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A novel optimization method for preparing carboxymethyl cellulose with higher yield from wheat straw.

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Abstract: Locally collected wheat straw sample was analyzed for chemical composition such as cellulose, hemicellulose, lignin, pectic matters, fatty & waxy matters. Cellulose extracted was 48% used for the synthesis of carboxymethyl cellulose (CMC) under heterogeneous condition with ethanol as the supporting medium. Effects of cellulose size, time, temperature, alkali dosage and concentration of monochloroacetic acid on the yield of CMC products were investigated. Yield of CMC in gram was calculated from per gram powdered wheat straw sample as waste. Prepared CMC was characterized in terms of degree of substitution (DS), molecular weight, intrinsic viscosity and water absorption capacity at various particle sizes. All parameters were increased with decreased cellulose particle sizes. Infrared (IR) Spectrophotometer was used to investigate the change of functional group from raw straw powder to cellulose and cellulose to CMC. The absence of peaks at 1515 and 1248 cm⁻¹ indicated the removal of lignin from cellulose and the presence of strong absorption band around 1400-1700 cm⁻¹ confirmed the presence of carboxyl group (-COO). The degree of crystallinity and surface morphology were determined by XRD and SEM analyses. The optimized conditions for CMC preparation were NaOH concentration 7.5 mol/L, MCA concentration 12.69 mol/L, reaction time 3 h,

reaction temperature 60°C and cellulose particle size 64 µm gives CMC with higher yield, 1.21g/g and higher DS, 2.5.

Key words: Wheat straw, Waste, Carboxymethyl cellulose, Degree of Substitution, Yield.

INTRODUCTION

The agricultural sector of Bangladesh annually produces large amounts of biomass in crops such as corn, rice and wheat. Every year, especially northern region of Bangladesh, huge amount of unused wheat straw residues are generated. It is the second largest agricultural residue produced in the world next to rice straw¹. Only a small percentage of this residue is used in applications such as domestic fuel, feedstock and energy production. Leaving wheat residue on the field may reduce organic matter of the soil and leads to soil erosion². Burning of this waste for cooking and heating and left or combusted directly on the land causes serious environmental pollution problems³. Therefore, it is necessary to find different methods of disposal or use of wheat straw.

Agricultural residues are a good sources of cellulose although they have a lower cellulose content compared to wood and other plant fibers⁴. But abundant availability of these inexpensive, underutilized residues makes the refining of agro-residues acceptable for the production of high value cellulose and its derivatives. There has been increasing interest in cellulose based-materials due to the abundance, renewable and eco-friendly nature of cellulose⁵. In order to utilize cellulose in the foods, pharmaceuticals and textile industries, cellulose must be converted into its derivatives. One of the most common derivatives is carboxymethyl cellulose (CMC), also referred to as Na-CMC.

In the recent years, the continuously increasing demand of instant and defatted food makes the CMC market grow dramatically⁶. Every year in Bangladesh, large amount of CMC is being imported to meets her demand and the importance of CMC is increasing day by day⁷. Generally purified cotton (a-cellulose > 98.3 wt%) has been widely applied as the feedstock for CMC production⁸. Effort have been made since 1980 in searching for less expensive alternatives to expensive cotton, such as various lignocellulosic biomasses that is rich in cellulose, for production of CMC. Therefore, there is growing interest worldwide in conversion of wheat straw or other crop residues into value-added by products, such as CMC.

Kim and Dale¹ observed 1.3 kg of wheat straw are generated from 1kg of wheat grains produced on average depending on its variety and climatic conditions. The unique physical structure of wheat straw makes it an excellent candidate for cellulose, fibers and fillers in structural composites^{9,10} and many works have been carried out on the preparation of bio- or nano-composites by using materials from wheat straw³. Though some researchers have done some works on wheat straw, but a literature search found no published reports for producing CMC from wheat straw elsewhere in the country.

MATERIALS AND METHODS

Materials: Wheat straw were collected from Regional Wheat Research Institute, Rajshahi, Bangladesh. Chemicals used during the study were sodium hydroxide (Merck, India), monochloroacetic acid (BDH, England), ethanol (Merck, Germany), methanol (Merck, Germany), glacial acetic acid (BDH, England), silver nitrate (BDH, England), n-hexane (Merck, Germany), sodium chlorite (Merck, Germany) etc. All chemicals were of reagent grade and used without further purification.

Preparation of sample: Locally collected wheat straw was dried in sunlight for three consecutive days to reduce moisture and cut manually into small pieces. The dried straw was ground into powder using a grinding disk mill (model: FFC-15). The powdered sample was then sieved of different sizes (sieve type: AFNOR X11-501) for separating different particle sizes such as 750, 300, 187, 125, 88, 65 μm and stored in a desiccators.

Estimation of Aqueous Extracts, Fatty & Waxy Matters, Pectic Matters and lignin: Pectic, fatty and waxy matters, Klason lignin and aqueous extracts were separated from different sized straw powder following by the method Yeasmin and Mondal¹¹. The results were expressed as weight percent and calculated according to a TAPPI standard¹². The other fractions including uronic acids, soluble lignin, acetyl groups etc were not determined owing to their minor importance for the purpose of this work. Aqueous Extracts, Fatty & Waxy Matters and Pectic matters were determined using equation (i), (ii) and (iii) respectively.

$$\text{Aqueous extracts, \%} = \frac{W_1 \times 100}{W_0} \dots \dots \dots (i)$$

$$\text{Fatty and waxy matters, \%} = \frac{W_1 \times 100}{W_0} \dots \dots \dots (ii)$$

$$\text{Pectic matters, \%} = \frac{W_1 \times 100}{W_0} \dots \dots \dots (iii)$$

Where W_1 is the loss in weight and W_0 is the initial weight of the sample (before treatment).

Estimation of Klason Lignin: The dewaxed and depectinized sample was treated with 72% sulfuric acid in the ratio of 1:15 (w/v) with frequent stirring at room temperature. The slurry was left alone for 2 h and then diluted to 3% acid concentration. After refluxing the mixture for 4 h, it was allowed to stand overnight. Then the mixture was filtered through a sintered glass funnel and washed thoroughly with hot distilled water. The residue in the sintered funnel was dried at 105°C until reaching a constant weight.

Separation of α -cellulose and hemicellulose: Cellulose was extracted from wheat straw according to the method described by Mondal and Haque¹³. The lignin free holocellulose was treated with an 18% NaOH solution for 2 h with occasional stirring in a solid to liquor ratio of 1:100. α -cellulose was separated by filtration, and washed thoroughly with 2% acetic acid. Then the α -cellulose was washed with hot distilled water and dried at 105°C to a constant weight. Each cellulose sample was ground to pass through different mesh sieves [20, 50, 80, 120, 170, and 230] to obtain 750, 300, 187, 125, 88, and 65 μm sizes and kept in different desiccators use for synthesis of CMC.

50 ml of the filtrate sample was mixed with 50 ml of 3N H_2SO_4 and heated in a hot water bath at about 70-90°C for a few minutes to coagulate the β -Cellulose. The precipitate was allowed to settle overnight. The precipitate was then filtered and dried at 105°C to obtain β - cellulose. The γ -cellulose was obtained by deducting the α - and β -cellulose from the total weight of the holocellulose.

Preparation of carboxymethyl cellulose: For the preparation of CMC, the method of Mondal *et al.*¹⁴ was followed with some modification. At first the different sizes of straw celluloses was swollen in 95% ethanol as solvent in the solid to liquid ratio of 1:20 in a covered round-bottomed reactor flask equipped with stirrer. The estimated amount of aqueous NaOH ranging from 20-45% was added into the reactor flask over a period of 15 min. The mixture was then stirred for 30 min at room temperature. Then aqueous mono-

chloroacetic acid (ClCH_2COOH) was added drop-by-drop to the mixture with different concentration ranging from 6.35-20.6 mol/L and placed in a water bath with horizontal shaker. Subsequently, the flask was heated to the reaction temperature which varied from 30°C to 75°C with different times. After cooling, the mixture was separated into two phases. The liquid phase was removed and the solid phase was suspended in methanol, and neutralized with 90% acetic acid (v/v). The residue was then recovered by filtration and washed with ethanol/water (70/30 v/v). Finally, the residue from filtration was oven dried at 55°C until constant weight and CMC was obtained.

Characterization

CMC yield: CMC yield was measured on a dry weight basis. The net weight of dried CMC was divided by the weight of dried cellulose to get the yield value¹⁵ as follows:

$$\text{CMC yield, \%} = \frac{\text{Weight of obtained CMC}}{\text{Weight of dried cellulose}} \times 100$$

Degree of substitution: To determine the degree of substitution (DS), 0.5 g of dried CMC was ashed gently between 450 and 550°C for 24 h and then dissolved in 100 ml of distilled water. 20 ml of this solution was titrated with 0.1 N sulphuric acid using methyl red as an indicator. After the first end point, the solution was boiled and titrated to a sharp end point. The degree of substitution of the carboxymethyl content¹⁶ was calculated as follows:

$$\text{Degree of Substitution (DS)} = \frac{0.162 \times B}{1 - 0.08 \times B}$$

Where, $B = \frac{0.1 \times b}{G}$, b is the volume (in ml) of 0.1 N sulphuric acid and G is the mass of pure CMC in grams.

Molecular Weight: CMC was dissolved in 0.78M NaOH solution and the molecular weight was determined using an Ostwald viscometer. From the intrinsic viscosity, the molecular weight of the CMC was calculated by the “Mark-Houwink-Sakurada” equation¹⁷ as,

$$[\eta] = K M^a$$

Where, K, a, $[\eta]$ and M are constants for solvent, polymer shape factor, intrinsic viscosity and molecular weight of CMC respectively.

Water absorption capacity: The prepared 2% CMC film (6 cm × 4 cm) was weighed accurately and immersed in distilled water for 15 h at room temperature. The film was wiped using tissue paper and weighted again. Water absorption capacity was determined using the equation¹⁸ below as,

$$\text{Water absorption capacity, \%} = \frac{(W_1 - W_0) \times 100}{W_0}$$

Where, W_0 (g) is the weight before immersion and W_1 (g) is the weight after immersion.

FTIR analysis: Infrared spectra of the raw wheat straw, cellulose and CMC samples were recorded with Shimadzu FTIR-8900 (Japan) using KBr disc technique. Pellets were made from 0.2 mg prepared samples ground with 2 mg KBr. Transmission was measured at the wave number range of 4000-400 cm^{-1} .

X-Ray Diffractometry: Diffraction diagrams of extracted cellulose and CMC samples were recorded using a Bruker D8 Advanced (Germany) X-Ray diffractometer that generated $\text{CuK}\alpha$ radiation. Powder samples were exposed to an X-ray beam (40 kV, 30 mA) at $2^\circ/\text{min}$.

Scanning Electron Microscopy analysis: To observe change in the surface morphology of prepared CMC samples, Scanning Electron Microscope (SEM) were used. Thin layers of CMC samples were conditioned in desiccator and coated with gold using an ion sputter under vacuum before analyses. The coated samples were viewed and photographed by the scanning electron microscope (Model-S 3400 N, VP SEM, Hitachi, Japan) using 20 kV accelerating voltage.

RESULTS AND DISCUSSION

Chemical composition: The compositional data of the wheat straw used as raw material for CMC production is presented in **Table 1**. **Table 1** shows that the α -cellulose content of the sample is higher than that of hemicellulose and Klason lignin. The extracted α -cellulose was 48 g per 100 g of dry biomass. The high α -cellulose content is required for the production of good quality cellulose derivatives. Lower α -cellulose content implies the presence of an excessive amount of low molar mass oligosaccharides, which may affect the yield and quality of cellulose derivatives¹⁹.

Table1: Composition of wheat straw

Composition	Weight % on oven dry basis
α -cellulose	48.01 ± 0.72
Hemicellulose (β - and γ - cellulose)	29.11 ± 0.55 (17.01 and 12.10 respectively)
Klason lignin	17.53 ± 0.88
Fatty and waxy matters	2.10 ± 0.12
Pectic matters	1.15 ± 0.27
Hot water extracts	1.08 ± 0.08
Others	1.02 ± 0.05

Results are expressed as mean \pm standard deviation; n = 3

Optimization of reaction conditions: Carboxymethylation reaction was optimized with respect to yield by varying the reaction parameters such as time, temperature, NaOH concentration, monochloroacetic acid (MCA) concentration and cellulose particle size. Yield of CMC in gram was calculated from per gram powdered straw sample as waste.

Effect of cellulose particle size on yield of CMC: Particle size plays an important role to give higher yield of CMC. Carboxymethylation reaction was continued by utilizing six different cellulose particle sizes such

as 750, 300, 187, 125, 88 and 65 μm where as other parameters were kept constant. Then the effect of particle size on yield was studied as given in **Figure 1**.

The reaction time was kept at 3 h and temperature was 60°C. **Figure 1** shows that yield of CMC increases with decrease of particle size. The carboxymethylation mainly depends upon the accessibility of reactants and the availability of the activated hydroxyl groups. When particle size decreases, surface area as well as available free –OH groups for substitution reaction increases, thus yield increases.

Reduced cellulose particle size has larger surface area per unit volume and therefore more cellulose may be accessible for the reactants to reach and at a faster rate^{20, 21}.

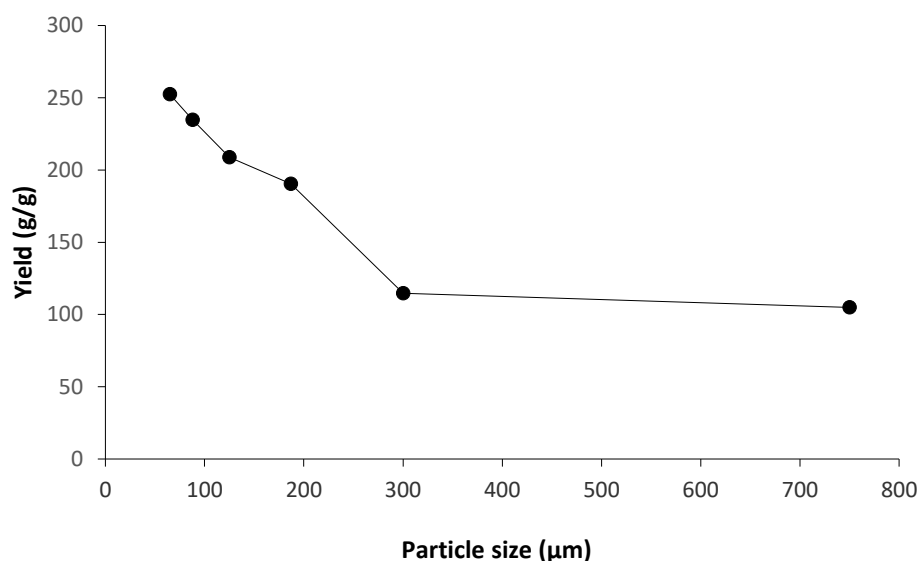
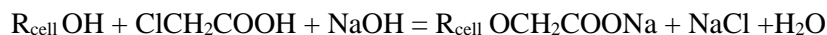
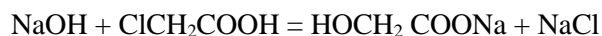


Figure 1: Effect of cellulose particle size on yield of CMC (NaOH, 30%; MCA, 12.69 mol/L; temp., 60°C; time 3 h).

Effect of sodium hydroxide concentration on yield of CMC: The sodium hydroxide (NaOH) concentration plays an important role in the production of CMC and by-products. The carboxymethylation process was carried out at different concentrations of NaOH ranging from 20 to 45% (w/v), while other parameters were kept constant. The yield of CMC was found to increase significantly when the concentration of NaOH increased to 30% (w/v), thereafter it decreased considerably, as shown in **Figure 2**.

During the process, aqueous NaOH was used to activate the reaction. Treatment with NaOH at higher concentration increases the swelling of the cellulose granules and produces more cellulose-O-Na resulting in an even more opportunity for carboxymethylation to occur with the hydroxyl group (O-H) in the cellulose molecules^{22,23}. However, further increase in NaOH concentration was accompanied by lowering the yield of CMC. This could indicate that at this stage the side reaction was more dominant to form sodium glycolate than the first reaction as increasing the concentration of NaOH above 30%. Similar results have been reported for carboxymethylation by Khaullar *et al*²⁴. The equation below shows the possible chemical reaction that occurred during the process:

Main reaction:**Side reaction:**

(Sodium glycolate)

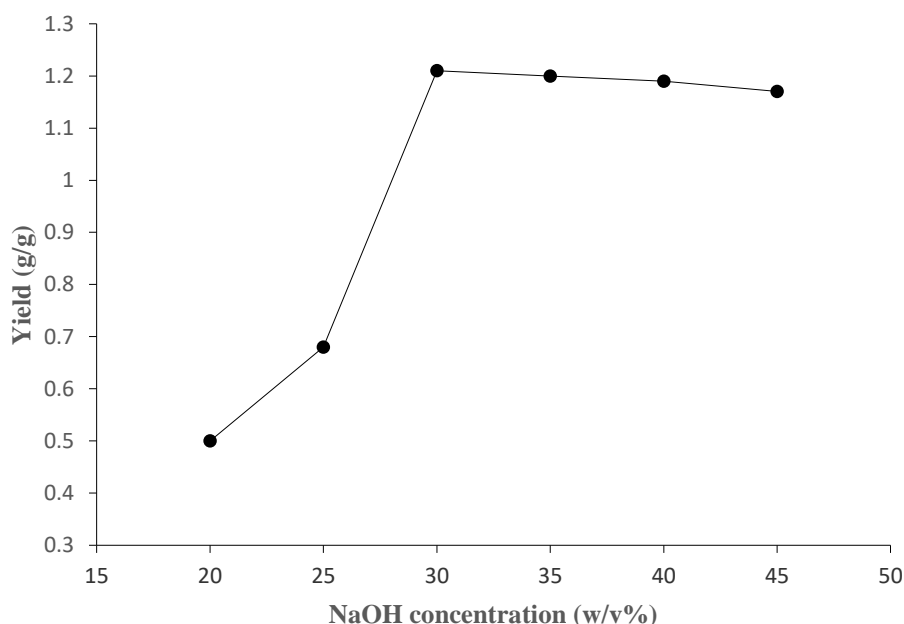


Figure 2: Effect of NaOH concentration on yield of CMC (MCA, 12.69 mol/L; temp., 60°C; time, 3 h).

Effect of monochloro acetic acid concentration on yield of CMC: The proportion of monochloroacetic acid (MCA) concentration and NaOH concentration must be at optimum to obtain a higher yield of CMC. From **Figure 3**, higher the MCA concentration, the higher content of functional groups of CMC thus more substitution of functional groups will occur. The maximum yield, 1.21g CMC/g waste, was obtained with 12.69 mol/L of MCA concentration. The increase is probably due to the greater availability of the acetate ions at higher concentrations in the proximity of cellulose molecules. On the other hand, the yield values decreased sharply by further increment in MCA concentration.

The higher concentration of monochloroacetic acid is not preferable as a concentration higher than 12.69 mole/L MCA, glycolate formation seems to be favored and the reaction efficiency decreased. This finding is supported by the reports of Khalil *et al.*²⁵ and Bhattacharyya *et al.*²⁶.

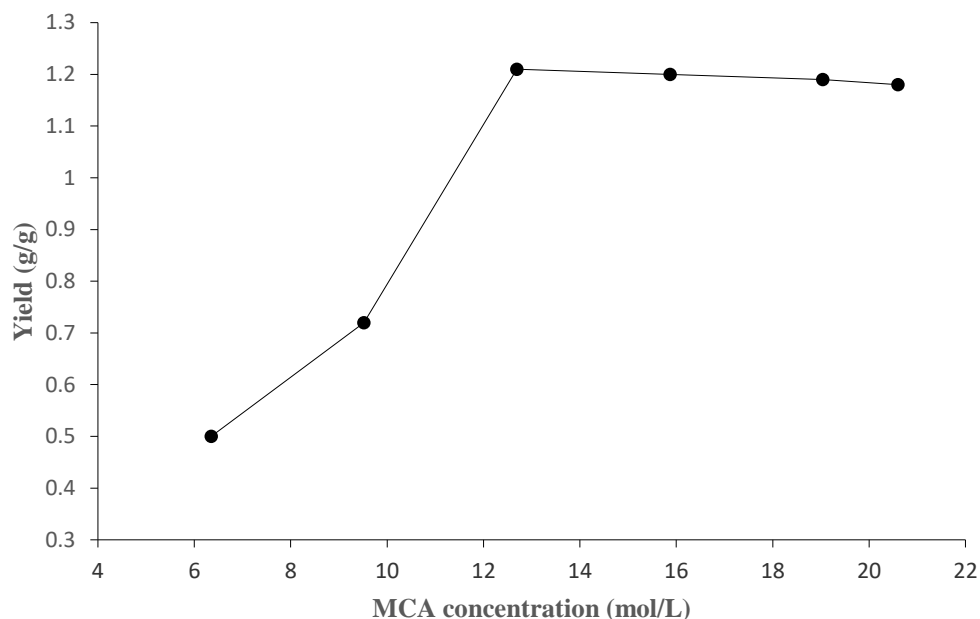


Figure 3: Effect of MCA concentration on yield of CMC (NaOH, 30% (w/v); temp., 60°C; time, 3 h).

Effect of time on yield of CMC: As shown in **Figure 4**, the carboxymethylation reaction was carried out in six different reaction periods. The yield of CMC increase with increase of reaction time. The maximum yield attained was 1.21 g/g at 3 and 3.5 h. Further increase in time resulted in a lowering the yield. This is because the longer the reaction time, the longer the alkalization process continues to substitute the functional groups of CMC. Prolonged time may significantly cause the degradation of cellulose chain and CMC structure.

The increase of yield with times was due to the effect on the swelling ability of the cellulose molecules as well as the diffusion and absorption processes of the reactants with improved contacts between the etherifying agents and cellulose. The lowering of yield after 3 h of carboxymethylation time may also be due to the atmospheric oxidative degradation of CMC ²⁵.

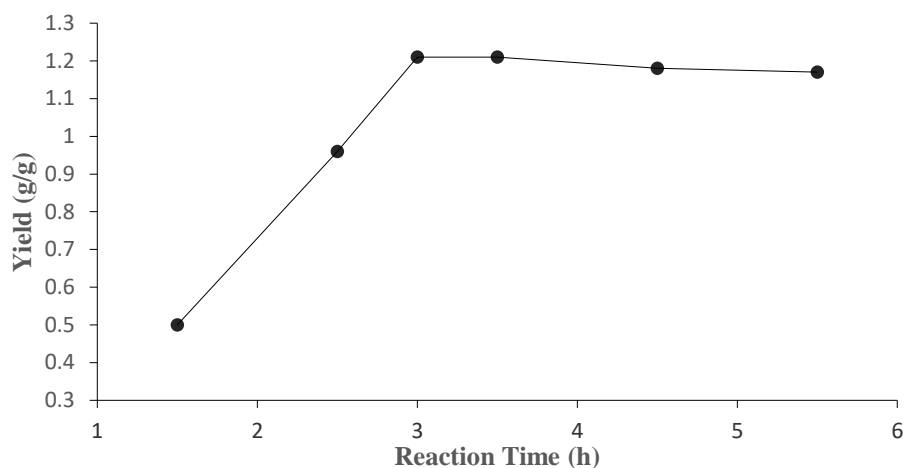


Figure 4. Effect of reaction time on yield of CMC (NaOH, 30%; MCA, 12.69 mol/L; temp. 60°C).

Effect of temperature on yield of CMC: The influence of the reaction temperature on the yield of CMC per gram waste is shown in **Figure 5**. The temperature for the carboxymethylation process was varied from 30°C to 75°C. The yield increased with the increase in reaction temperature upto 60°C that was 1.21 g/g. Temperature will favour on the effect of the swellability of cellulose as well as diffusion and adsorption of reactants. This condition may provide better environment for carboxymethylation reaction as well as to obtain higher yield of CMC. In contrast, higher temperature may cause degradation not only on CMC but also other products as well. The polymer structure of cellulose might degrade during the alkalization process hence the decrease in yield with the increment of reaction temperature. Similar observations have been observed for cellulose carboxymethylation in literature too ²⁷⁻²⁹.

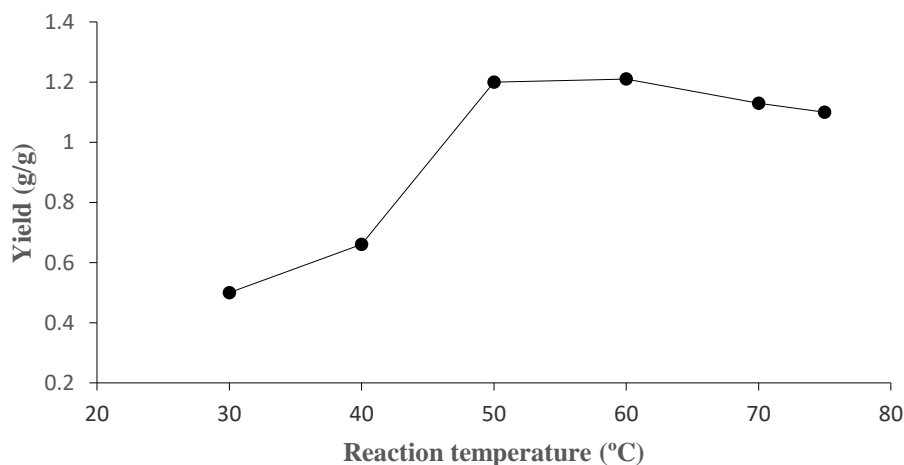


Figure 5: Effect of reaction temperature on yield of CMC (NaOH, 30%; MCA, 12.69 mol/L; time, 3 h).

Characterization: CMC was prepared at optimized conditions and characterized in terms of DS, molecular weight, yield, intrinsic viscosity and Water absorption capacity. DS represents the number of the carboxymethyl groups in the molecular unit of the anhydroglucose units. In principle, all hydroxyl groups (HO-2, HO-3, and HO-6) in the anhydroglucose unit can be substituted and the maximum DS is being 3³⁰. DS is the most important factor because CMC is available in several grades and in a variety of types depending on the DS¹⁹. The determination of the solution intrinsic viscosity as well as molecular weight of polymeric materials is very important to the industry both to research and manufacturing since it can be used to estimate molar mass providing important information relating to the physical and mechanical properties of polymers. The ability of CMC to function as a thickener or flow-control agent depends largely on its water absorption capacity. The DS, intrinsic viscosity, Molecular weight and water absorption capacity of the prepared CMC at different cellulose particle size was determined and the data presented in **Table 2**.

Table 2: Characterization of CMC with respect to cellulose particle size (NaOH 30% in the cellulose-liquor ratio 1:2.7; ClCH₂COOH 120% in the cellulose-liquor ratio 1:1.2; Temperature 60⁰ C; Time 3 hrs).

Particle Size, μm	Degree of Substitution	Intrinsic viscosity	Molecular weight (KDa)	Water absorption capacity (g/g)
750	0.22	0.40	79.60	Not found
300	0.37	0.53	154.00	0.50
187	1.50	2.00	1489.38	4.50
125	2.26	2.41	1937.27	4.89
88	2.39	2.99	2325.74	5.01
65	2.50	3.2	2766.54	5.88

From **Table 2**, it can be seen that the DS of the prepared CMC increase gradually with the decrease of cellulose particle sizes and highest DS obtained is 2.5 with respect to particle size 65 μm . As cellulose particle size decreases, surface area where the reaction takes place increases. Number of available free – OH groups for substitution reaction also increases with increase of surface area thus DS increases. The etherification mainly depends upon the accessibility of reactants and the availability of the activated hydroxyl groups⁷.

It can be seen from the **Table 2** that the intrinsic viscosity as well as molecular weight of the prepared CMC increased with the decrease of cellulose particle size. Such molecular weight also increased with the increase of DS. As the DS increased, the number of OH groups was replaced by carboxymethyl groups. As the carboxymethyl group is heavier than OH group, the molecular weight of the final product CMC increased⁷. Intrinsic viscosity is increase due to the higher conversion of cellulose into CMC.

It can also be seen from the **Table** that the water absorption capacity at cellulose particle size 750 μm was not found. Afterwards water absorption capacity increase with decrease of cellulose size. The high water absorption capacity proves that prepared CMC are highly hydrophilic because during etherification, more hydroxyl groups were replaced by carboxymethyl groups that are hydrophilic³¹.

A comparison between DS value of CMC prepared from wheat straw cellulose and CMC from other sources cellulose is presented in **Table 3**. The DS values of reference CMC were almost the same, but the DS value in this method was very high, 2.5 compared to reference values.

Table 3: DS value of CMC from different agro cellulosic source.

Sources of cellulose	Degree of substitution
Water hyacinth ³²	0.24-0.73
Sago waste ³³	0.33-0.82
Sugar beet pulp cellulose ³⁴	0.11-0.67
Lantana camara ³⁵	0.20-1.22
Palm kernel cake ³⁹	0.67
Durian husk ³⁷	0.67
Corn husk ¹⁴	2.41]
Wheat straw	2.50 [This work]

FTIR analysis: The infrared spectra were studied to confirm the substitution reaction in carboxymethylation. The FTIR spectra of powdered straw, cellulose and prepared CMC samples are shown in **Figure 6**. The main alterations were found in the region from 1800 to 1200 cm⁻¹. **Figure 6(a)**, **6(b)** and **6(c)** represents the peak of powdered wheat straw, purified extracted cellulose and prepared CMC respectively. The absorption peaks at 1741.52, 1627.89, 1604.22 and 1515.05 cm⁻¹ were present in powdered wheat straw sample, but not observed in the purified extracted cellulose.

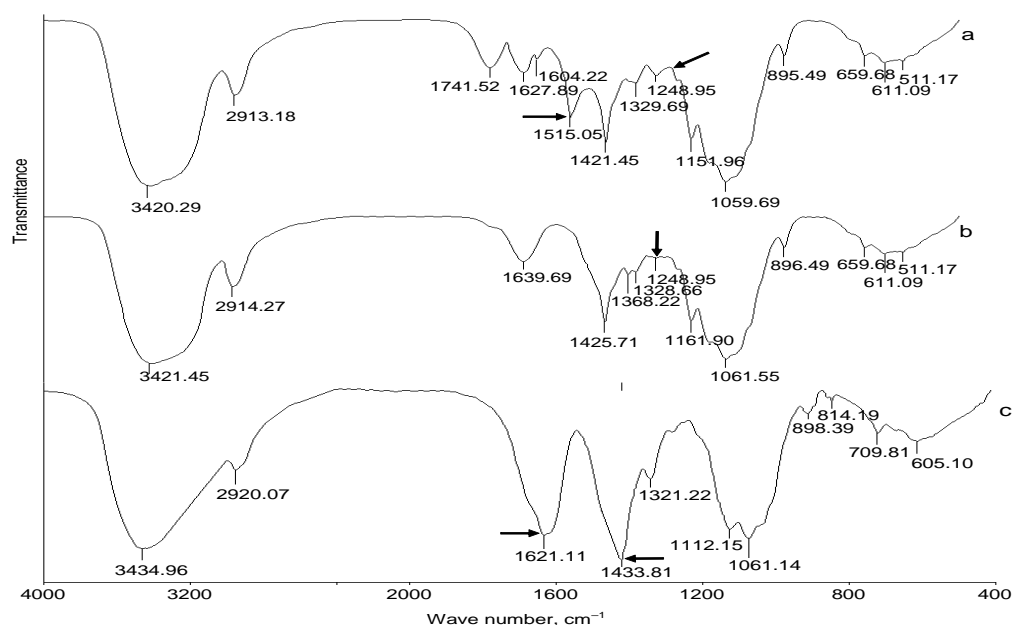


Figure 6: FTIR spectra of (a) wheat straw, (b) extracted cellulose, (c) prepared CMC with DS 2.5

Particularly, two absorption peaks must be emphasized: the peaks at 1515 and 1248 cm^{-1} . The peak at 1514 cm^{-1} was not present and the peak at 1248 cm^{-1} was drastically reduced on the purified cellulose spectra. These two absorption peaks were important because their absence in the extracted cellulose spectra strongly indicates that most of the lignin had been removed^{37, 338}. The presence of a new and strong absorption peak at 1621.11 cm^{-1} confirms the stretching vibration of the carboxyl group (COO^-), 1433.81 cm^{-1} is assigned to carboxyl groups as the sample salts^{39, 40} shown in **Figure 6(c)**. It is an evidence that hydroxyl group of cellulose was replaced with carboxyl group when carboxymethylation reaction occur. Mario *et al.*⁴¹ have found that the carboxyl groups and their salts wave numbers are between 1600-1640 cm^{-1} and 1400-1450 cm^{-1} respectively. The peaks at 1321.22 cm^{-1} and 1112.15 cm^{-1} are assigned to -OH bending vibration and -C-O-C stretching respectively. Wavelength 898 cm^{-1} is detected for 1, 4- β glycoside of cellulose⁴².

XRD analysis: X-Ray diffraction (XRD) analysis is a definitive technique for estimating the degree of crystallinity in polymer. Cellulose is semi-crystalline in nature. **Figure 7** shows diffraction pattern of (a) straw cellulose and (b) carboxymethylated cellulose. The peaks correspond to the crystalline phase and the background corresponds to the amorphous phase. The peaks are broad due to the small crystallites in cellulose granules which is in agreement with the theory of XRD. This theory state that very small imperfect crystals give broadened diffractions. Crystallinity of the extracted celluloses is 64.39%. The diffraction spectra of CMC show a destruction of the crystalline structure of the original cellulose.

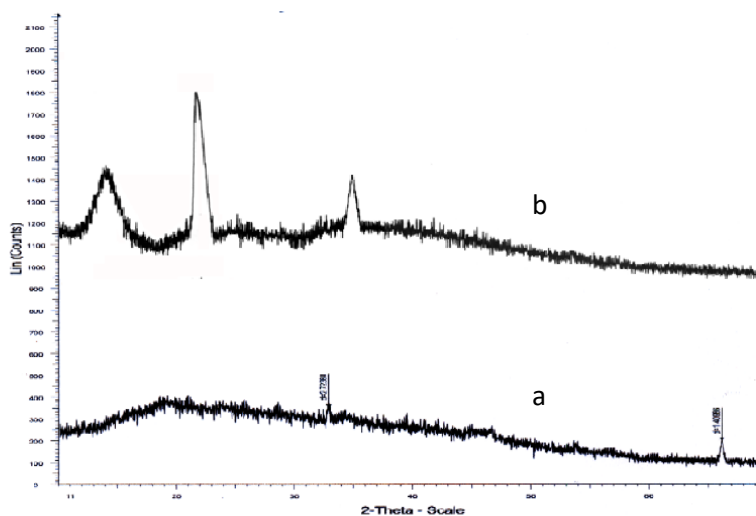


Figure 7: X-ray diffractogram of (a) straw cellulose and (b) carboxymethylated cellulose (DS=2.5).

All characteristic peaks for native cellulose have almost disappeared and transformed into an amorphous phase. Therefore CMC has excellent solubility⁴³ as lower crystallinity represents higher solubility⁴⁴. During the carboxymethylation process, the cellulose molecules are placed in alkaline solution. The swelling of the cellulose granules exert a tension on neighbouring crystalline of cellulose molecules and tend to distort them. Further swelling leads to uncoiling or dissociation of doubled-helical region and the breakup of crystalline structure⁴⁵.

SEM analysis: SEM analysis allows a large amount of sample to focus at one time and produces images of high resolution, which means that closely spaced features can be examined at high magnification.

Figure 8 shows the surface morphology of prepared CMC at 1000X magnification (10 μm size bar). It can be clearly seen that the obtained products are rod-like (or ribbon shaped) and surfaces are more extended, rough and collapsed which is similar to other reported images for a typical CMC molecule as reported by Ahemen *et al.*⁴⁶ and Rachtanapun *et al.*⁴⁷.

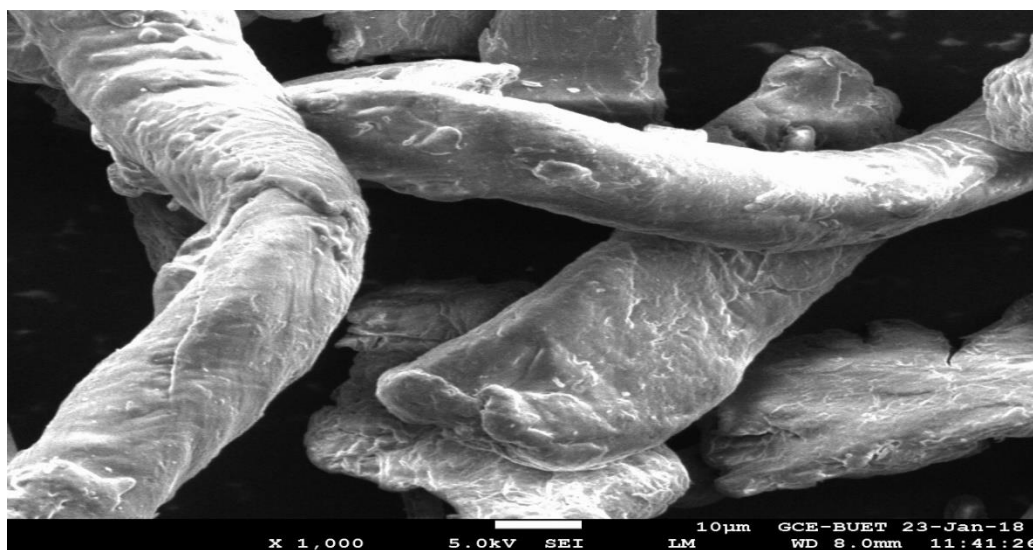


Figure 8: SEM image of CMC at 1000 magnification (10 μm size bar).

CONCLUSION

Tons of unused wheat straw residues are generated every year throughout the world. Use of these agricultural crop residues would open new markets for wheat straw and improve the rural agriculture based economy. A limited number of studies have reported on the use of wheat straw. Significant improvement in process technology, in product quality and in production efficiency is being trying to develop. Utilization of wheat straw as raw material for CMC production regarding the optimum DS value as well as yield has not been developed. In this work, CMC was successfully prepared from wheat straw with higher yield as well as DS. The DS value is 2.5 with yield of 1.21g/g.

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