Newsprint from NSSC Bagasse Pulp Mixed with Hardwood CMP Pulp and Bleached Softwood Kraft Pulp

Ahmad Samariha,[a,]* Alireza Khakifirooz,[b] Mohammad Nemati,[a] Foad Ravanbakhsh,[c] Majid Kiaei,[d] and Amir Saghafi [e]

In this work, the possibility of using neutral sulfite semi-chemical (NSSC) bagasse pulp mixed with hardwood chemimechanical pulp (CMP) and bleached softwood kraft pulp (BSKP) was investigated with the aim of reducing hardwood and BSKP consumption. The bagasse NSSC pulp had a digester yield of about 73% and was unbleached. It was refined by a PFI mill to 400 mL CSF, but in the case of the hardwood CMP and imported long fiber pulp, the final refined freeness were selected to be 350 and 500 mL CSF. Handsheets were made (60 gm^{-2}), and their strength indices and optical properties were measured. Results of this research on a laboratory scale indicated that using bagasse NSSC pulp mixed with hardwood CMP to make newsprint with acceptable quality is possible, and this process will also noticeably reduce the consumption of imported long fiber pulp and wood for producing the grades of paper usually made from CMP.

Keywords: Bagasse; CMP; Kraft; Newsprint; Bleached

*Contact information: a: Young Researches and Elites Club, Science and Research Branch, Islamic Azad University, Tehran, Iran; b: Faculty of Chemistry and Petrochemical Engineering, Department of Paper& Packaging Technology, Standard Research Institute (SRI), Karaj P.O. Box 31745-139, Iran; c: Department of Mechanical Engineering, Dezful Branch, Islamic Azad University, Dezful, Iran; d: Department of Wood and Paper Engineering, Chaloos Branch, Islamic Azad University, Chaloos, Iran; e: Department of Computer Software Technology Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran; * Corresponding author: a_samariha@yahoo.com*

INTRODUCTION

Demand for various types of paper products and the fast population growth rate in developing countries has led to expanded consumption of non-wood resources of fibers, particularly those based on agricultural products. It has been estimated that over 21 million tons of pulp are produced from non-wood fiber resources every year throughout the world (Jahan Latibari *et al*. 2011). Large amounts of bagasse are found typically in tropical countries that produce sugarcane, *e.g.* Brazil, India, Cuba, and Iran (Samariha and Khakifirooz 2011). Currently, bagasse is commercially used to produce various types of paper (Zanuttini 1997). Although soda pulping of bagasse has been developed extensively, there is still not enough knowledge concerning effective application of modern pulping technologies such as high-yield pulping, for the purpose of producing pulps which are appropriate for newsprint (Khakifirooz *et al.* 2013).

Mazandaran Wood and Paper Industries (MWPI) with its annual capacity of 175,000 tons is the largest manufacturer of paper in Iran. MWPI produces newsprint or printing paper on Paper Machine No. 1 while making fluting paper on Paper Machine No. 2 from CMP and NSSC pulp, respectively. The CMP product line is based on using 75% hornbeam and 25% beech wood (Ebrahimpour Kasmani *et al.* 2012). For instance, in MWPI (Iran) newsprint is produced from 83% mixed hardwood CMP and 17% bleached softwood kraft pulp (BSKP), which is imported from Sweden (Jafari-Petroudy *et al.* 2011).

There are some limitations in procurement of the imported long fibers pulp as well as its associated costs and deposited investments and difficulties in supplying the required raw materials. Thus, any strategy that simultaneously saves consumption of the raw materials and reduces the use of imported long fiber pulp will be rather crucial. However, MWPI is now facing serious challenges due to a shortage of adequate hardwood species and a lack of financial resources for importing enough BSKP (Jafari-Petroudy *et al.* 2011).

Every year, about 4.3 million tons of bagasse is produced in southwestern province of Iran, Khuzestan (Najafi *et al.* 2009). According to the existing literature and previous international experiences in manufacturing newsprint from bagasse (Granfeldt and Sadawarte 1988; Ryrberg *et al.* 1998; Jafari-Petroudy *et al.* 2011; Khakifirooz *et al.* 2013), newsprint made from a mixture of NSSC bagasse pulp and hardwood CMP pulp has not been reported in the literature. Therefore, in this study the possibility of using NSSC bagasse pulp mixed with hardwood CMP and BSKP was investigated with the aim of reducing hardwood and BSKP consumption for newsprint production.

EXPERIMENTAL

Materials

Wet, depithed bagasse was collected from a local pulp and paper mill (Pars Paper Co., Haft Tapeh, Iran). The pulping liquor was prepared from NSSC pulping line of MWPI (Sari, Iran). In MWPI (Iran) newsprint is produced from 83% mixed hardwood CMP and 17% bleached softwood kraft pulp (BSKP), which is imported from Sweden.

Methods

NSSC pulping was carried out batch-wise in a 10-liter rotary digester under cooking conditions of 10 and 20% chemical charge such as sodium sulfite and bicarbonate (on the basis of oven dry mass of bagasse), L:W = 10:1, and 30 and 40 min, at 170 °C, with total pulp yields of 72.8 to 84.4%. The optimum conditions for producing NSSC pulp from bagasse are summarized in Table 1.

Unbleached bagasse NSSC pulp was refined by a PFI mill to 400 mL CSF, but in the case of the hardwood CMP and imported long fiber pulp, the final refined freeness was selected to be 350 and 500 mL CSF, respectively. The different ratios of unbleached bagasse NSSC pulp, CMP, and imported long fiber pulp used for handsheet making are shown in Table 2.

Handsheets (with basic weight of 60 gm^{-2}) were made according to TAPPI 205 sp-02. The paper sheets were conditioned at 23 °C and 50% RH for 24 h. Then, tensile strength index, tear strength index, burst strength index, and optical properties (opacity, brightness, and yellowness) of the handsheets were determined according to T494 om-01, T414 om-04, T403 om-02, T425 om-01, T452 om-02, and T524 om-02 test methods, respectively.

Table 1. Optimum Conditions for Producing NSSC Pulp from Bagasse

Cooking Condition	NSSC Pulping	Cooking Condition	NSSC Pulping
Chemical charge	Sodium sulfite (Na_2SO_3) and bicarbonate ($NaHCO_3$)	Chemical charge	10 and 20
Liquor-to-Bagasse ratio	10:1	Time of Impregnation (min)	30
Cooking temperature (°C)	170	Cooking time at maximum temperature (min)	30 and 40

Statistical Analysis

Data analysis was performed using SPSS Statistical Software (IBM Software, Armonk, New York) in terms of one-way analysis of variance. The average values of strength indices and optical properties were compared and classified using the Duncan test at the 95% confidence level.

Table 2. Combinations of Different Ratios of NSSC Bagasse Pulp, CMP Hardwood Pulp, and Imported Long Fiber Pulp for Newsprint

Sample code	NSSC bagasse pulp (%)	CMP hardwood pulps (%)	Imported long fiber pulp (%)
1	100	0	0
2	40	60	0
3	30	70	0
4	20	80	0
5	0	80	20

RESULTS AND DISCUSSION

Optimal NSSC pulping of bagasse was achieved under conditions of 20% chemical charge, for 40 min, at 170 °C. Under these conditions, the pulp yield was 72.8%. The selected pulp from optimum conditions had a lighter color.

Tensile strength provides a very useful property to describe general strength of any material. The tensile strength of paper is the maximum force per unit width of a paper strip that bears load before failure, when the force is applied parallel to the length of the test sample. Burst strength is the maximum pressure that a paper bears before failure when the force is applied perpendicular to the test sample. Tensile strength index and burst strength index are obtained by dividing the tensile strength and the burst strength by base weight of the paper. Tear strength represents the force required for further tearing of the paper from an initial cut. This parameter depends on length of fiber, strength of fiber, bonding between fibers and arrangement of fibers within paper. Brightness is the reflection of a blue visible light from surface of the paper at the wavelength of 457 nm. Based on Kubelka-Munk theory, there is a relation between brightness degree, absorption coefficient, and scattering coefficient of light (Sixta 2006),

$$B \times 0.01 = 1 + k/s - \sqrt{(k/s)^2 + 2(k/s)} \quad (1)$$

where, B is the brightness degree (%), while k and s represent absorption coefficient and scattering coefficient of light (m^2/g), respectively.

Blend Proportions and Strength Results

The effects of different mixing levels of these pulps (Table 1) on the properties of handsheets compared to commercial newsprint (20% long fiber pulp and 80% CMP hardwood pulp) were investigated, and the results are summarized in Fig. 1 to 6. The tensile strength index of the newsprint made of different ratios of NSSC bagasse pulp, hardwood pulp, and imported long fiber pulp showed that the combination of 60% hardwood CMP pulp and 40% NSSC bagasse pulp was similar to a mixture of 20% long fiber pulp and 80% CMP hardwood pulp, whereas the tensile index of 100% NSSC bagasse was significantly higher than other compositions (Fig. 1).

The tensile strength index and the burst strength index of the 100% bagasse pulp produced with 3800 rpm refining speed in a PFI mill laboratory refiner was greater than that of the CMP pulp from hardwoods. Refining of the pulp leads to separation of some parts of the initial cell wall of cellulose fibers, and also causes internal and external fibrillation of the fibers, solution and removal of the colloidal particles, re-distribution of the hemi-cellulose material from inside the fibers to their outer side, abrasion on surface of the fibers in molecular scale and creation of a gelatin-like surface. As a result of the abovementioned effects, the fibers become wider and more flexible after refining, with their bonding area being increased (Gullichsen and Paulapuro 2000). Therefore, the strengths properties related to bonding and connection between the fibers, *i.e.* tensile strength and burst strength, will be increased.

The burst strength index of the 100% NSSC bagasse newsprint was significantly higher than for other compositions, whereas 80% hardwood CMP pulp and 20% long fiber was significantly lower than that of other compositions (Fig. 2).

The tear strength index of newsprint made of 80% hardwood CMP pulp and 20% long fiber was significantly higher than that of other compositions that can be related to lower tear strength of bagasse (Fig. 3).

One of the adverse effects of refining is breakage of the fibers, which makes them shorter in length (Gullichsen and Paulapuro 2000). Since length of fibers has the greatest effect on the tear strength of the paper, reduction of this parameter due to refining process can be attributed to smaller length of the fibers.

Studying the mechanical properties of the papers obtained from 100% NSSC bagasse pulp in comparison with those made from hardwood CMP indicated that the 100% NSSC bagasse paper had the best mechanical strength properties except for tear strength index. Its measured characteristics in this research, including tensile strength index and burst strength index, were better than papers with other mixing ratios. This can be attributed to the fibrillated, softer, and looser structure of NSSC bagasse fibers, which enabled more chemicals to penetrate and, at the same time, provided stronger connections between the fibers (Seraeian 2003). This resulted in more flexible papers and eventually improved the strength properties (Seraeian 2003). Only the tear strength index of 80% CMP pulp of MWPI and 20% imported long fiber was higher than 100% bagasse pulp and all other combinations, which can be related to using 20% long fiber.

Optical Properties

One important printability characteristic of paper is opacity, which is directly related to the bulk of newsprint. Wood and Karais (1991) have reported that increasing the surface bonding between the fibers will have an adverse effect on the opacity characteristics. The opacity and brightness of the newsprint made of 80% hardwood CMP pulp and 20% long fiber were significantly higher than those of other compositions, whereas 100% bagasse NSSC gave results that were significantly lower than other compositions (Fig. 4 and 5).

Refining of the pulp led to just a small reduction in the brightness degree of the paper. This phenomenon can be interpreted based on Kubelka-Munk theory. The greater the scattering coefficient of the light, the greater will be the brightness degree, assuming that the absorption of light remains the same. Refining of the NSSC pulp will decrease the scattering coefficient of the paper and thus reduce its brightness degree. The smaller brightness degree of the unbleached sample is usually attributed to absorption of light by chromophores in the pulp that remain from lignin.

The yellowness of the newsprint made of 80% hardwood CMP pulp and 20% long fiber was significantly lower than other compositions, whereas 100% NSSC was significantly higher than other mixtures (Fig. 6). Studying the optical properties of the papers from 100% NSSC pulp of bagasse against those papers made from hardwood CMP indicates that the paper made from 100% NSSC bagasse exhibited poorer optical properties. The measured optical properties in this work, namely opacity and brightness, were reported to be much poorer as compared with those of papers made from other mixing ratios. This can be related to a production process of the paper that involves neutral sulfite semichemical as well as its non-bleaching situation. Comparing the poor optical properties and the high value of yellowness for the mixtures containing bagasse pulp to the control sample (80% hardwood bleached CMP + 20% imported long fiber pulp), it seems that this kind of pulp would not perform well if used for making newsprint. However, since the bagasse pulp in this work has not been bleached, it can be expected that bleaching the bagasse pulp would lead to improved brightness of the handsheets.

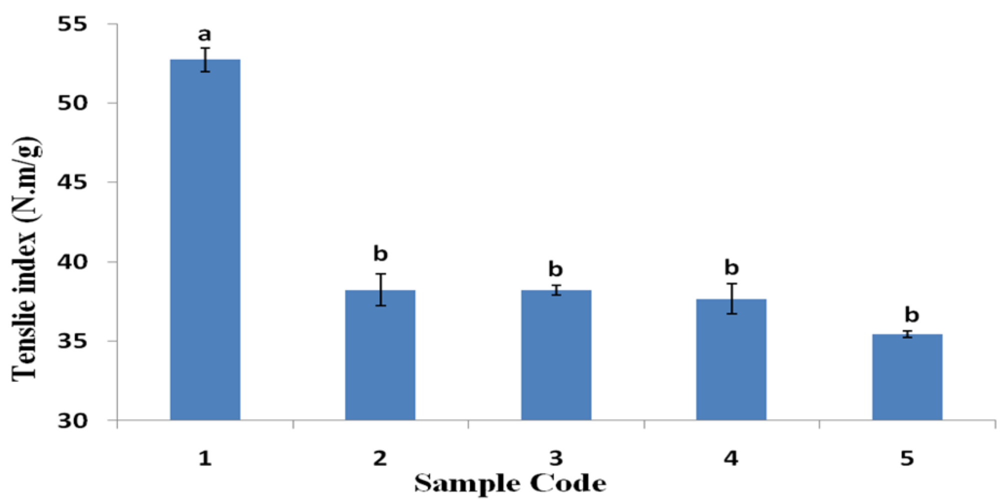

Fig. 1. Comparison of handsheets' tensile strength index made from different ratios (1 = 100% NSSC bagasse; 2 = 60% (CMP), 40% (NSSC bagasse); 3 = 70% (CMP), 30% (NSSC bagasse); 4 = 80% (CMP), 20% (NSSC bagasse); 5 = 80% (CMP), 20% (long fiber)) (small letters indicate the Duncan ranking of the averages at a 95% confidence interval.)

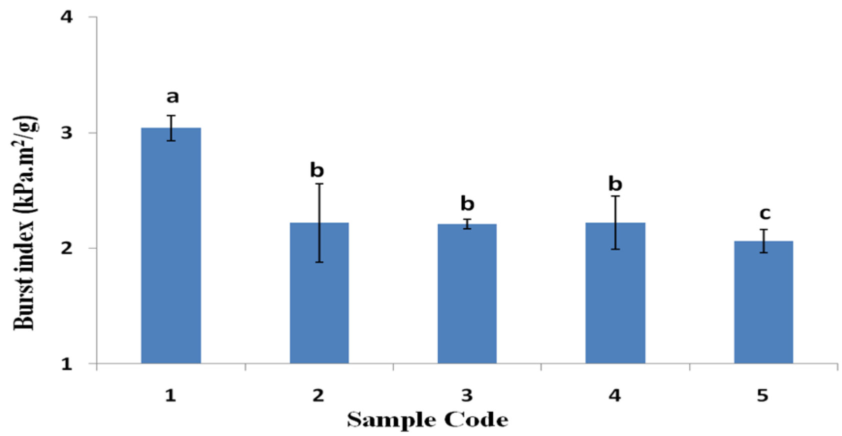

Fig. 2. Comparison of handsheets' burst strength index made from different ratios (1 = 100% NSSC bagasse; 2 = 60% (CMP), 40% (NSSC bagasse); 3 = 70% (CMP), 30% (NSSC bagasse); 4 = 80% (CMP), 20% (NSSC bagasse); 5 = 80% (CMP), 20% (long fiber)) (small letters indicate the Duncan ranking of the averages at a 95% confidence interval.)

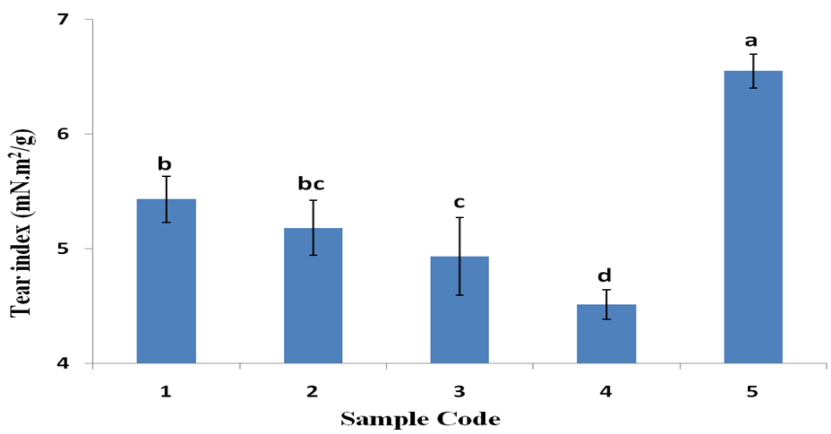

Fig. 3. Comparison of handsheets' tear strength index made from different ratios (1 = 100% NSSC bagasse; 2 = 60% (CMP), 40% (NSSC bagasse); 3= 70% (CMP), 30% (NSSC bagasse); 4= 80% (CMP), 20% (NSSC bagasse); 5= 80% (CMP), 20% (long fiber)) (small letters indicate the Duncan ranking of the averages at a 95% confidence interval.)

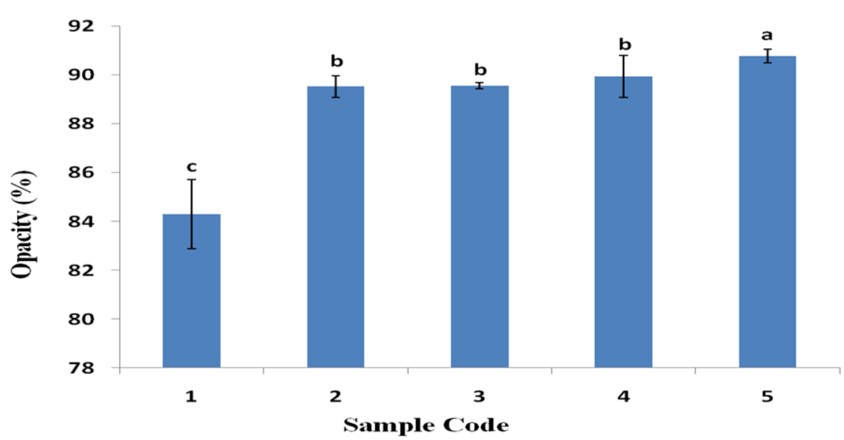

Fig. 4. Comparison of handsheets' opacity made from different ratios (1 = 100% NSSC bagasse; 2 = 60% (CMP), 40% (NSSC bagasse); 3 = 70% (CMP), 30% (NSSC bagasse); 4 = 80% (CMP), 20% (NSSC bagasse); 5 = 80% (CMP), 20% (long fiber)) (small letters indicate the Duncan ranking of the averages at a 95% confidence interval.)

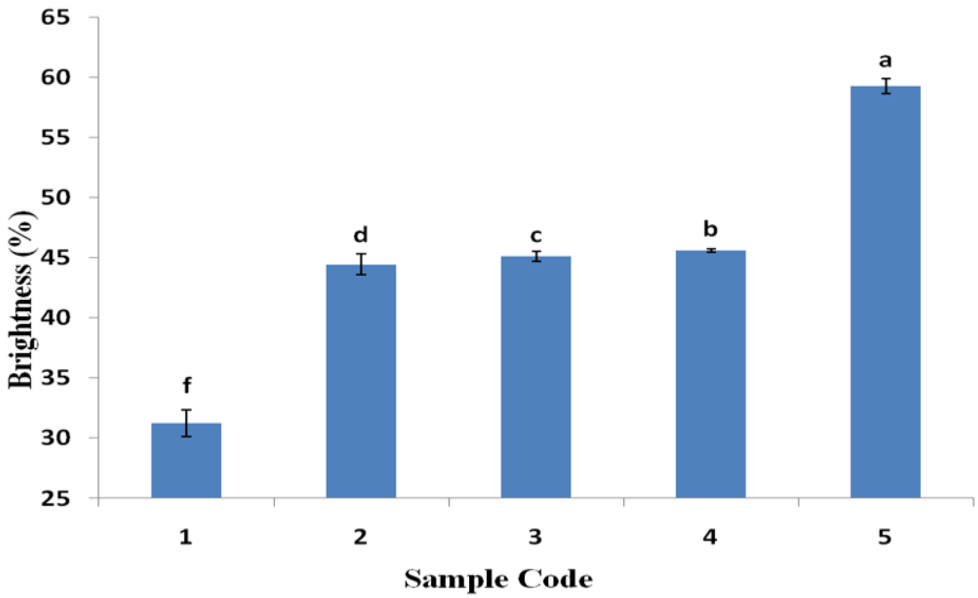

Fig. 5. Comparison of handsheets' brightness made from different ratios (1 = 100% NSSC bagasse; 2 = 60% (CMP), 40% (NSSC bagasse); 3 = 70% (CMP), 30% (NSSC bagasse); 4 = 80% (CMP), 20% (NSSC bagasse); 5 = 80% (CMP), 20% (long fiber)) (small letters indicate the Duncan ranking of the averages at a 95% confidence interval.)

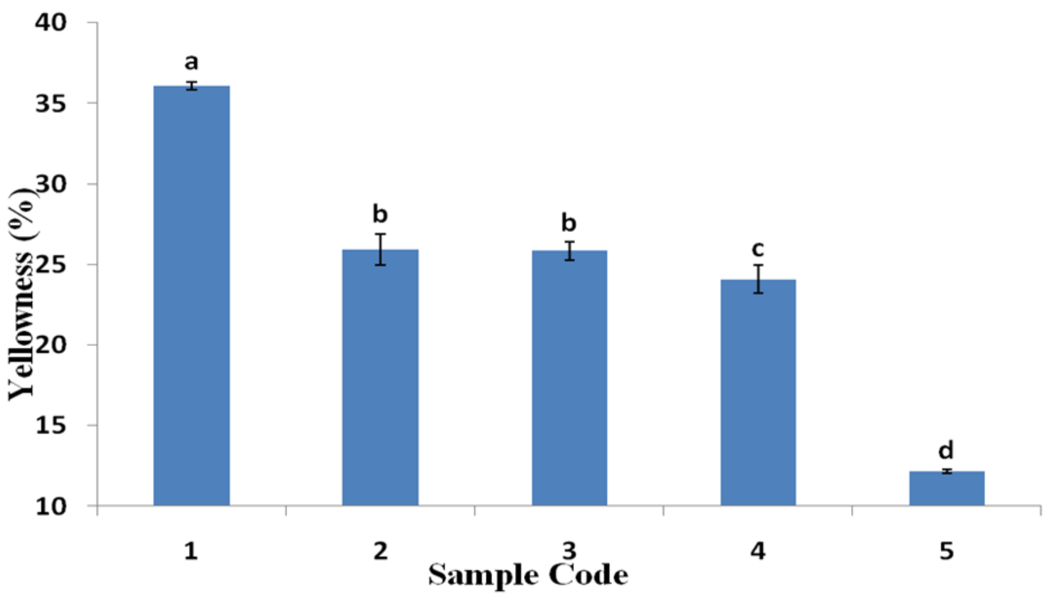

Fig. 6. Comparison of handsheets' yellowness made from different ratios (1 = 100% NSSC bagasse; 2 = 60% (CMP), 40% (NSSC bagasse); 3 = 70% (CMP), 30% (NSSC bagasse); 4 = 80% (CMP), 20% (NSSC bagasse); 5 = 80% (CMP), 20% (long fiber)) (small letters indicate the Duncan ranking of the averages at a 95% confidence interval.)

CONCLUSIONS

1. In a mixture of neutral sulfite semichemical (NSSC) bagasse pulp and hardwood chemimechanical pulp (CMP), favorable tensile, burst, and tear results were obtained when increasing proportions of up to 40% bagasse pulp. The results were attributed

to a favorable combination of the bonding ability of the bagasse pulp and the bulk and stiffness of the CMP fibers.

2. The NSSC pulp, which was unbleached, had an unfavorable effect on brightness and yellowness when it was mixed with CMP. Those two optical characteristics are of a type that can be addressed by bleaching of the bagasse pulp.
3. Decreasing opacity of the sheet was observed with increasing content of the NSSC bagasse pulp. These results were in line with the expected influence of increased inter-fiber bonding of the paper.
4. The use of bleached softwood kraft pulp as a reinforcing fiber had favorable effects on strength as well as brightness, which is a reflection of the combination of high intrinsic strength (zero-span tensile strength) and bonding ability, in addition to its highly bleached nature.
5. Mechanical properties such as (tensile and burst indexes) were decreased by increasing the hardwood CMP pulp.
6. Except in comparison to the mixture 80% hardwood CMP and 20% long fiber that gave the highest tear strength index, tear generally was improved by 100% NSSC bagasse pulp and the lowest strength tear index was exhibited by a blend of 80% hardwood CMP and 20% NSSC bagasse.
7. Optical properties such as (opacity and brightness) were increased by increasing the hardwood CMP pulp.
8. Yellowness was decreased by increasing the hardwood CMP pulp.
9. The results of this research on a laboratory scale indicated that using bagasse NSSC pulp mixed with hardwood CMP to make newsprint with acceptable quality will not only be possible based upon the results of research, but this process will also noticeably reduce the consumption of imported long fiber pulp and wood for producing CMP.

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