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Optimization of production and characterization of homolog vivacel from rice straw

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ABSTRACT

A study about optimum condition for production of microcrystalline cellulose from rice straw has been done. A total of 500 grams of rice straw powder were made into alpha-cellulose by the method of multistage pulping and variation of hydrolyzing time were 15, 30, 45, and 60 minutes with hydrochloric acid 2,5 N and the temperature was 100 ^{o}C to produce optimum microcrystalline cellulose. The yield of microcrystalline cellulose which obtained in 15 minutes, 30 minutes, 45 minutes, 60 minutes hydrolyzed respectively was 60 %, 86.02 %, 93.12 %, 96.72 %. Microcrystalline cellulose from rice straw based on the characters test, identification, pH, water soluble substances, solubility, loss on drying, bulk density, and starch test are not significantly different from Vivacel or Avicel PH 102®, meanwhile for tap density, Carr's index and Hausner ratio are significantly different.

Keywords: microcrystalline cellulose, rice straw, optimum condition, Vivacel or Avicel PH 102

INTRODUCTION

Microcrystalline cellulose (MCC) is an important additional ingredient in the pharmaceutical, food, cosmetics, and other industries. In addition, MCC in the pharmaceutical industry is very often used as an excipient in the manufacture of tablets especially for direct compression tablets. Direct compression tablet manufacturing with more and more because it has many advantages such as not using a granulation process, giving a uniform particle size, and make the tablet more stable in a long time, as well as favorable economic terms [1]. In the manufacture of tablets, microcrystalline cellulose (MCC) serves as a binder, filler, and the destroyer. MCC will produce tablets with high hardness, not easily fragile and have destroyed a relatively short time, and can improve the flow properties of the granules [2].

MCC can be produced by reacting cellulose in mineral acid solution boiling for a certain time to limit the degree of polymerization is reached [1]. The process aims to reduce the molecular weight, degree of polymerization, and the long chain to form microcrystalline cellulose. In the process of hydrolysis using hydrochloric acid will decrease the molecular weight of the cellulose from 300000-500000 be 30000-50000. Likewise, the degree of polymerization fell from 2000 - 3000 be 200-300 at MCC, while the length of the cellulose chain dropped from 10000-18000 Armstrong became 1000-1500 Armstrong [2].

Agricultural waste rice straw is available in a number of relatively more who have been wasted which largely burned. In general, rice straw (*Oryza sativa*) and other lignocellulose materials composed of cellulose, hemicellulose and lignin. Cellulose is a polymer of β-glucose with β-1-4 bonds between glucose units. Cellulose found in wood, cotton, hemp and other plants. Cellulose is an organic compound found in the cell walls together lignin role in cementing the structure of plants. Wood cellulose generally ranges from 40-50 %, whereas in cotton almost 98 % [3].

The purpose of this study was to determine the bioconversion techniques of rice straw into raw materials derived Microcrystalline Cellulose (MCC) i.e. homologous Vivacel or Avicel. Avicel is a pharmaceutical raw material which is very important and widely used as additives or matrix drugs in the pharmaceutical industry, agriculture and packaging. In previous studies we have managed to find a way to convert rice straw into homologous Avicel in common with more than 75 % [4, 5]. This research is still in the laboratory scale. The yield obtained is not optimum, so it needs to be optimized bioconversion processes, in order obtained bioconversion technology which can be upgraded for production on a larger scale. In addition, it is also necessary to determine the physical properties, chemical and physicochemical properties of the resulting product, in order to qualify as modern pharmaceutical raw materials [6].

MATERIALS AND METHODS

Materials

Rice straw powder, distilled water, ethanol (Brataco®), nitric acid (Brataco®), sodium hydroxide (Brataco®), sodium sulfite (Brataco®), sodium nitrite (Brataco®), sodium hypochlorite (Bayclin®), hydrochloric acid (Merck®), zinc chloride (Merck®), potassium iodide (Merck®), hexane (Brataco®), copper(II) sulphate (Merck®), ammonia (Merck®), iodine (Merck®), and Avicel PH 102 (Rettenmeyer®).

Equipment

Water bath, desiccator, measuring glass, beaker, test tubes, filter paper (Whatman 42), flask, watch glass, spatula, vaporizer cup, oven, pH meter, analytical balance (Mettler PM200®), round-bottom flask, condenser, electric stove, Jasco FT IR spectrometer 460+, and tap volumeter.

Procedure

Sample preparation

Rice straw is chopped and washed several times with water, then dried at 60 °C for 24 hours and pulverized in a blender. Rice straw powder was weighed as much as 500 g, refluxed with a mixture of hexane and ethanol in a ratio of 2:1 for 6 hours, then allowed to cool and filtered. Furthermore, the remaining is dried at room temperature [1].

Extraction of alpha-cellulose with multistage pulping method

500 g rice straw powder was mixed with 6.7 L 3.5% nitric acid (containing 40 mg of sodium nitrite) in a beaker. The mixture in the container was then placed in a water bath for 2 hours at a temperature of 90 ^{o} C. The next part of the insoluble was separated by filtration and the residue obtained was washed with distilled water. The residue was immersed in a 5 L solution containing sodium hydroxide and sodium sulfite respectively of 2 % w/v at 50 ° C for 1 hour. Then the mixture was filtered and washed again as described above to obtain a residue. The residue was bleached by mixing them into 4 L mixture of water and sodium hypochlorite 3.5 % w/v (the ratio of water and 3.5 % sodium hypochlorite solution is 1:1), then boil for 10 minutes, followed by filtration and washing. The residue obtained from filtering was mixed with 4 L of sodium hydroxide 17.5 % w/v and heated at a temperature of 80 ° C for 30 minutes. Then the mixture was filtered and washed. The residue obtained is alpha-cellulose. The extraction process was continued by mixing alpha-cellulose into 4 L mixture of water and sodium hypochlorite 3.5 % w/v (the ratio of water and 3.5 % sodium hypochlorite solution is 1:1), and heated at 100 ° C for 5 minutes. This mixture was filtered and washed with distilled water to obtain a residue which was clean. The residue is then dried at a temperature of 60 ° C in order to obtain alpha-cellulose [1].

Production of Microcrystalline Cellulose (MCC)

A total of 50 g of alpha-cellulose was introduced into the beaker and hydrolyzed by heating in 2.5 N HCl (1.2 L) during the time variation of hydrolysis as follows:

1. A sample of 50 g of alpha-cellulose + 2.5 N HCl at 100 °C for 15 minutes (MCC A)
2. A sample of 50 g of alpha-cellulose + 2.5 N HCl at 100 ° C for 30 minutes (MCC B)
3. A sample of 50 g of alpha-cellulose + 2.5 N HCl at 100 ° C for 45 minutes (MCC C)
4. A sample of 50 g of alpha-cellulose + 2.5 N HCl at 100 ° C for 60 minutes (MCC D)

Then the hot mixture was poured into cold water while stirring strong by using a spatula and allowed to stand overnight. Microcrystalline cellulose formed was then neutralized again by washing it in water, then filtered, dried in an oven at a temperature of 57-60 °C for 60 minutes and then crushed. MCC obtained was stored in at room temperature in a desiccator [1].

Characterization of Microcrystalline Cellulose

Characterization of microcrystalline cellulose include organoleptic examination, identification, measurement of pH, determination of substances soluble in water, measuring the solubility in a mixture of ammonia-copper (II) sulphate,

determination of drying shrinkage, determination of real density and compressed density, determination of Carr's index and Hausner ratios, starch test, and determination of FT IR spectra [1, 7, 8].

RESULTS AND DISCUSSION

Optimization of microcrystalline cellulose manufacture was done by hydrolyzing alpha-cellulose with 2.5 N hydrochloric acid solution and then be varied the hydrolysis time during 15 min, 30 min, 45 min, 60 min. This process proved to produce microcrystalline cellulose yield was increased in number each difference time of hydrolysis performed. Alpha-cellulose was obtained as much as 281.96 grams (56.39%) of 500 grams of dry rice straw. Results of the time variation of hydrolysis on alpha-cellulose were obtained a yield of MCC A 60 %, MCC B 86.02 %, MCC C 93.12 %, MCC D 96.72% (see Table 1).

Table 1: Results of microcrystalline cellulose from rice straw

Total of rice straw powder (g)	Results				
500	Alpha-cellulose (g)	Microcrystalline cellulose (MCC) of alpha-cellulose			
	281.96 g (56.39 %)	MCC A (%)	MCC B (%)	MCC C (%)	MCC D (%)
		60	86.02	93.12	96.72

Selection of rice straw to make microcrystalline cellulose was because rice straw contains a lot of cellulose in the stalks. In addition, rice straw was also easily found and many discarded as agricultural waste. Rice straw was used only as fodder. The sample size of rice straw affects the acquisition of microcrystalline cellulose. The greater the amount of rice straw the better microcrystalline cellulose obtained. Conversely the smaller the rice straw it would be a little too microcrystalline cellulose obtained. This is because the finer the sample the more easily cellulose disconnected at the time of multistage pulping so more depolymerization of cellulose to form monosaccharide.

The result of the time variation of alpha-cellulose hydrolysis into MCC has been compared with Avicel PH 102®. Statistically the average measurements of the four samples were tested by one-way ANOVA and non-parametric test of independent samples to see which treatment effects was maximally close to the characterization by comparison Avicel PH 102. The fourth type of MCC produced meets the requirements of the United States Pharmacopoeia and British Pharmacopoeia.

Comparisons of characters ranging from organoleptic inspection include shape, color, smell, and taste. The results obtained showed similarities to one another as well as meeting the requirements of the Pharmacopoeia (see Table 2).

On the results of the identification with iodinated zinc chloride solution, MCC showed positive results. The reagent was a reagent specific to microcrystalline cellulose. Avicel PH 102® also gave similar results (Table 2).

Measurement of pH with time variation hydrolysis of MCC has a value of eligible British Pharmacopeia. The pH test results do not differ much from the comparison Avicel pH 102®. Substances dissolved in water, the maximum residue weight was not more than 0.25 % of tests performed [8]. Measurement of solubility of MCC and Avicel PH 102® in a solution of copper ammonium sulfate tetramin was also performed. The results were in accordance with the requirements that do not leave residual dissolved (see Table 2) [8].

Table 2: Examination of the effect of time variations of alpha-cellulose hydrolysis on the results of microcrystalline cellulose

No	Examination	MCC A	MCC B	MCC C	MCC D	Avicel PH 102
1	Organoleptic [8]	Fine powder, white, odorless, tasteless	Fine powder, white, odorless, tasteless	Fine powder, white, odorless, tasteless	Fine powder, white, odorless, tasteless	Fine powder, white, odorless, tasteless
2	Identification [7]	Blue violet	Blue violet	Blue violet	Blue violet	Blue violet
3	pH [8]	7.38 ± 0.05	7.35 ± 0.05	7.28 ± 0.02	7.15 ± 0.06	7.15 ± 0.03
4	Water soluble substances (%) [8]	0.104 ± 0.023	0.113 ± 0.009	0.095 ± 0.010	0.095 ± 0.017	0.126 ± 0.014
5	Drying shrinkage (%) [8]	3.773 ± 0.998	5.296 ± 0.880	3.846 ± 0.612	4.490 ± 1.028	5.287 ± 0.090
6	Solubility in ammonia -copper sulfate [8]	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved
7	Real specific gravity	0.384 ± 0.015	0.375 ± 0.021	0.394 ± 0.005	0.397 ± 0.046	0.397 ± 0.005
8	Specific gravity of compressed	0.531 ± 0.008	0.489 ± 0.033	0.531 ± 0.008	0.526 ± 0.041	0.582 ± 0.010
9	Carr's index [1]	27.526 ± 1.922	23.209 ± 1.109	25.625 ± 0.259	24.425 ± 2.219	31.751 ± 1.704
10	Hausner ratio [1]	1.572 ± 0.133	1.302 ± 0.019	1.326 ± 0.208	1.314 ± 0.035	1.465 ± 0.037
11	Starch test [8]	Negative	Negative	Negative	Negative	Negative

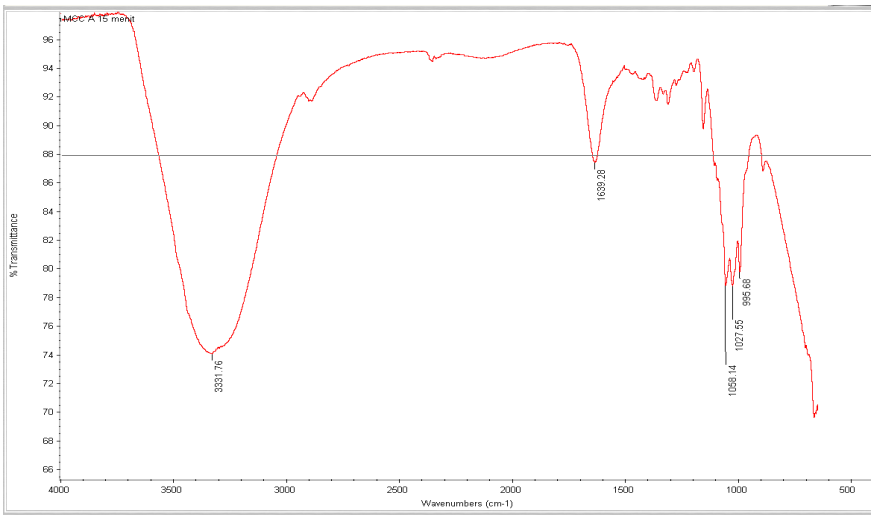

Figure 1: The spectrum of infrared MCC A

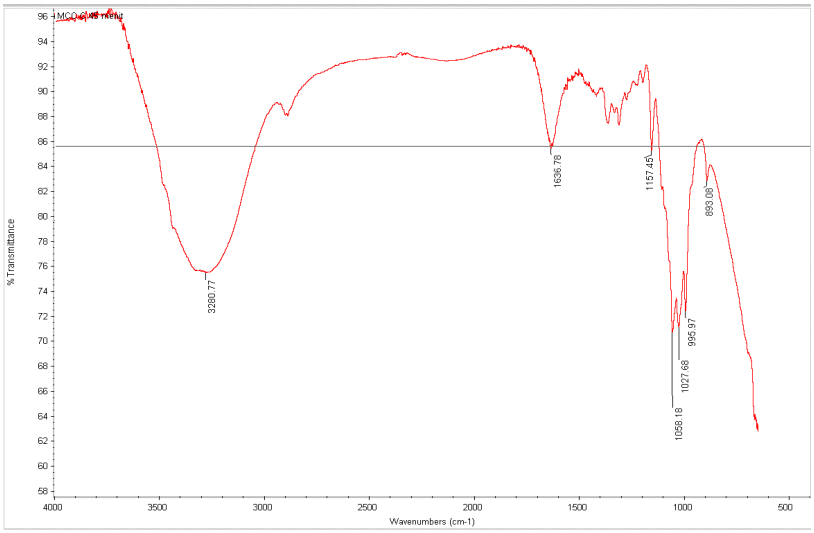

Figure 2: The spectrum of Infrared MCC B

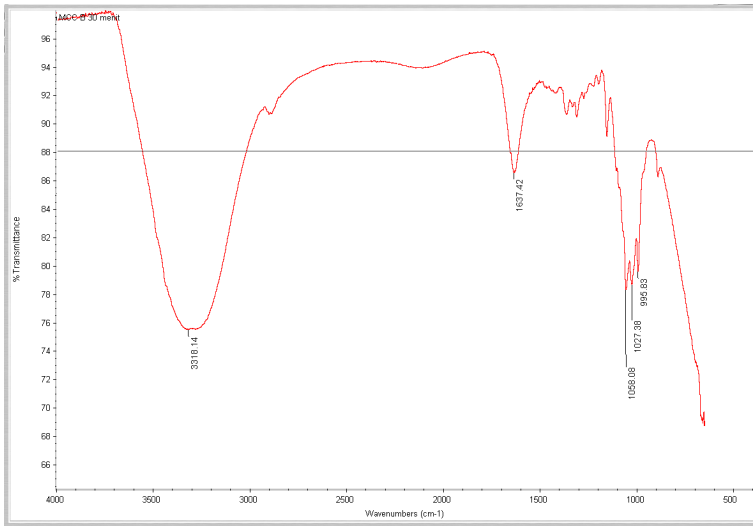

Figure 3: The spectrum of infrared MCC C

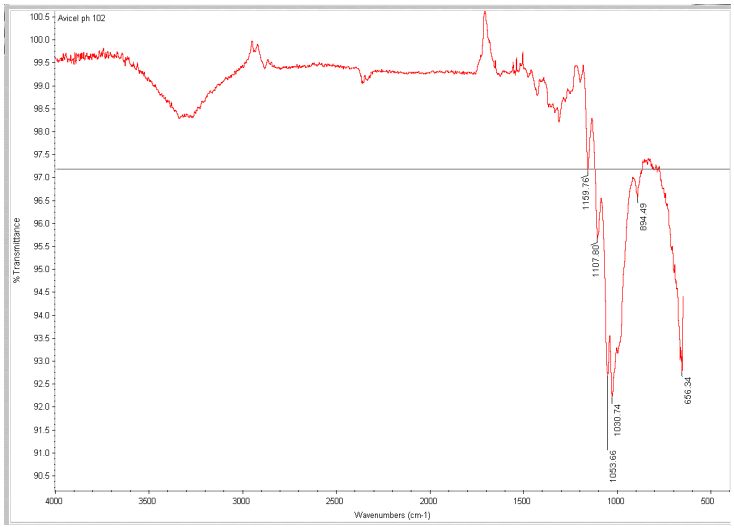

Figure 4: The spectrum of infrared MCC D

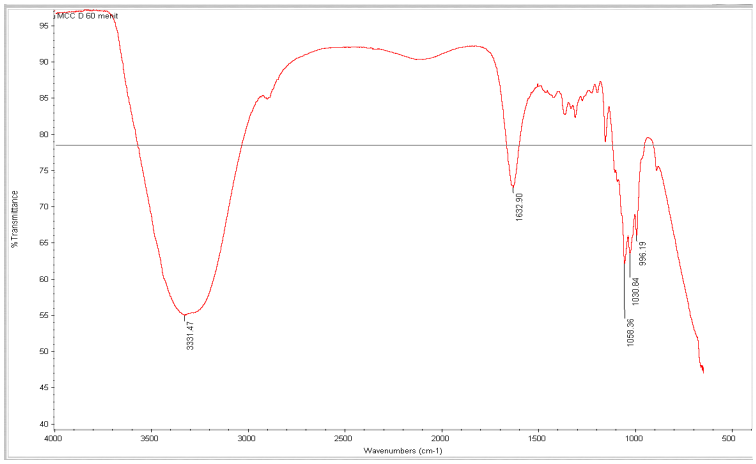

Figure 5: The spectrum of infrared Avicel PH 102

MCC drying shrinkage value is still below the limit values allowed on British Pharmacopeia, which is 6 %. When compared with Avicel PH 102®, it can be concluded that there is no significant difference in drying shrinkage MCC. On the measurement of the real specific gravity of MCC and Avicel PH 102® there is no significant difference in the real specific gravity between MCC and Avicel pH 102. While the specific gravity of compressed there is a real difference between the MCC and Avicel pH 102.

Hausner ratio and Carr's index is an indirect way of measuring to see the flow properties of powders and compression properties. Hausner ratio indicates the friction between the particles, while Carr's index showed the ability of the powder to reduce its volume or referred to as compressibility. In general, the ratio of Hausner was > 1.25 shows the flow properties were poor. Carr's index-value < 16% indicates good flow properties and > 35% showed the strength and cohesion of particles [9].

The compressed nature of microcrystalline cellulose can be caused by hydrogen bonds between the hydroxyl groups plastically changing its form around the particles. During compression, MCC may be suspected because deformation stress release by some mechanism that produces hard tablets with low tensile force [10].

Indeed pure cellulose does not contain starch in it. This can be tested by the presence of starch in cellulose by reacting cellulose with iodine. According to the requirements, the results obtained in the test color, starch is not formed in blue. This occurs because the non-occurrence of the absorption of iodine by the cellulose so no blue coloration as in starch [8]. The test results showed that MCC A, B MCC, MCC C, D MCC and Avicel PH 102® meet these requirements.

Test results show the FT IR spectrum of MCC lies in wave numbers which are almost the same as Avicel PH 102®. The fingerprint region that is located on the wave number 1600 - 900 cm^{-1} have similarities peak between MCC and Avicel PH 102® (see Figure 1-5). Thus the MCC has the same functional group with Avicel PH 102®.

Hydrolysis optimal results have been obtained in the MCC D (Figure 6), which is about 96.72 % by the hydrolysis time of 60 minutes, using a 2.5 N HCl at a temperature of 100 °C. While the results have been obtained at the smallest MCC A, namely 60 % with hydrolysis time 15 minutes, using a 2.5 N HCl at a temperature of 100 °C. This shows that the longer hydrolysis time, the more the interruption of the chain of cellulose, whereas cellulose is a polysaccharide that has a chain length when the hydrolysis time of over 60 minutes the lower the degree of polymerization because the number of polymers or chains are broken off so that the result obtained was can be reduced.

Figure 6: Photo of microcrystalline cellulose (MCC D) from rice straw

CONCLUSION

Microcrystalline cellulose has been obtained at the optimal hydrolysis time for 60 minutes using 2.5 N HCl at a temperature of 100 °C from rice straw. Microcrystalline cellulose from rice straw is not significantly different from Avicel PH 102® by organoleptic inspection, identification, pH, dissolved substances in water, solubility, drying shrinkage, apparent specific gravity, starch test, and have as well as the infrared spectrum. In testing the density of compressed, Hausner ratio and Carr's index there is a noticeable difference between the microcrystalline cellulose from rice straw and Avicel pH 102.

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