SEGREGATING WOOD AND BARK CHIPS BY PHOTOSORTING

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Bark, foliage, and dirt have prevented the widespread use of whole-tree chips in the pulp and paper industry. A chip debarking process has already been developed by the Forest Engineering Laboratory, North Central Forest Experiment Station (Arola *et al.* 1976), and has been installed in a production-scale pilot plant in New Brunswick, Canada (Wawer and Misra 1977). A "scalping" or presorting process could first remove a "clean fraction" of chips and reject fractions with much bark, thus reducing the amount of material processed by compression debarking. Such presorting would reduce the size of the compression debarking system and in turn reduce the overall capital investment needed.

Sorting processes based on differences in optical properties, particularly color or spectral characteristics, have been used for various agricultural commodities (Bilanski and Fisher 1976, Chamberlin 1976, Massie and Norris 1975, Rohrbach *et al.* 1973, Worthington *et al.* 1973). Most of these systems segregate on the basis of spectral reflectance measurement, i.e., surface color. Due to the presence of bark/wood chips (bark attached to a wood chip) during the dormant season and problems caused by the variation in surface colors of bark and wood, the transmittance of light through wood and bark chips was investigated rather than reflectance. The purpose of this paper is to show that bark and wood chips differ sufficiently in their optical transmittance to be sortable, and to present preliminary results of an experimental sorting system based on this difference.

SPECTRAL MEASUREMENTS

The average spectral transmittance of bark and wood chips was measured for several species using a Gamma Scientific[1] scanning spectral radiometer. This instrument consists of a model 700-31 grating monochromator and a model 2900 auto-photometer which uses a photomultiplier tube (PMT) as a detector. Wood and bark chips were placed over the entrance aperture of the monochromator (fig. 1), and the relative spectral transmittance was measured at each of seven equally spaced wave lengths from 500 to 800 nanometers (nm). This range is from the green to the near infrared regions, respectively. The data for ten randomly selected wood and bark samples from the ⅝-inch size chip fraction (chips which have passed through a screen with 1⅛-inch diameter holes and were retained on a screen with ⅝-inch holes) were averaged logarithmically. Logarithmic averaging was chosen because chip transmittance varies exponentially with chip thickness. The average spectral transmittance curves are shown for aspen, maple, and loblolly pine in figures 2, 3, and 4, respectively.

After obtaining the average transmittance for both wood and bark chips for each species, the ratio of average wood transmittance to average bark transmittance was calculated at each of the seven wavelengths to obtain

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[1]Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.

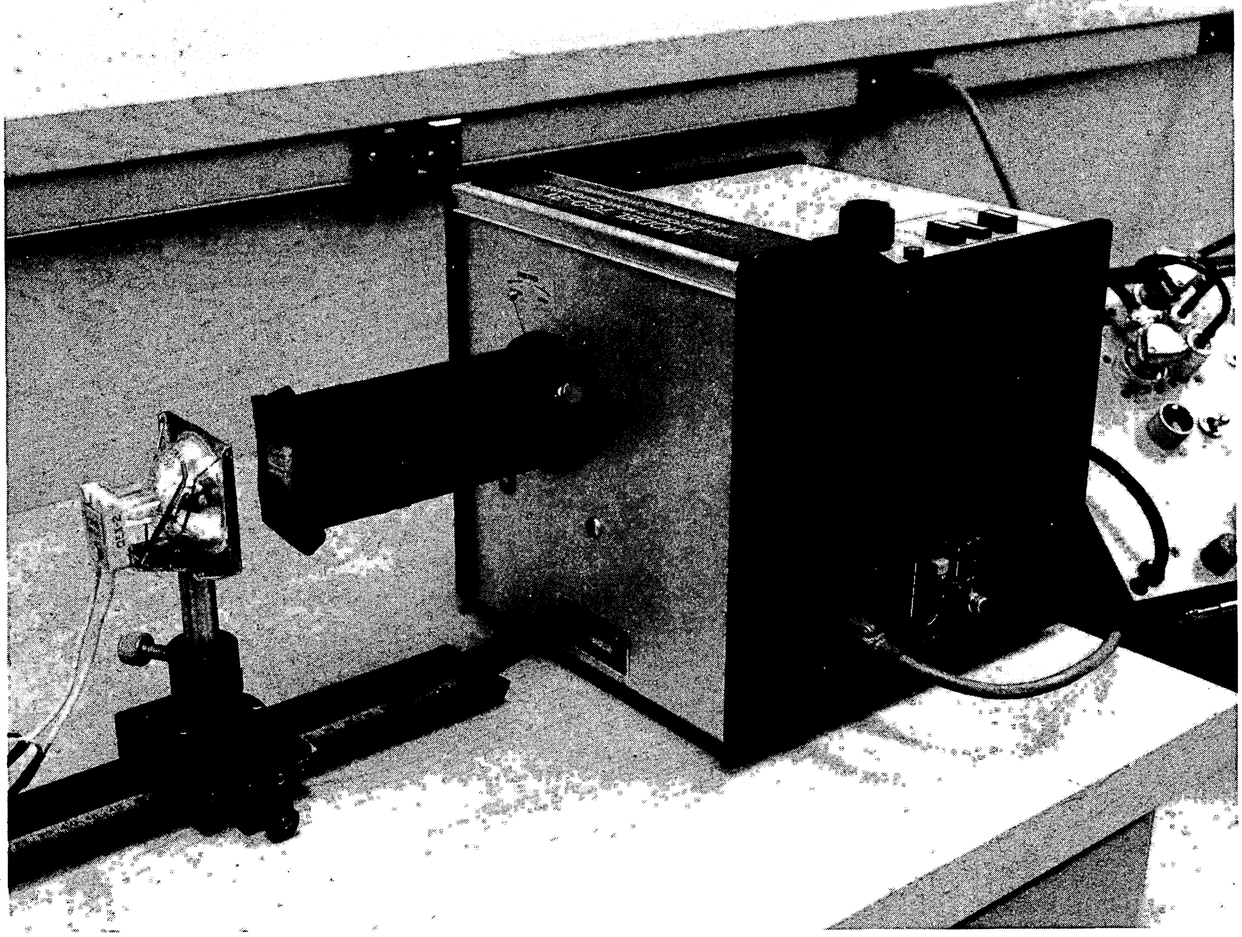

Figure 1.—*Monochromator used to measure the spectral transmittance of the chips.*

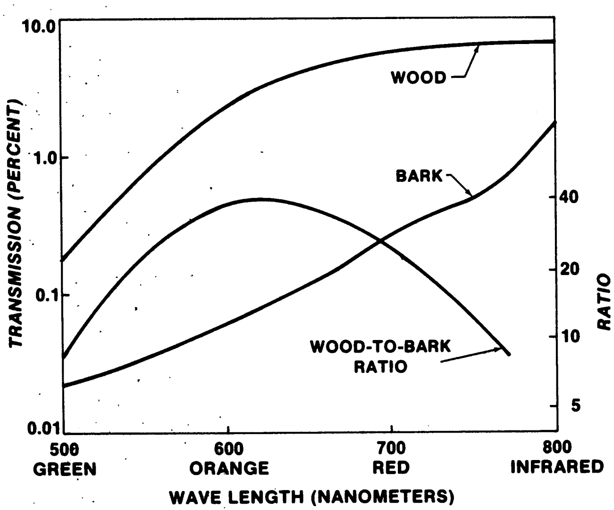

Figure 2.—*Average spectral transmittance of aspen chips.*

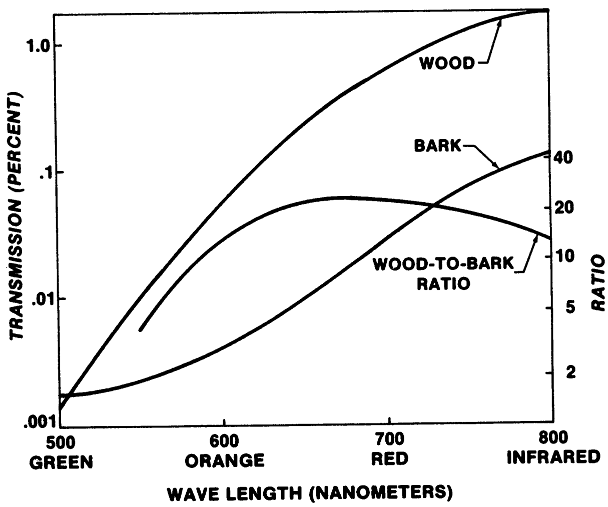

Figure 3.—*Average spectral transmittance of maple chips.*

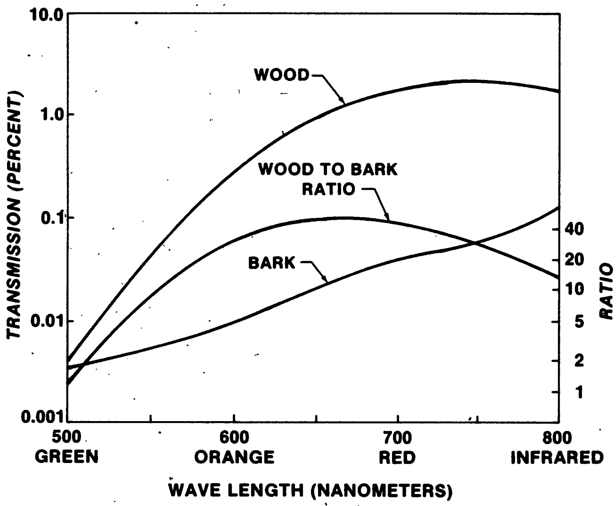

Figure 4.—*Average spectral transmittance of loblolly pine chips.*

curves (figs. 2, 3, and 4). These curves are useful in determining the optimum spectral region for differentiating between bark and wood chips. The same or greater differences were also obtained between the wood and bark chips of sweet gum and hickory.

The wood-to-bark ratio curves for the species measured have all peaked within the interval 600 to 700 nm. This indicates that the most reliable segregation of chips would occur when the response peak of the source-detector system also lies in the 600- to 700-nm region. While a PMT was used to gather basic data on the chip spectral characteristics, the actual sorting system uses silicon phototransistors to detect the light transmitted through the chips from the incandescent source. The silicon detector spectral response curve peaks at 800 nm with the 50 percent relative response points being located at 500 and 1,000 nm.

The spectrum of a typical incandescent lamp is very broad compared with the silicon detectors, peaking in the neighborhood of 1,000 nm. The overall spectral response is thus determined primarily by the silicon detectors if no auxiliary filters are used. Spectral optimization with filters has not been attempted as the slight discrimination improvement would be more than offset by the corresponding light level increases that would be needed.

EXPERIMENTAL PHOTOSORTER

As implied by the graphical data in figures 2, 3, and 4, bark and wood chips from some species can be readily differentiated from one another on the basis of their optical transmittance. A block diagram of the system used to sort the chips is shown in figure 5. The chips are fed by a conveyor over a linear array of optical detectors (silicon phototransistors). Light from an incandescent source is incident on the chips from above. The light intensity is adjusted such that most wood chips transmit sufficient light to be sensed by the detector array; thus the detectors "see through" the wood chips. When a bark chip passes over the detectors, however, the transmitted light falls below a preset detection threshold and the detector photocurrent decreases. The resulting signal is amplified to energize an air valve, deflecting the bark chip with a blast of air.

The mechanical arrangement used is shown in figure 6. An incandescent quartz-halogen slide projector lamp (type ELB, 30V, 80W) is used as a light source. It is focused into a line image aligned with the detector array by a cylindrical lens. The detector array consists of silicon phototransistors spaced on 0.1-inch centers (Fairchild FPA 700A) in a molded opaque epoxy module with clear windows. Each detector module contains nine separate phototransistors.

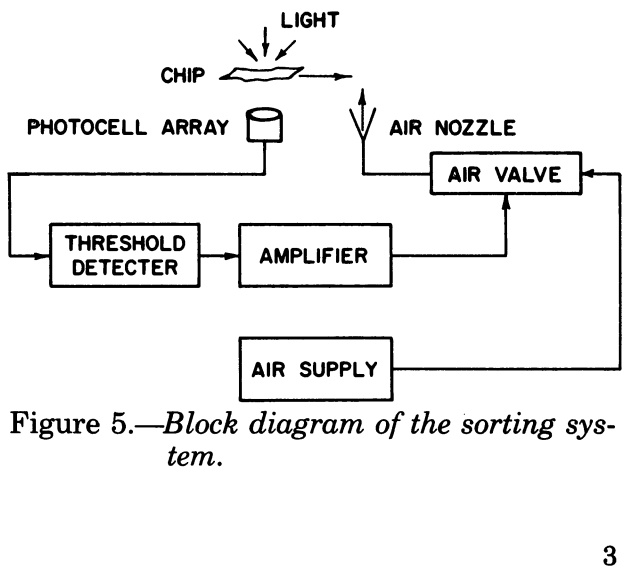

Figure 5.—*Block diagram of the sorting system.*

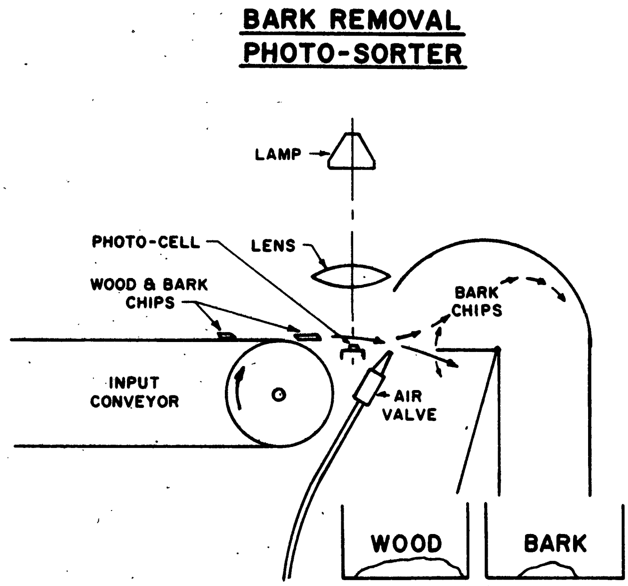

Figure 6.—*Mechanical configuration of the sorting system.*

The location of both the sensor array and the air valve nozzles must be carefully considered. The optimum sensor location is determined with respect to the free-flight trajectories of the chips as they leave the end of the conveyor. If the detectors are too low, small bark chips will not be reliably detected because of the excessive light passing around the chips and striking the detectors. On the other hand, it is undesirable to have the chips actually slide aross the windows of the detectors as the windows can erode rapidly under such conditions. Therefore, the detectors should be as close to the chip trajectory as possible without actually touching the chips.

The conveyor belt speed and the mechanical and inductive delay in the valve must be taken into account in selecting the optimum air nozzle location. A brief air pulse caused by a small bark chip must intercept the chip as it continues along its free-flight path. For a belt speed of 400 feet per minute (12.5 milliseconds per inch) and a valve turn-on delay of about 6 milliseconds, the optimum location for the nozzles is about 0.5 inch from the sensors.

The pilot system contains a detector array 9.9 inches long consisting of eleven detector modules (fig. 7). Each module has a separate threshold detector, amplifier, and air valve associated with it. Each air nozzle is aligned

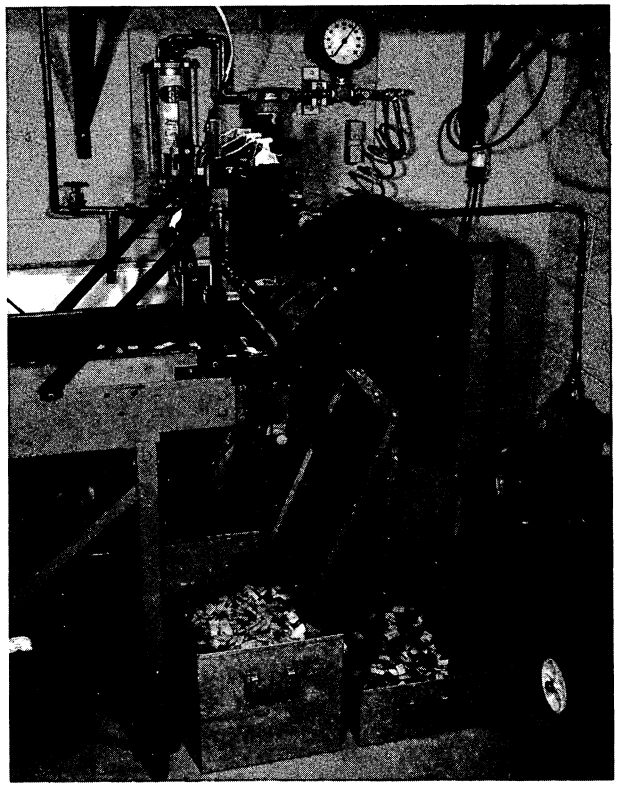

Figure 7.—*Pilot model of photosorter system. The electronic portions of the system are not shown.*

with the center of its corresponding detector module. The circuit is designed such that the air in a given nozzle is turned on if the illumination level on any one (or more) of the detector cells in the corresponding module falls below a preset threshold value. The detectors are illuminated in the pilot system by three lamp/lens pairs.

The detectors within each module are matched for sensitivity; the variation from one module to another is much larger and must be compensated for, however. Compensation is also required for variations in the brightness of the light incident on the phototransistors. Good matching of the sensitivity across the entire detector array is achieved by initially adjusting the detection threshold of each channel separately. The equivalent detection threshold level of the entire system can then be scaled up or down by varying the intensity of the lamps (by changing the filament current). This permits optimizing the system for different species without separately adjusting each channel again.

RESULTS AND DISCUSSION

Preliminary results for ⅝-inch aspen chips were obtained by passing the chips over the photosorter, giving "accept" and "reject" fractions (table 1). Included are results for four different light levels that ranged from 2.5 to 5.5 milliwatts per square centimeter. The results indicate that a compromise has to be made between wood recovery and the bark content of the accepts. At the lowest light level the accepts had a bark content of 1.4 percent and contained 70 percent of the wood, whereas the highest light level gave 5.1 percent bark in the accepts and 96 percent wood recovery.

In a production process the photosorting would be a first stage "scalping" or presorting process where the accepts obtained are suitable for pulping and the rejects would be beneficiated further. Using the results obtained at the 2.5 milliwatts per square centimeter light level (table 1), 63 percent of the input material would be recovered as clean fiber and 37 percent would be conveyed to another process such as compression debarking. The accepts and rejects from each chip size fraction (possibly two or three fractions) would be combined to form one accept and one reject fractions. Instead of processing the photosorter rejects by a second method, an alternative would be to recover 60 to 80 percent of the material as clean chips and use the rejects for fuel.

Table 1—*Effect of light level on photosorting ⅝-inch aspen wood and bark chips*[1]

(In percent)

Product	Bark content	Portion of total chips	Portion of total wood	Portion of total bark
LIGHT LEVEL[2]-2.5 mW/cm²				
Input	10.6	100	100	100
Accepts	1.4	63	70	8
Rejects	26.2	37	30	92
LIGHT LEVEL—3.3 mW/cm²				
Input	9.3	100	100	100
Accepts	2.3	79	86	19
Rejects	36.7	21	14	81
LIGHT LEVEL—4.3 mW/cm²				
Input	8.9	100	100	100
Accepts	3.3	88	93	32
Rejects	48.5	12	7	68
LIGHT LEVEL—5.5 mW/cm²				
Input	9.7	100	100	100
Accepts	5.1	91	96	48
Rejects	56.4	9	4	52

[1]Chips passed through a 1⅛-inch perforated screen and were retained on a ⅝-inch screen. Moisture content of the chips ranged from 49.4 to 50.8 percent (wet basis). The sorting was conducted at a feed rate of 1 ton/hour/foot of belt width.

[2]The light level was measured with a United Detector Technology Model 40X optometer through a 0.252-cm (0.099-inch) diameter aperture. This instrument uses a silicon detector that does not respond to wavelengths longer than 1 μm. Since incandescent lamps produce a substantial quantity of infrared radiation (with a wavelength $>1 \mu$m.), the true total irradiance levels would be somewhat higher than the values given above.

The photosorting technique can also be used as a quality-control system to monitor the relative bark content of a chip mixture. The manual sampling and counting process presently used could be eliminated, and more frequent sampling of the chip mixture would be feasible. Such an application would entail optically counting the total number of chips as well as the number of bark chips. Increased sorting accuracy could be achieved in a quality-control system because more time could be allocated for measuring each chip than could be tolerated in a production-oriented sorting system. Utilizing a microprocessor to perform the required logical and arithmetical operations would then be possible; this would permit a direct readout of the bark chip percentage.

SUMMARY

The average optical densities for bark and wood chips for some species are sufficiently different to permit segregating the chips on this basis. The peak wood-to-bark transmission ratio is typically in the range from 10 to 50.

Preliminary segregation results indicate that 70 to 80 percent of the wood fiber can be recovered with less than 2 percent bark content. The segregation threshold is continuously variable and can be readily altered to accommodate different species or use requirements. The optical and electronic components are readily adaptable to a variety of desired system sizes, configurations, and feed mechanisms.

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