TECHNICAL

SODA – AQ PULPING OF WHEAT STRAW AND ITS BLENDING EFFECT ON OLD CORRUGATED CARDBOARD (OCC) PULP PROPERTIES

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ABSTRACT

Pulping of wheat straw was carried out by conventional soda-anthraquinone (AQ) process under different conditions. The influence of alkali charge (10, 12 and 14% on oven dried, as Na_2O) and cooking time (20, 35 and 50 min.) on pulp properties were studied. Results indicated that alkali charge and cooking time had a significant influence on kappa number. In contrast, no significant effects were observed on the screened yield

The results also showed that total yield increased significantly as alkali charge decreased whereas, cooking time had only a minimal effect. However, the best result with respect to yield, kappa number and alkali consumption was obtained with 10% alkali charge with 50 min. cooking time. The corresponding pulp was then blended with OCC pulp. Blending of wheat straw soda – anthraquinone pulp with OCC pulp in different ratios significantly improved all the paper properties compared to 100% OCC pulp. Thus, this study showed that unbleached wheat straw soda – AQ pulp can be used as a blend with the OCC pulp for making fluting paper.

1. INTRODUCTION

Paper consumption is continuously increasing across the world. The available wood supply in many countries will not meet the growing demand. Increasing attention is currently being paid to non-wood fibres worldwide.

In Iran, the main fibrous raw material resources available for papermaking are short-fibred hardwoods and recycled papers and non-wood fibres especially agricultural wastes.

Non-wood fibres are important raw material sources for papermaking in many developing countries. Of all the non-wood fibres used for papermaking, straws or grasses such as wheat straw, rice straw, reed and sugar cane bagasse account for most of the total non-wood pulp capacity[1]. Wheat straw has better quality for papermaking compared to the other non-wood fibres such as sunflower stalks, vine shoots and cotton stalks due to its stronger breaking length of paper handsheets[2].

Demand for paper has been forecasted to grow by nearly 50% by 2010.[6] The available wood supply in many countries will not meet this growing demand. Therefore, the utilization of nonwoods may help to solve the fibre shortage anticipated to arise in the future.

Caustic soda and modified soda (e.g. Soda-AQ) pulping are an important area of research in the pulping methods as well as total fractionation of biomass constituents. Soda-AQ is one of the well known methods of pulping of non-wood materials.[7] It is believed that AQ is the most cost-effective sulfur free accelerator for nonwood soda and kraft pulping.[8-11]

Another important source of fibre for papermaking is recycled paper.

In Iran, the biggest source of recycle papers is old corrugated cardboard (OCC), followed by old newspapers (ONP). Because the fibres in recycled paper and paperboard have been fully dried and then rewetted, they generally have different physical properties than virgin wood pulp fibres, and a portion of the fibres tends to be broken or damaged because of recycling. The recycled pulp must be treated to restore its bonding strength, through mechanical treatment, chemical additives, chemical treatment, fractionation, papermaking process modification and blending with virgin fibre.[12] Although, some mills produce 100% recycled paper, the majority augment their used pulp with some virgin fibre.

Thus, the main objective of this study was soda–AQ pulping of wheat straw and to investigate its favourable effect as a blend with the weaker OCC pulp.

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2. MATERIAL AND METHODS

2.1. Raw material
The raw material used was air-dried wheat straw from Iran. Characteristics of this material are shown in Table 1. Before cooking, foreign materials and grains were removed and then wheat straw was chopped to a length of 3-5 cm.

2.2. Chemical and physical analysis
The chemical composition of wheat straw was determined in accordance with the related Tappi standards for different components, namely: T 222 om 88 for lignin, T 264 om 88 for cellulose, T 204 om 85 for ethanol-benzene extactables and T 211 om 85 for ash. Fibre dimension evaluation was carried out using a microscope at x 300 and x 400, after maceration with 1:l acetic acid:30% H_2O_2.

Component	Composition of wheat straw dry solids(%)	
	Mean (%)	S.D. (%)
Cellulose(ash free)	49.7	0.30
Lignin	21.2	0.28
Ethanol-benzene extactables	5.4	0.35
Ash	9.7	0.26
Fibre length (mm)	1.27	0.28
Fibre width (µm)	14.32	4.53

Table 1 - Some characteristics of wheat straw

2.3.Soda-AQ pulping
The soda–AQ pulping was carried out in a 10-litre electrically heated and thermostically controlled rotary digester. The cooking conditions are shown in Table 2. Each condition was replicated 3 times and results are expressed as mean values.

Amount of wheat straw (oven dry)	440
Alkali charge, on o.d. wheat straw (as Na2O) (%)	10 , 12 , 14
Time at maximum temperature (min)	20 , 35 , 50
Time to maximum temperature (min)	60
Anthraquinone (%)	0.1
Liquor-to-wheat straw ratio	10:01
Maximum temperature (?C)	165
Maximum pressure (Bar)	6.9

Table 2 - Cooking conditions of wheat straw soda-AQ pulping

At the end of each cook, in order to evaluate separation of black liquor, the pulp was thoroughly washed with water. Then, resulting pulp was screened on a 20 mesh screen to remove rejects. After dewatering and homogenizing the accepted pulp was put into a plastic bag and stored in a refrigerator to determine the screened yield and kappa number.

In each case, the total yield, screen yield and the amount of reject were calculated according to the o.d. feedstocks and pulp. The kappa number of screened pulp samples was determined according to CPPA G.18.

2.3. Blending of soda-AQ pulp with OCC pulp and pulp properties
Blending was carried out with optimum unbleached wheat straw pulp and Old Corrugated Cardboard (OCC) pulp furnish (prepared of a board mill), in 25/75, 50/50 and 75/25 ratios. Prior to making handsheets, the freeness (CSF) of these pulps was measured according to TAPPI standard NO. T 227 om 94 and a laboratory blender used for desintegration of the selected wheat straw pulp.

Handsheets of about 120 gr/m^2 of these blends were made according to CPPA C.4 standard and thickness, air resistance, roughness, breaking length, folding endurance, burst index, tear index, CMT (Concoa Medium Test) and RCT (Ring Crush Test) were evaluated according to TAPPI and SCAN standards (T 411 om 97, T 460om 96, T 555 om 94, T 494 om 96, T 411om 97, T 511om 96, T 403 om 97, SCAN – P 11:73, T 818 om 97, respectively) and compared to those of the unblended papers.

2.4. Statistical analysis
The data were subject to analysis of variance and the sample means tested for significant differences using the multiple intervals test (Duncan). This was carried out using the statistical package SPSS 13.0.

3. RESULTS AND DISCUSSIONS

3.1. Pulp properties

3.1. 1.Soda – AQ pulping
Table 3 shows the average results of screened yield, total yield and kappa number of wheat straw pulp obtained with soda – AQ pulping at different

Cook number	Alkali charge(as Na_2O)(%)	Cooking time (min.)	Screened yield (%)	Reject (%)	Total yield (%)	Kappa number
1	10	20	44.0	1.7	45.7	24.6
2	12	20	45.6	0.7	46.3	13.6
3	14	20	44.6	0	44.6	10.9
4	10	35	45.8	1.1	46.9	23.0
5	12	35	44.7	0.1	44.8	12.7
6	14	35	44.5	0	44.5	10.1
7	10	50	47.0	0.9	47.9	22.8
8	12	50	44.4	0.1	44.5	12.4
9	14	50	44.3	0	44.3	9.6

Table 3 - Soda – AQ pulping average results of wheat straw[1]

[1] Active alkali(as Na2O) % on o.d. wheat straw , Liquor-to-wheat straw ratio 10:1 , Maximum temperature (•'3fC) 165 and AQ charge 0/1 % on o.d. wheat straw. Each experiment was repeated 3 times and the figures given are average values.

conditions. According to results, the pulp from cook # 7 had the highest yield. The pulp from cook # 1 had the highest kappa number. In contrast, the pulp from cook # 9 had the lowest kappa number. The highest rejects were obtained by using 10% alkali charge level due to insufficient cooking, whereas the cooks with 14% alkali charge were without rejects.

Figs. 1 and 2 , shows the effects of alkali charge(as Na_20) and cooking time on total yield, screened yield and kappa number during the soda – AQ pulping of wheat straw.

It can be seen that both alkali charge and cooking time had a significant influence on kappa number. Thus, either an increase in alkali charge at a constant cooking time or an increase in cooking time at a constant alkali charge resulted in a clear reduction in kappa number. It can also be seen that total yield increased significantly as alkali charge decreased, implying a more prominent dissolution and/or alkali–catalyzed degradation of pulp carbohydrates.

Cooking time had only a minimal effect. In addition, the alkali charge and cooking time had minor effects on screened yield. When Table 3 is examined, it can be seen that the effect of alkali charge on pulp properties is more important than that of pulping time. This observation is in agreement with a previous study in which the alkali charge and time varied during soda-AQ cooking of a wheat straw.[13]

In all experimental conditions, less rejects and kappa number were produced. This indicated that a wide combination of the various cooking parameter could be used in the soda–AQ pulping of wheat straw without any significant effect on the cooking results.

Therefore, the optimum condition among cooks with respect to yield, kappa number and alkali consumption, 10% alkali charge with 50 min. cooking time was selected. The freeness of selected pulp was 435 ml and without refining blended in various proportions with OCC pulp furnish which had a freeness of 333 ml.

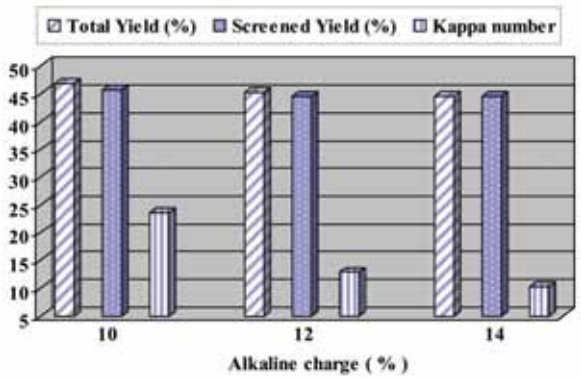

Fig. 1 Effect of alkali charge on pulp total yield of wheat straw soda-AQ pulp

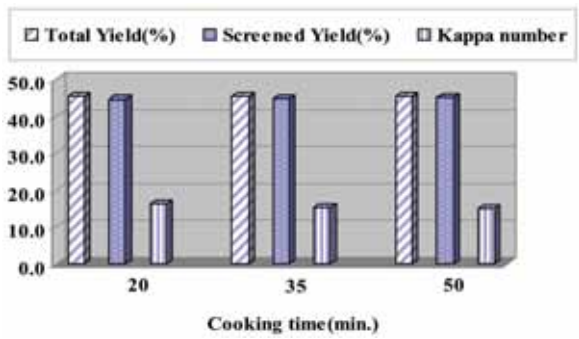

Fig. 2 Effect of cooking time on kappa number of wheat straw soda-AQ pulp

3.2. Hand sheet properties;

3.2.1.Unblended pulp properties,
The properties of the handsheets made from wheat straw soda – AQ and OCC pulps are shown in Table

Properties	Wheat straw	OCC(blends of old paperboard and waste paper)
Thickness (µm)	203	275
Air resistant (Sec)	108	11
Tensile index (N.m/g)	67.9	19.4
Folding endurance	958	8
Burst index (KPam2/g)	5.7	1.3
Tear index (mNm2/g)	7.3	7.1
CMT (N)	330	103
RCT (N)	289	124

4.

Table 4 - Properties of the papers made from wheat straw soda - AQ and OCC pulps in different ratios.

The paper made from OCC pulp in comparison to wheat straw soda–AQ pulp has a lower tensile index, burst index, folding endurance, CMT and RCT. This is probably due to some loss in the inter-fibre bonding as a result of multiple recycling.

During a drying and rewetting cycle, the fibres lost their conformability and swelling capacity that is associated with the phenomenon of irreversible hardening or hornification of fibres as first introduced by Jayme.[14] It has been suggested that hornification occurred when the hydrogen bonds that were formed between cellulose chains in the cell wall during drying resist being broken during the rewetting process, resulting in only partial swelling since some chains remain bonded.

In contrast, thickness for OCC pulp increased compared to wheat straw pulp because recycled fibres are stiffer and not so easily compressible.

3.2.2. *Blended pulp properties*
The influence of blending of wheat straw soda–AQ pulp with OCC pulp on hand sheet properties are shown in Figs. 3-6. In comparison with the control (100% recycled pulp), the paper properties were greatly affected by the percentage of blending with wheat straw pulp. Virgin fibres were able to absorb water and swelled to a higher degree than the recycled fibres. Swelling is an important factor in the

development of paper strength by virtue of increasing fibre flexibility; the more flexible the fibres, the more their conformation can be altered that could enhance inter-fibre bonding between themselves and the recycled fibres.

By blending both pulps a significant improvement in all properties except tear index was obtained. As seen in fig. 1, thickness decreased significantly as the proportions of wheat straw pulp increased. On the other hand, the air resistance improved with increasing amount of wheat straw. This is due to the flexibility and inter-fibre bonding and the presence of more short fibres and fibre fragments in the straw pulp, which result in higher paper density. This produced a highly bonded structure with high air resistance and low thickness.

As seen in figs. 4-5, blending of wheat straw soda–AQ pulp with OCC pulp increased significantly the tensile index, burst index and folding endurance compared to 100% OCC pulp but no significant effect on tear index.

The compressive strength of paper (RCT and CMT) played an important role for the determination of paperboards efficiency, especially for corrugated board and core boards. These properties could be correlated with paper properties as thickness, internal bonding strength and air resistance. The CMT and RCT of the blends were considerably improved compared to that of 100% OCC pulp.

The flexibility and collapsibility increases fibre bonding of a paper sheet. Fibre bonding increases the burst, corrugated medium test, ring crush, tensile index and folding endurance of the recycled paper but it decreases the tear index, as also observed by Rushdan.[15]

Because the fibres in OCC pulp have been fully dried and then rewetted, they generally have different physical properties than virgin pulp fibres, and a portion of the fibres tend to be broken or damaged because of recycling. The improvement reasons in the blended paper properties stemmed from the properties of the wheat straw pulp – its flexibility potential, inter-fibre bonding, virgin nature and morphological structure. Thus, adding wheat straw pulp increased the structural and mechanical properties. Jacobs et al.[16] and Schott et al.[17] studied the blending of wheat straw with recycled paper and reported a similar finding.

Fig.3 The influence of blending of wheat straw soda-AQ pulp with OCC pulp on thickness and air resistance.

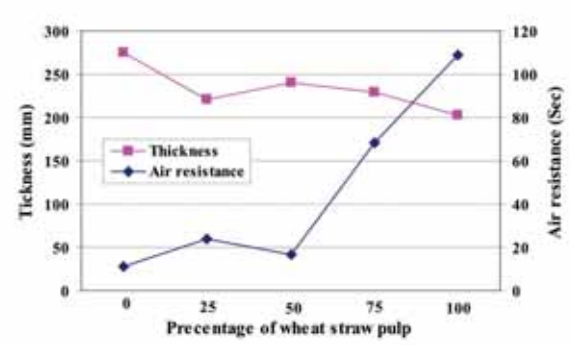

Fig.4 The influence of blending of wheat straw soda-AQ pulp with OCC pulp on tensile index and folding endurance.

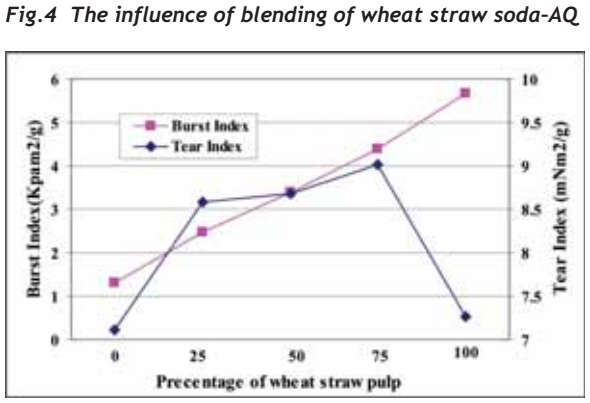

Fig.5 The influence of blending of wheat straw soda-AQ pulp with OCC pulp on burst index and tear index.

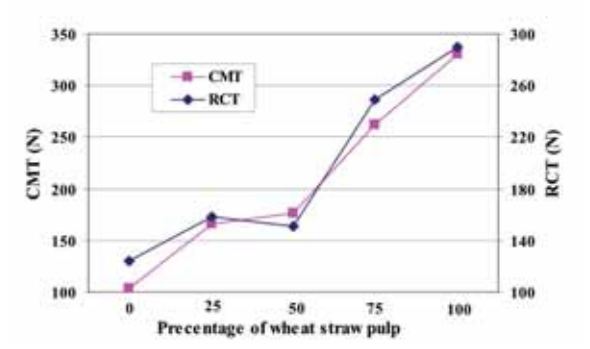

Fig.6 The influence of blending of wheat straw soda-AQ pulp with OCC pulp on CMT and RCT.

Among these blends, 75/25 ratio has the best physical and strength properties from the three blends. According to the results, unbleached wheat straw soda–AQ pulp can used as a potential reinforcement component in fluting manufacture.

4. CONCLUSION

This study has shown that wheat straw can be successfully pulped with soda–AQ process in different conditions. Wheat straw pulps of 44-47% yield could be prepared with a relatively small charge (10-14% on o.d. basis). Results indicated that a wide combination of the various cooking parameter could be used in the soda–AQ pulping of wheat straw

without any significant effect on the cooking results. In any case, the optimum pulping conditions were determined as follows: alkali charge 10%, cooking time 50 min. Pulp yield of this pulping system is 47/9%; kappa number is 22/8.

Blending of wheat straw soda–anthraquinone pulp with OCC pulp in different ratios significantly improved all the paper properties, except tear index, compared to 100% OCC pulp. With a 75% substitution of wheat straw pulp in a OCC pulp, the following major characteristics could be achieved: thickness 229 *m*m; air resistance 68 sec; tensile index 64 Nm^2/g; folding endurance 224; burst index 4 $KPam^2/g$; tear index 9 mNm^2/g; CMT 260 N and RCT 250 N.

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