2009, Rockville, The United States Pharmacopoeial Convention, 1199-1200, 1922-1923.
24. Omidian, H., and Park, K., Swelling Agents and Devices in Oral Drug Delivery, Journal Drug Delivery Science Technology, 2008,18(2), 83-93.

*****