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Pulping of Wheat Straw using Sulfite Process: An Experimental Study

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Abstract

Properties of the finished products like paper and board depend on parameters namely cooking liquor concentration, the chemicals and temperature in the digester. In this study digestion of wheat straw is investigated experimentally in sulphite process by varying alkali ratio keeping all other parameters constant. Resulting pulp is characterized by a set of properties (percentage yield, consistency, Kappa No., SR and Ash content). Results reveal that the best combination of properties can be achieved at alkali ratio of 10.5 % NaOH and 3.5%Na_2SO_3.

Keywords: pulp, sulfite process, wheat straw, straw pulp, cooking

Introduction

The annual production of pulp can hardly meet current demand, which is growing dramatically in developing countries and, to a lesser extent, in developed countries (e.g. by 2–3% in the USA). Deforestation has resulted from excessive use of wood for pulp making. Therefore, the use of alternative, non-wood materials is of particular interest [1]. In the recent past, much attention of the world agricultural research was focused on non-wood materials with perspective for environmental industrial utilization. Agricultural wastes constitute one of the main alternative raw materials for the pulp and paper industry [2, 3, 4, and 5]. Wheat straw, bagasse, reed, and rice straw as a one of the important non-wood fibers sources for pulping and paper making, have been studied [6,7,8].

The estimated production of agricultural residue is over 2900 million tons each year that is burnt, thereby losing energy and causing significant pollution. This raw material possesses a high economic potential [9, 10]. Non-wood raw materials account for 5–7% of the total pulp and paper production worldwide. Production of pulp from non-wood resources has many advantages such as easy pulping capability, excellent fibers for the special types of paper and high-quality bleached pulp. It can be used as an effective substitute forever decreasing forest wood resources [11, 12].

A problem arises from the fact that the spent cooking liquor contains significant levels of silica and is thus difficult to recycle [13].

In this paper, the effects of wheat straw cooking conditions on the quality of pulp are investigated experimentally in the sulfite process at laboratory scale. The results are presented and discussed

Experimental

Sun-dried, fine (2.5 inches) and sand free wheat straw was used as raw material (the material was taken from the processing belt of a local company). Sample of known mass were kept at 105°C for sufficient time to expel all free moisture content. The dried sample in ratio of 1:5 with the liquor (cooking liquor+ make up water) was taken. The cooking liquor was mixture of $NaOH_{(aq)}$ and $Na_2SO_{3\ (aq).}$ The reaction mixture was charged in the digester and digested at 165 ^{o}C for 3 hours, after steady state condition, while the digester rotation was 5-7 rpm. At steady state, pressure in the digester was almost 6.9 bar. After digestion pressure of the digester was released and blow-weight was recorded. Black or spent liquor was separated with washing. Cooked material was washed with plenty of water. Then washed material was de-fiberated at 3000 rpm in defibrator. The de-fiberated material was diluted with excess of water and passed through strainer to remove the uncooked material. The uncooked material was weighted. The cooked material, pulp, was washed and transferred to storage tank, 20 liters, for testing and making the hand sheets for testing.

Table 1: Compositions of the cooking liquor

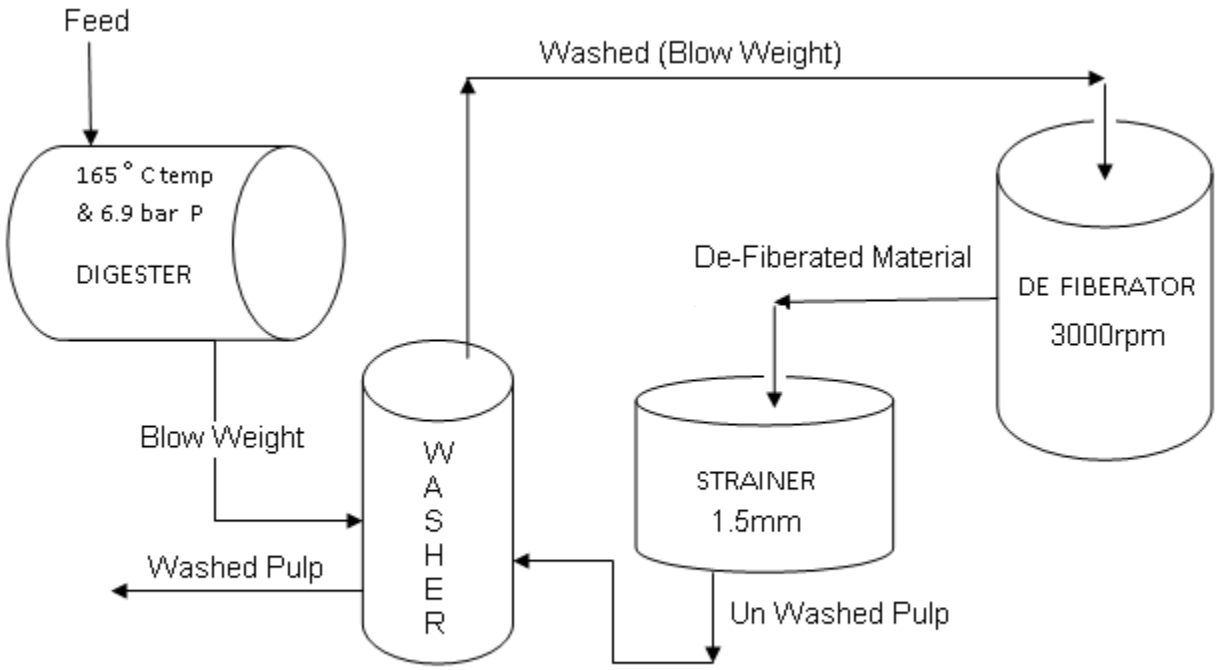
Test	Concentration of NaOH	Concentration of Na_2SO_3
1	0	14
2	3.5	10.5
3	7	7
4	10.5	3.5
5	14	0

Different compositions of cooking liquor were used as given in Table 1. Consistency, Kappa No, screen yield and crude yield, SR and ask contents of the pulps were determined according to standard procedures given in Table 2. A schematic diagram of the pulping process is shown in Figure 1.

Table 2: Testing Standards

Physical properties	Testing standard
Consistency	T 240 om-88
Kappa No.	T 236 cm-85
Ash contents	T 211 om-02
SR	T 227 om -85

Figure 1: Schematics of Sulfite pulping process



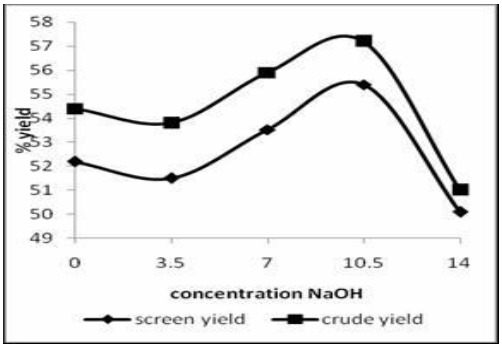
1. Results and Discussion

Characterization of Pulp

i- Effect of concentration on Screen and Crude yield

Quality of pulp is characterized by its SR value, consistency, Kappa No. and ash content. Yield is important from economic point of view. These properties may vary owing to the cooking liquor composition. Figure 2 displays the effect of cooking liquor composition on yield of the pulp. Crude as well as screen yields are displayed. Starting at 0% NaOH the yield slightly decreases and then increases to a maximum of 57% and 55% respectively at 10.5%NaOH. The yield is significantly lower at the next point of 14% NaOH. It is obvious that the screen yield is always lower than the crude yield and the difference between the two decreases as the NaOH concentration in the cooking liquor increases. At higher NaOH concentration better cooking is achieved however after 10.5% the attack on cellulose results in lowering of the yield of pulp. On the other hand, acid soluble lignin content decreased for the whole range of alkali ratio. It is evident from the figure 2 that the yield of unscreened pulp decreased with increase in the alkali ratio [14].

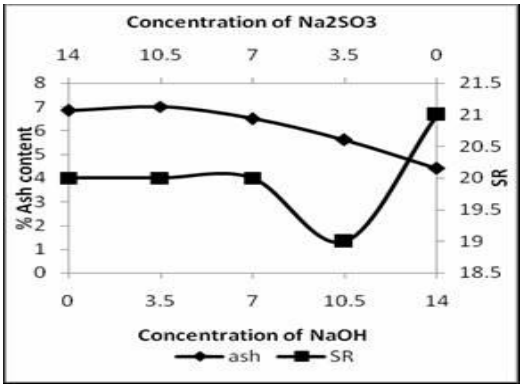
Figure 2: Effect of concentration on Screen and Crude yield



ii- Effect of concentration on Ash and SR

The effect of cooking liquor composition on SR and Ash content of the pulp is depicted in Figure 3. Ash content decreases gradually as NaOH content increases while the SR value shows a minimum at 10.5% NaOH. It is obvious that more lignin removal is achieved as the NaOH proportion is increased thus reducing ash content of the pulp. As for as SR is concern it is higher owing to either incomplete lignin removal at lower concentrations of NaOH or attack on cellulose at higher NaOH concentrations. The values of SR do not change appreciably for the whole range alkali ratio used in the study. Ash is the residue left after complete combustion of paper at higher temperatures generally represents filler content in paper. Ash contents go on decreasing with rise in alkali ratio as shown in figure 3.

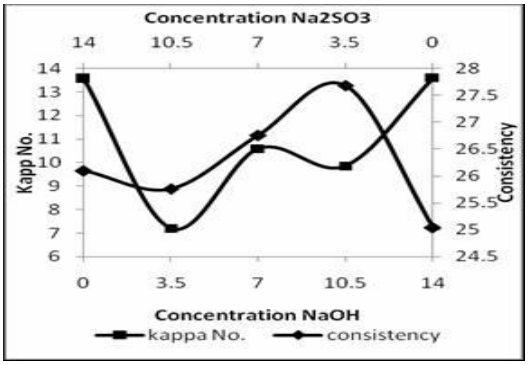
Figure 3: Effect of concentration on Ash and SR



iii- Effect of concentration on Kappa No. & Consistency

Consistency and Kappa Number versus NaOH concentration are displayed in Figure 4. The consistency is maximum at 10.5%. Kappa Number is minimum at 3.5% and 10.5%. The The Kappa number is an indication of the lignin content or bleachability of wood pulp. It estimates the amount of chemicals required during bleaching of wood pulp to obtain a pulp with a given degree of whiteness. Since the amount of bleach needed is related to the lignin content of the pulp, the Kappa number can be used to monitor the effectiveness of the lignin-extraction phase of the pulping process [16]. The number is in the range of 1-100 (10-70 for most types of wood pulp)[17]. Although both values are in the range, the value at 10.5% NaOH is more appropriate. Figure 4 depicts that the Kappa Number decreases at the beginning and then show increase in the trend as alkali ratio increases. the work of Lử Yanna and Zhang Yunzhan to study effect of alkali ratio also supports these results [14].

Figure 4: Effect of concentration on Kappa No. & Consistency



Conclusions

The wheat straw is digested using sulfite process in the bench top digester in the laboratory of a local pulp and paper industry. The chemical content of the liquor is 14% while NaOH content is varied from 0-14%. Resulting pulp is characterized using standard testing procedures. Results reveal that the optimum cooking liquor composition is 10.5% NaOH and 3.5% Na_2SO_3. At this composition the crude yield, screen yield, consistency, Kappa No., SR and Ash content are 55%,57%, 27, 10, 19 and 6 %respectively.

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