EUCALYPTUS SUBSTITUTIONS FOR UNCOATED PRINTING PAPER

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Abstract

As eucalyptus fiber has become a prime component of many fine printing papers, its price has risen. This study was concerned with assessing the change in printability and network properties resulting from the substitution of North American fibers for imported eucalyptus. Results from three pilot plant machine trials of waterleaf paper are reported. In addition to changing softwood and native hardwood fiber ratios, the effect on gravure printability tests was considered for altering the process variables of machine shake, rush-drag ratio and press load. Fiber composition proved to be the dominant variable in printability with native blends offering qualified substitutes for eucalyptus.

INTRODUCTION

Eucalyptus fiber has found increasingly widespread application in printing papers due to the uniformity, good formation, dimensional stability, stiffness, good opacity, smoothness, and ink receptivity it imparts to sheets. With this increased use, the price of this bleached sulfate tropical hardwood pulp has risen to match that of the premier North American bleached sulfate softwood pulps. For North American papermakers and printers (whom they must pass their costs along to), it is reasonable to inquire whether the price of this imported pulp is justified over that of domestic hardwood pulps. This study was conducted in part to address that question by providing a comparison of certain printing relevant properties of contrasting fiber-blend ("furnish") papers made under identical circumstances.

In order to emphasize the dependence of the sheet properties on the type of fiber used, uncoated waterleaf papers were used. Thus the network and surface properties of the paper are not influenced by the presence of mineral particles ("fillers" and "coating pigments"). All the paper was manufactured on a Fourdrinier papermachine in order to better approximate actual printing substrates. In order to complement an earlier study [Bobalek, 1989] and better assess the impact of only one other main effect, the important variable of refining [Claudio-da-Silva,Jr., 1981] was also kept constant.

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To investigate whether changes in manufacturing variables might noticeably moderate the effect of the different furnishes, the influence of shake, rush-drag and press load were considered. "Shake" is an oscillatory motion imparted to the Fourdrinier wire on certain low velocity machines used to produce fine papers. Shake can lead to better formation, good formation being one of the attributes of eucalyptus-furnish papers. "Rush-drag", or jet-to-wire ratio, is the ratio of the slice velocity of the slurry leaving the papermachine headbox to the speed of the moving "wire" (drainage screen). The ratio of these two velocities can influence paper structure, particularly formation and strength properties. "Press load" refers to the pressure exerted on the wet web after the drainage table in the first nip. Again, the magnitude of this pressure can influence the formation and network properties if the hydraulic displacement is sufficiently large.

EXPERIMENTAL CONDITIONS

A. FIBER SELECTION & FURNISH STUDIES

Traditional woody fibers for papermaking come from the softwood (gymnosperm) and hardwood (angiosperm) genera of trees. A common furnish for printing papers consists of a blend of about 40% softwood fibers (for strength properties) and 60% hardwood fibers (for optical, formation and smoothness properties). This combination is largely dictated by economics, hardwood pulp usually being less costly than softwood pulp. Since fiber expenses are generally the most costly single item in producing paper just as paper is the most costly raw material in a printing job, a good starting point for cost reduction is to explore the quality impact on maximizing the use of hardwood in any given grade.

Accordingly, the first pilot plant trial was run with domestic hardwood to softwood percent fiber ratios of 60%/40%, 70%/30% and 80%/20% (percentages on the basis of the weight of oven-dry fibers). It was determined that the highest percentage hardwood furnish yielded an acceptable paper (as a first approximation for uncoated gravure applications). On the basis of this first trial, a second trial was run substituting Brazilian eucalyptus for the domestic hardwood while varying the cited machine variables. Finally, a third trial was run employing 100% Brazilian eucalyptus with the same sequence of machine variable variations.

The domestic hardwood utilized was bleached sulphate (kraft) quaking aspen, <u>Populus tremuloides.</u> Aspen was used since it has an extremely fine fiber, even for hardwoods.

This likeness in fiber morphology and its rapid rate of growth (especially for triploid quaking aspen), make aspen perhaps the most similar of North American hardwood species to Brazilian eucalyptus, Eucalyptus globulus, with dimensions of about 1 mm length, 16 microns diameter and cell wall thickness of 3 microns. In contrast to this, the bleached kraft softwood pulp used came from southern yellow pine, Pinus taeda, with dimensions of about 4 mm length, 35-50 microns diameter, and a cell wall thickness of 3-8 microns. The pine is clearly a coarser fiber than the eucalyptus and the resulting papers might be expected to exhibit different properties as a result of this difference as has been elsewhere discussed [Bobalek, 1989].

B. PILOT PLANT TRIALS

All papermachine trials were conducted on a 24-inch wide Fourdrinier papermachine after refining the dry-lap pulp to 410 CSF on a Claflin refiner. A basis weight of 50 gsm was maintained throughout all three trials. The paper was manufactured under acidic wet-end conditions, 1.6% alum and 0.5% rosin size being added to the hollander beater (before the Claflin) and the final pH adjusted with sulfuric acid. No other additives were introduced into the system (no fillers, starch, etc.).

Trials were run according to an experimental design allowing for the different combinations of shake on and off; rush-drag less than, equal to and greater than unity; and first press at settings of 15 and 30 psi. Paper was dried to 5-7% moisture. After cutting to workable lengths, the paper was run through a laboratory supercalender at 60 psi and ambient temperature (ca. 25 degrees Celsius).

C. TESTING & STATISTICAL ANALYSIS

All papermachine trial paper was tested per TAPPI standard methods in uncalendered (off the machine) and supercalendered states. Four test determinations were made for each experiment in every trial on the properties of grammage, caliper, tensile strength, tear strength, Sheffield smoothness, Gurley porosity, Parker Print smoothness, brightness, opacity, Helio gravure printability (distance to 20th skipped dot in mm) and Diamond National Printability (missing dots per square centimeter, printed area 25%, 175 lines per square inch). For the tensile and tear strength, both machine direction and cross direction strength was measured and indexed (normalized) for the basis weight. The means and variances were calculated and analyses of variance conducted for significance at the 5% level employing SAS software run on an IBM 360.

FURNISH AND SUPERCALENDERING AS MAIN EFFECTS

The desirability of running the paper tests on the sheet in its two states (uncalendered and supercalendered) is evidenced by two considerations. First, any contribution due to a difference in the fiber blends ("furnishes") has potentially twice the chance of being observed and second, uncoated paper is inevitably supercalendered before rotogravure printing. The properties of the supercalendered sheet are thus of principal interest to the gravure printer.

Due to the nonsignificance of the papermachine process variables in the latter two trials conducted, the experimental design collapsed into data amenable to a two-way analysis of variance with interaction. Here, the two main effects are the furnish and supercalendering with occasional surprising interaction phenomena.

To better consider the differences between the three papers produced, it is helpful to look at the sheets'physical test data (Table 1), optical test data (Table 2), and rotogravure printability test data (Table 3).

Table 1. Physical tests of machine made papers.

		Furnish as Wt. % Hardwood		
Property	State	100% EUC	80% EUC	80% NHW
Density, g/cubic cm	UC	0.61	0.63	0.65
	SC	0.97	0.92	0.85
Bulk, cubic cm/g	UC	1.63	1.59	1.55
	SC	1.03	1.09	1.18
Compressibility (PPS 10kg/20kg)	UC	1.12	1.14	1.08
	SC	1.11	1.10	1.14
% Compressibility (PPS 20kg/10kg)	UC	89	88	93
	SC	90	91	88
MD Tensile Strength, kg/15 mm	UC	2.6	2.4	2.6
	SC	1.9	2.2	2.4

Means presented of UC (uncalendered) and SC (supercalendered) furnish papers. SC:1 pass through lab supercalender at 60psi.

Table 2. Optical tests of machine made papers.

Property	State	Furnish as Wt. % Hardwood 100% EUC	80% EUC	80% NHW
Brightness, % Reflectance	UC	88	88	85
	SC	90	90	81
Opacity, %	UC	76	76	79
	SC	73	75	77
Density, g/cubic cm	UC	0.61	0.63	0.65
	SC	0.97	0.92	0.85
Bulk, cubic cm/g	UC	1.63	1.59	1.55
	SC	1.03	1.09	1.18

Means presented of UC (uncalendered) and SC (supercalendered) furnish papers. SC:1 pass through lab supercalender at 60psi.

Table 3. Gravure Printability tests of machine made papers.

Property	State	Furnish as Wt. % Hardwood 100% EUC	80% EUC	80% NHW
Helio, mm to 20th missing dot	UC	354	256	121
	SC	440	431	195
Diamond National, (25% area)	UC	1223	2250	85
	SC	95	163	5
Roughness, microns Parker Print Surf**	UC	4.9, 4.2	4.9, 4.2	4.7, 4.2
	SC	2.6, 2.3	2.6, 2.2	2.4, 2.1

Means presented of UC (uncalendered) and SC (supercalendered) furnish papers. SC:1 pass through lab supercalender at 60psi.

**Parker Print Surface, Measurement of Rotogravure Printability, (10 kgf/square-cm, 20 kgf/square-cm).

Table 1 lists the apparent density (calculated from the measured basis weight and caliper) and its inverse, the apparent bulk, the Parker Print Surf compressibility and its inverse, and the indexed machine direction tensile strength for each of the three furnishes in the uncalendered and supercalendered states. The inverse expressions are given as a convenience. The machine direction tensile strength behaves predictably, always decreasing upon supercalendering. Also as expected, the furnishes containing 20% softwood fibers exhibit greater tensile strength. What is surprising is the interaction of supercalendering and furnish for the 100% eucalyptus paper: the drop of 27% instead of the 8% observed for the other two furnishes. That this is a genuine change is corroborated by the density interaction observed for the 100% eucalyptus furnish upon supercalendering. Taken together, these data indicate a radical change in the eucalyptus network due to supercalendering. It is an inference worth further testing that, on the papermachine, the stiff fibers form an open three-dimensional structure that is well bonded due to a multiplicity of transverse fiber contact points. Upon supercalendering, the fine fibers are apparently compacted in densely layered lamellae with a concomitant loss of interfiber bonding. The slightly coarser aspen fibers are seen to pack less compactly under supercalendering and correspondingly suffer less of a strength attrition.

Table 2 lists the Tappi brightness and opacity of the three furnishes. All the data is more alike than dissimilar, a condition frequently encountered when working with clean bleached kraft pulps [Bobalek and Chaturvedi, 1989]. The density figures have been listed along with these because of the demonstrated correlation of scattering with density. Here the correlation is weak, supercalendering uniformly resulted in a small drop (1-4%) in the opacity due to loss of scattering surface as the network is compacted. Difference in the furnishes is most evident upon supercalendering with the greatest drop again being in the most dense network (100% eucalyptus). Note that the bulkiest compacted network (aspen/pine) has the highest opacity of the graded series. The small rise in brightness for the compacted eucalyptus furnishes is commensurate with the foregoing data and probably due to an enhanced specular surface due to compaction (a sort of "mirror polishing" under pressure).

Table 3 lists the Helio and Diamond National printability test results from the three papers. Parker Print Surface is also listed in this table, although it is not a printing test per se, because surface smoothness is so strongly associated with good rotogravure printability [Voas, 1989]. Judging from the Print Surf data, there is no furnish effect on the roughness of the paper surfaces, only a difference between the uncalendered and supercalendered paper. Certainly the differences indicated by the bulk, tensile, opacity and brightness data are small and could easily be missed by an insufficiently sensitive test. And if the measurements themselves are insufficiently sensitive, it would not be surprising that the use of their ratio (the compressibility) is not a good indicator of rotogravure printability [Bery, 1990], as is implied by the nonsignificance of the compressibility data in Table 1. It is evident that satisfactory means of predicting gravure printability for uncoated paper is lacking just as it is for coated paper [Von der Heyde, 1982].

However, the results of the Helio test do imply that dot-skip is halved by the substitution of eucalyptus for aspen in the furnish. The Helio test, considered as one of the more reliable indicators of gravure printability, also reinforces the conclusions drawn from considering the physical and optical data. The surface which performs best (440 was the maximum distance inked in the test, the actual distance to the 20th missing dot in the test limit is not determinable) in the Helio is the supercalendered 100% eucalyptus furnish, indicated by the density, tensile, opacity and brightness measurements to be the smoothest surface present.

SUMMARY

One of the basic tenets of total quality control programs is that more uniform raw materials leads to more uniform product. This is the real glamor of imported eucalyptus pulp, once the particular practices (such as refining procedure) required to handle it well are understood, the properties it will impart to the sheet can be predicted with great confidence. This is especially true of monoclonal variants of the species such as the highly successful experiments carried out in Brazil. If availability of a uniform fiber capable of providing the paper properties listed in the Introduction of this article is of importance to papermakers/printers, then eucalyptus pulp will continue to be imported to the USA. Availability is assured due to the incredible growth rate of the trees, capable of attaining 20 meters height in 3 years after field planting [Zobel, 1981]. Currently both Brazil and the Iberian peninsula are increasing their export capacity of eucalyptus while India continues its forestry research on the species.

But with this increased demand and the unavoidable freight charges, the pulp is apt to continue to demand a premium price. Is it worth it? Understanding why the eucalyptus fiber functions so well, the influence of its fiber dimensions on paper properties, implied that similar homegrown fibers might function nearly as well. Perusal of the data in Tables 1-3 generally does not reveal great differences between these furnishes. Use of quaking aspen instead of eucalyptus in fact may yield a stronger, more opaque paper, perhaps at the expense of poorer rotogravure printing capability. It is important first of all to clearly understand the printing requirements of the paper to be produced and then specify its manufacture starting with the optimum furnish. In many cases, the best fiber for a particular paper may yet be developed by the new techniques of tissue culture and genetic engineering. And in this search for the appropriate fiber, the native resources of the host country should not be ignored.

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