# WATER-BASED FLEXO PRINTABILITY OF WHEAT STRAW TOP LINER FOR BOARDS

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**ABSTRACT:** Laboratory handsheets with a furnish varying from 100% wheat straw pulp to 100% pine kraft pulp were made. Roughness in the range of 6.1-6.2 microns was achieved by hard nip calendering to obtain surfaces characteristic of linerboards. During the calendering, it was found that less energy is needed to calender wheat straw handsheets than softwood ones to achieve the same roughness values. Handsheets were taped together and flexo printed using a Mark-Andy flexo press and water-based ink. Reflective density slightly increased with a higher content of wheat straw, but no statistically significant differences were found. Also, the gloss and mottle did not show statistically significant differences within tested furnishes of wheat straw and softwood liners. Slightly better print uniformity was found at image detail of samples with increasing wheat straw content. The measured data confirmed that wheat straw is an excellent fiber source for linerboard from the point of view of printability.

## INTRODUCTION

Non-wood fibers are a major fiber source in developing countries with limited access to forest resources. Worldwide, non-woods made up 16.5 million metric tons of the fiber supply for paper production in 1991, corresponding to 10 % of

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the virgin fiber supply and 6 % of the total fiber supply (including recovered fiber).

The worldwide increase in capacity of non-wood plant fiber pulps for papermaking has dramatically increased to 10.6 % total fiber supply in 1993, and was projected to go to 11.2 % in 1998 (1). In the United States, the non-wood capacity recently was approximately 400,000 metric tons, corresponding to 0.6 percent of the virgin fiber supply (2).

Traditionally, straw-corrugating board occupied a favored position in the U.S., peaking in the early 1940's, when strawboard achieved a production record of 2/3-million tpy (3). Before pulping, straw has to be reduced in length and cleaned to remove dust, grain, and metal. It can be cleaned wet or dry. A combination of dry cleaning followed by wet cleaning immediately prior to the digester appears to give the best removal of dirt and sand. New baling technology and new pulping equipment should make wheat straw competitive with wood as a fiber source for paper.

Wheat straw contains 50 % bast and sclerenchyma fibers, 30 % parenchyma, 15% epidermal cells, and 5 % vessels (4). Straw fibers are much more heterogeneous than wood pulp fibers. The fiber dimensions of cereal straws are 680 -3120 μm in length with an average of 1480 μm, and 7-24 μm in diameter with an average of 13 μm. The excellent paper formation characteristics of straw fibers are attributable to their relatively high ratio of average length to diameter.

The total holocellulose content of wheat straw is similar to that in trees. In comparison with wood, straw contains less cellulose. The lignin content of wheat straw (16-21 %) is significantly lower than that of softwoods (26-34%) and hardwoods (23-30%). Cereal straws have a relatively high silica and potassium content which makes the black liquor difficult to recover. The ash content of straw is invariably much higher than in most other fibrous materials.

Although non-wood fibers can be pulped with the same processes used for wood, most non-wood pulping operations worldwide use a soda process. The soda process uses no sulfur compounds and thus has a simpler recovery system and no odor problems; for these reasons, the soda process is preferred to the Kraft process. Non-wood fibers are well suited for mechanical or chemi-mechanical pulping processes. They have a relative advantage over wood chips in such processes because less energy is required. For various reasons, wheat straw appears to be most appropriately used in combination with other fibers. Because of its short fibers, wheat straw makes a weak paper that drains slowly. However, in combination with long-fiber pulps, these shortcomings can be alleviated. Wheat straw is ideally used to increase the bulk of corrugating medium. Incorporating wheat straw into virgin or recovered fiber corrugating medium, linerboard, and boxboard has high potential (5). A mixed cook of wood chips with wheat or rice straw will remarkably increase the pentosan content in the pulping liquor. At the end of the cook, when the alkali content decreases, pentosans reabsorb onto the surface of the fibers. An increased amount of hemicellulose greatly reduces the beating time of pulps (6). Also, an increased pentosan content will improve the wet strength of the resulting pulp (6). This will help to increase the speed of paper machine.

However, there are some disadvantages connected with wheat straw processing; for example, high silica content makes the black liquor difficult to recover. Silica may not be a major problem if the non-wood line is added to a large wood pulp mill and black liquors are processed in one combined recovery system. There are several examples of these mills worldwide (e.g., Hungary, Spain).

Boxboard manufacturers are pressed to provide better surface finish for printing, because the printing of boxes used for identifying the product containers has become one of the primary challenges in the manufacturing of high-quality corrugated board. Water-based flexography is the dominant process for the printing of corrugated boards and of other packaging materials as well. It is the practical, cost-effective process for short and medium-length print jobs.

Flexography is a rotary printing method that applies fast-drying, fluid inks from a simple inking system and prints from resilient plates of rubber or photopolymer that have the image in relief. The flexible printing plates are able to contact the rough surfaces of corrugated board under relatively low pressure. Linerboards can be printed by water-based flexography, either before or after being combined with corrugated medium. Surface roughness, porosity, and water absorbency are important factors for print quality. The image quality of post-printed combined boards depends on the surface properties of the liner, the structure of the fluted medium, and the effects of washboarding (7).

The objective of this project was blend non-wood pulp fibers from wheat straw with softwood kraft pulp with the aim to obtain different pulp furnishes for top liners for board production. The main goal was to determine whether or not the wheat straw pulp furnish will affect flexo print quality with water-based ink.

## EXPERIMENTAL

### Materials

Wheat straw for delignification was harvested in 1998. Its moisture content was 6 %. Softwood kraft pulp was a commercial paper grade, unbleached pinewood pulp with Kappa number of 48.

### Pulping

Wheat straw was delignified in 6.5 L batch M+K laboratory digester equipped with an external cooking liquor circulation and external heat exchanger. Pulping chemical was NaOH with a charge of 8 % $Na_2O$, calculated on wheat straw. Liquid to solids ratio was 12.8: 1. Impregnation with cooking liquor was done at 115 °C for 15 minutes. Maximum pulping temperature was 165 °C and the reaction time at maximum temperature was 90 min. The delignified pulp was defibrated with a kitchen blender at medium speed for 30 seconds, washed in a 50 mesh sieve to a neutral pH, and screened with a 0.006" slot screen. The total yield of wheat straw pulp was 47.8% with 3.6% rejects; thus, screened yield was 44.2 %. Washed wheat straw was beaten in a PFI mill according to TAPPI standard T 200 sp-96 to 300 ml CSF freeness. Softwood kraft pulp was beaten under the same conditions to 480 ml CSF. Freeness was determined according to TAPPI Standard T 227. Handsheets were made using a Nobel and Wood mold.

Handsheets of the following composition were made:

100 % wheat straw pulp
50 % wheat straw pulp and 50% softwood kraft pulp
25 % wheat straw pulp and 75% softwood kraft pulp
100 % softwood kraft pulp

### Calendering

Calendering with the aim of smoothing of the surface was done. The goal of the calendering was to obtain approximately the same roughness values as found with commercial linerboards. Calendering was done at the following conditions:

Table 1: Calendering of mixed softwood kraft- wheat straw pulp handsheets

| Wheat straw content [%] | Applied pressure [psi] | Number of passes through calender | Roughness at 1000 kPa [μ] | Compressibility $R_{500}/R_{1000}$ |
|---|---|---|---|---|
| 0 | 24 | 2 | 6.15 | 1.02 |
| 25 | 22 | 2 | 5.85 | 1.05 |
| 50 | 21 | 2 | 5.74 | 1.06 |
| 100 | 20 | 2 | 5.68 | 1.07 |

## Papermaking Properties

The basis weight of handsheets was determined according to TAPPI T 410 om-93 standard method. PPS roughness was determined according to TAPPI T 555 pm-94. PPS porosity was determined at 1000 kPa clamping pressure. Paper caliper was determined according to TAPPI T 411 standard method.

## Printing Procedure

A Mark-Andy 830 label press was used for printing of laboratory-made handsheets, trimmed to a width of 7 inches and taped together into a web. A 7-inch (17.5 cm) central impression cylinder equipped with an EPICS photopolymer plate 0.067 " mounted with 0.015 " compressible stickyback was used. An anilox roll with 280 LPI, and 4 BCM was used. The printing was performed at 225 ft/min with black flexographic water based ink (Ultra Gloss Plus Jet UGLO41201), Water Inks Technologies; viscosity of the ink measured as efflux time with a Zahn #2 cup was 25 seconds.

## Contact Angle

Dynamic contact angles of paper samples were measured using Fibro 1121/1122 DAT - Dynamic Contact Angle and Absorption Tester (FIBRO System AB, Stockholm, Sweden). Contact angles of a mixture 1:1 of deionized water and black water based ink were taken at 0.1, 0.25 and 0.5 sec.

## Printability Evaluation

Specular gloss was measured in solid areas using a Gardner gloss meter with 60 degree geometry. Reflective density was measured in solid areas using an X-Rite 408 densitometer. Mottle index was determined from the standard deviation of density (100 density measurements) and calculated as follows:

Mottle Index = $STD_{Density}$ *1000. Bar code readability was tested by means of commercial LS 2000 MX scanner (Symbol Technologies).

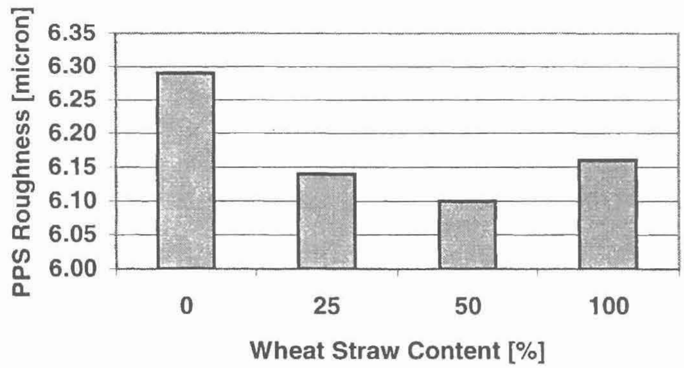
### Image analysis

Image analyses of black dots were recorded at 28 % tone scale by means of a Hitachi HV-C10 camera (Hitachi Denshi, Ltd., Japan). Computer software, Image–Pro Plus, Version 3.0, was used for image detail analysis.

## RESULTS AND DISCUSSION

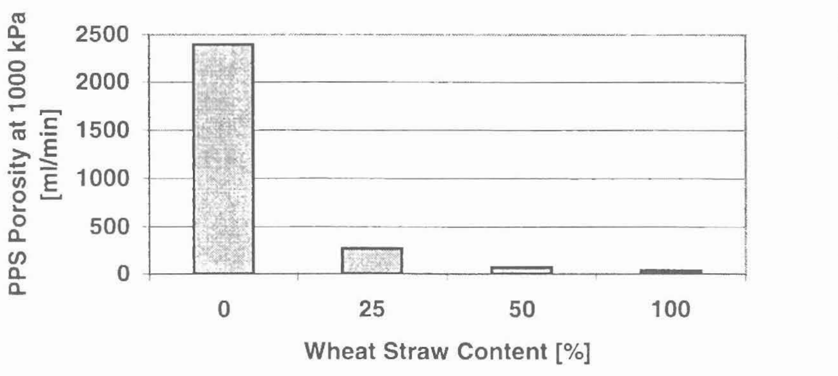
Linerboard is a relatively lightweight board commonly used as the outer plies of corrugated box stock. Standard liner is 205g/m$^2$, but other grades cover the range from 112 to 439g/ m$^2$. The laboratory handsheets from mixed wheat straw pulp and pine kraft pulp were made with the aim to mimic linerboard grades and to test their flexo printability.

Fig.1: Roughness at 500 kPa vs Wheat Straw Content



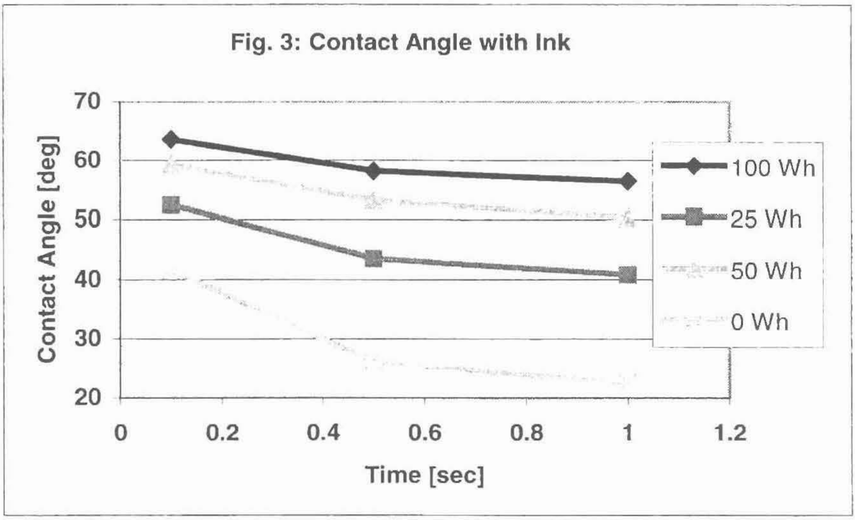

The laboratory made handsheets of wheat pulp furnish 0-100% were calendered with the aim to obtain a roughness similar to commercial linerboards (about 7 micron at 500 kPa). To achieve this goal, different calendering conditions were applied [Tab.1]. The highest pressure was applied to 100% softwood kraft handsheets and decreasing pressure was applied to handsheets with increasing wheat straw content. Final roughness of these handsheets was in the range of 6.10- 6.34 µ at 500 kPa [Fig.1] and 5.68-6.15 µ at 1000kPa [Tab.1]. Less pressure was applied during calendering of wheat straw fibers than softwood fibers. Wheat straw fibers conform more easily into smoother surfaces than softwood fibers. The surface compressibility slightly increased with increased content of wheat pulp. The porosity of boards

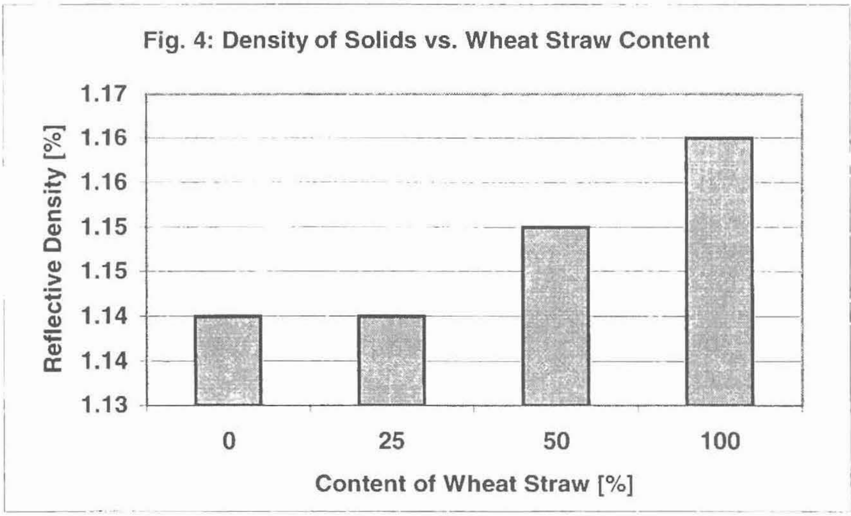
Fig. 2: Porosity vs Wheat Straw Content



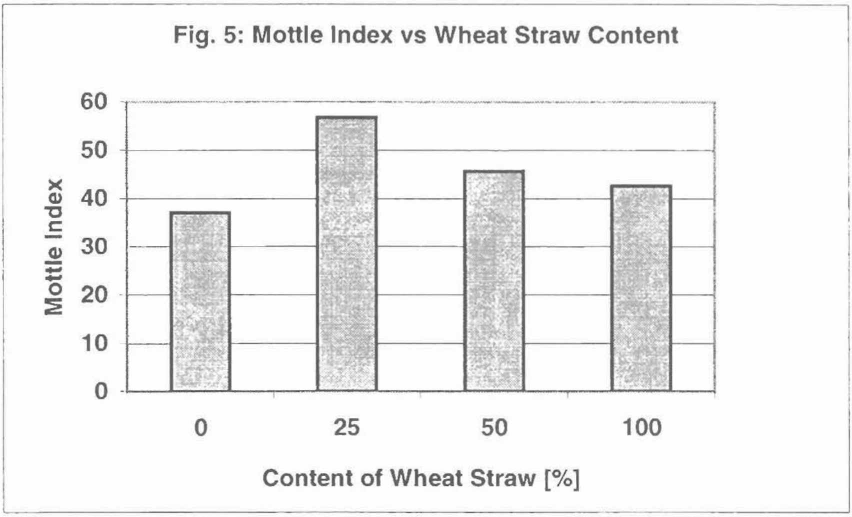

decreased very significantly with wheat straw furnish [Fig. 2]; the shorter fibers probably filled the pores in between large pine fibers.

Dynamic contact angles of water based flexo ink with mixed wheat straw pulp-softwood pulp handsheets were measured [Fig. 3] with calendered handsheets. Higher contact angles were found with wheat straw than with softwood kraft handsheets. The contact angles decreased with decreasing wheat straw content. Also, absorptivity, or the decrease of contact angle with time, was more obvious with softwood handsheets than with wheat straw handsheets and increased with increasing content of softwood pulp in mixture.




The print quality evaluation was done by measurement of reflective density [Fig.4], mottle index [Fig. 5], and specular gloss [Fig. 6]. Reflective density was found to increase slightly with increasing content of wheat straw pulp in the paper mixture [Fig. 4]. However, this increase of 0.02 density units is not significant, because it lies within the sensitivity range of the X-Rite densitometer (0.02 units).




Mottle index was calculated from standard deviation of density. Mottle [Fig. 5] was very low at all samples (Mottle index in the range of 38-55), meaning that all samples had a fairly uniform print and no significant variation was found with changing wheat straw furnish. Specular gloss of softwood liner was 5.0 % and that of 100% wheat was 5.12%. Overall, specular gloss did not show statistically significant differences with changing wheat straw content in linerboards [Fig. 6].

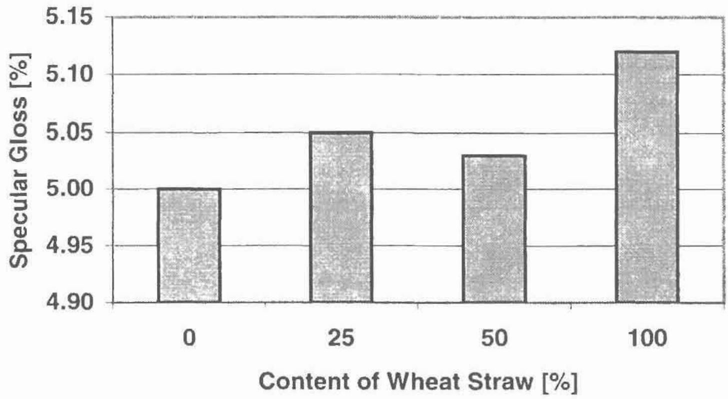



Fig. 6: Gloss of Solids vs Wheat Straw Content

Image detail was studied at 28 % tone. The area of printed dots slightly increased with decreasing wheat straw content. This is in concert with contact angle determinations, where decreasing contact angle, or, larger spreading with decreasing wheat straw pulp content was found. Perimeter of dots was most uniform with 100% wheat liner. The edge definition was best at this sample, with minimum wicking. Also, the roundness was smallest with 100% wheat liner. (Ideal roundness parameter for flexo dots is 1, which represents perfectly round dots). Standard deviations of area, perimeter, and roundness can be considered as parameters of print uniformity. The more uniform the print, the lower the standard deviation. A light increase in standard deviation of area, perimeter, and roundness with decreasing wheat straw pulp was found [Tab.2]. This indicates that uniformity of print slightly decreases with decreasing wheat straw furnish.

Bar code readability was investigated for all furnishes. 100% bar code readability was determined for all wheat straw pulp and softwood pulp furnishes.

Table 2: Image analysis of flexo- printed mixed softwood-wheat straw pulp handsheets

| Sample | Area $[\mu^2]$ | Area $STD[\mu^2]$ | Perimeter $[\mu]$ | Per.Std $[\mu]$ | Roundness | Rou.Std |
|---|---|---|---|---|---|---|
| 100 % Wheat | 16 588 | 2025 | 503 | 64 | 1.23 | 0.28 |
| 50 % Wheat | 16 968 | 1843 | 522 | 68 | 1.29 | 0.30 |
| 25 % Wheat | 18 680 | 6489 | 610 | 218 | 1.62 | 0.71 |
| 0 % Wheat | 17 308 | 1944 | 544 | 79 | 1.39 | 0.44 |

Where: Area = Area of Flexo Dot
Area Std = Standard Deviation of Dot Area
Per. Std = Standard Deviation of Dot Perimeter
Rou.Std = Standard Deviation of Dot Roundness

## CONCLUSION

Laboratory handsheets from 100% wheat straw pulp to 100% softwood kraft pulp were made. Roughness in the range of 6.1-6.2 micron was achieved by hard nip calendering. Lower pressure was needed to calender wheat straw handsheets than softwood ones to achieve the same roughness values. Handsheets were taped together and flexo printed using a Mark-Andy flexo press and water-based ink. Reflective density was slightly higher at furnishes with a higher content of wheat straw, but no statistically significant differences were found. Also, the gloss and mottle did not show differences within tested furnishes of wheat straw and softwood liners. Slightly better print uniformity was found at an image detail of samples with increasing wheat straw content. Printability analysis confirmed that the wheat straw fiber is an excellent raw material for linerboard manufacturing.

## LITERATURE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