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Papermaking Properties of *Eucalyptus* Trees, Woods, and Pulp Fibers

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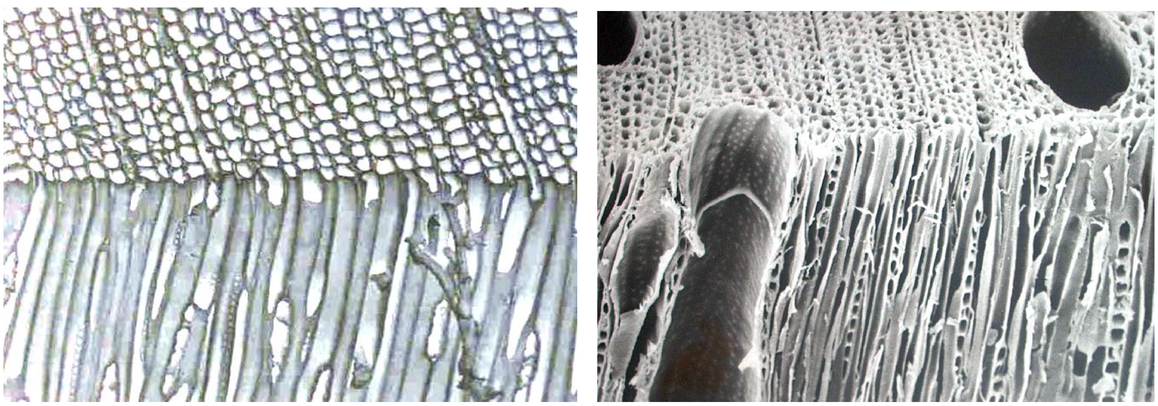
INTRODUCTION



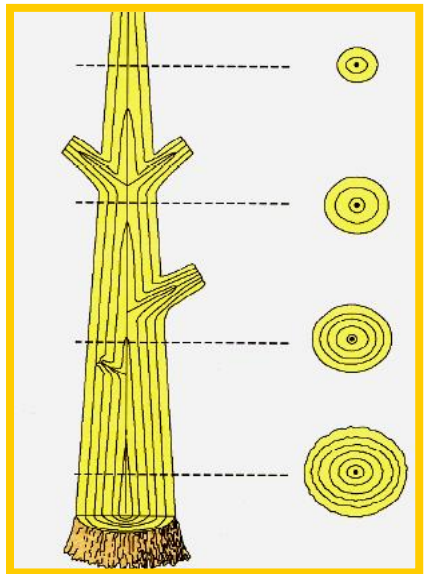
Softwoods and hardwoods: the main fibrous raw materials for pulp and paper manufacturing

Almost all pulp for paper manufacturing is worldwide based on the use of woods from different types and species of trees. They are distinct and varied plant species offering their fibers to add competitiveness and vitality to this industry. In the Northern hemisphere, a large part of the wood used by the pulp & papermaking industry originates from natural softwood forests (narrow acicular leaves on the trees and long fibers in the wood). As biodiversity in those forests is low, the number of woody tree species is relatively small. In spite of that, the offer of wood is somewhat non-uniform in its dimensions, ages and aspects. As a matter of fact, in technological terms, this non-uniform mix of wood supplied to the mills shows a significant variability, despite the anatomical simplicity of softwoods. This happens because in those natural forests there are several tree species growing together, including trees of broad-leaved/leafy species (broad leaves on the trees and short fibers in the wood). Another factor adding further variability is the presence of trees with different ages. In spite of the effort to harvest separately softwood and hardwood trees, there always occurs some "contamination" of one kind of wood into the other one. In general, the predominant kind of wood is harvested first, followed by the other type. Both types (softwood and hardwood) may be oriented to feed pulp mill digesters. Other times, thicker logs are forwarded to the sawmills, while thinner ones are reserved for the pulp and paper mills. There will be always some type of contamination in the harvested wood, this is inevitable under these conditions of varied species. For this reason, long fiber pulps of many producers of the Northern hemisphere contain some percentage of hardwood short fibers, and vice versa. This is a fact accepted and understood by the markets.

Another very important additional source of the variability of wood supplies in those regions is the fact that the mills also consume residual wood from other wood industries: sawmills, veneer factories, panel and plywood manufacturers, etc. The leftover wood, such as log slabs, central cylinders from the veneering process, little panel stubs, etc., end up being converted into chips in the place of generation and sold to pulp mills. For all these reasons, in its places of birth, or origin, the pulp and paper sector has coexisted with high variability in terms of fibrous raw materials.

In addition, and to complicate matters further, wood itself is a non-uniform natural material within the same tree and among the trees of the same forest. The fact that the cambium (or lateral meristem) of the trees, which forms the xylem (wood), is capable of improving the quality of the anatomical elements it creates, as the tree grows older and older, is very well-known. As time passes by and the tree ages, in the same position of the tree with regard to its height the cambium forms longer and thicker walled anatomical elements. This is the general rule for almost all trees.

Another important factor, often forgotten by users of wood, is that the same tree contains differently aged tissues. Are you surprised? At the same point being considered in the tree along its height, there are wood sections of different physiological ages. The wood itself, formed by the cambium in the last growing season, is not even one-year old. The trees grow in height and diameter throughout their lives, do you agree? The only section of these trees containing the wood formed from the seedling time up to their present age is the base of the tree. For this reason, the tree-top is the youngest section of any tree, while the base is the oldest one.



Each different tree height corresponds to different physiological ages

With regard to this fact, my career records an interesting experience at the time we were used to provide consulting services to companies through the Technology Unit of Riocell S/A. A client of ours requested us to visit them, as they had a big problem. They were using *Pinus taeda* wood to manufacture unbleached kraft pulp and brown packaging paper. The traditional management of *Pinus* planted forests at that company was based on clear cutting and wood harvesting, when the trees were a little less than 14 years of age. An intermediate thinning was also done at the age of 8, and that juvenile wood was used as energetic biomass. When the forest managers decided to adopt the multi-purpose tree management with more thinnings, harvesting the older trees to sell the thicker logs from the tree base to the sawmills of that region, both the pulp and the paper mills noticed at once the difference in quality and performance of their products and their raw materials. The wood they began to receive had lower basic density; the fibers were shorter and younger, and were also thinner walled. The question they posed us was as follows: "we began to receive wood from almost 20-year-old plantation forests and the quality worsened a lot!!!" It was easy to demonstrate to them that those receiving wood from tree regions with almost 20-year physiological age were actually the sawmills. They began to receive thin logs and juvenile tree-tops, possibly of physiological ages under 12 years. The solution found and recommended was to purchase from the sawmills the chips produced there from the log slabs (lateral sections of the outermost part of the logs). That outer-region of the logs (in relation to log diameter) is the most recently formed one by the (most mature) cambium of the tree, having in general longer and thicker walled fibers, and higher basic density. This procedure would compensate the losses in wood quality they were experiencing.

Besides the variability inside the same tree, there also exists the variability among the trees of the same forest, even if they are equally aged i.e. were planted at the same time, and genetically similar (seeds or clones). Such a variability is due to genetic factors (forests based on seedlings from seeds) and to environmental factors (soil, climate, pests, diseases, declivity, hydrological deficit, sun-shining, etc.). In natural forests the variability is still higher than at plantations, as there are trees that although belonging to the same species, are rather differently aged and have rather different genetic bases. In single-species planted forests, variability tends to be lower, but it also exists and it is not to be discarded.

With the advent of the clonal silviculture, the belief of many forest tree breeders was that the trees would be exact copies from each other in terms of their wood qualities. After all, so they dreamed, all trees concerned had the same genotype; therefore, the phenotypic expression in the wood should be similar. They believed it so much, that the wood sampling for quality evaluations was done based on the material collection from an only average tree of the clonal forest stand. A very great candour and ingenuity of them, soon clarified by tests showing the high variability existing among the trees, even if the forest is a clonal plantation.

Taking account of all these initial considerations, it is most certainly possible to state that pulp production is based on a non-uniform raw material. This non-uniformity in terms of basic density, porosity, permeability, chemical composition, anatomical element dimensions, etc., must be well-known, understood and absorbed by the pulp and paper producers and by their industrial processes. Even the pulps produced and known as "single species pulps", or else as "cloned tree pulps", are produced from woods with properties presenting significant variability.

Besides the natural variability of the wood, which we will discuss in more detail in specific chapters of our **Eucalyptus Online Book**, there are numerous additional sources adding variability to the woods and pulp production processes:

- Chip contamination with tree bark;
- Wood contamination with knot-wood;
- Irregular dimensions of wood chips in their different fractions;
- Defective woods, such as: decayed, from sick trees, from trees having endured a forest fire, etc.
- Etc.

A more inattentive person looking at a stack of chips of a pulp mill gets the impression that this raw material is perhaps uniform and bulky material. It is something like observing a "heap of sand". Now, it should be born in mind that chips present significant variation in the quality of their woods.

They have different wood qualities, present distinct dimensions, and even if they are screened and improved, they are an additional source of variability in the impregnation and kraft cooking processes of the wood.

The pulp industry has had badly managed this problem of high variability of the wood as raw material for many years. Some mills try to control variability by carrying out a previous evaluation of the quality of their forests prior to forest harvesting. Other ones try to coexist with such a variability by developing "magic wood mix recipes". They try to dose their woods in more or less known and constant mixtures, so as to make digester feeding uniform. A vast majority of companies have wood supply difficulties and must use the wood they have available, sometimes from geographically distant sources.

Wood: a fibrous raw material variable in its qualities

Another interesting observation can be made about pulp mills is that it was not until more recently that the log storage and chip preparation areas endured more significant technological advances. Also, it was only in the last decade that pulp mills began to pay more attention to and invest more in these areas. In the past, the wood storage area had just the mission to keep wood in order to prevent the process from falling short of it. The chipping area had the function of fragmenting wood into small pieces, screening them to separate sawdust, wood slivers, and knots. It was just that and nothing more than that. At that time, wood losses were enormous, easily reaching values equal to or even higher than 5%, among wood slivers, stubs, wood dust, over-thicked chips, etc. Since then, this situation evolved very much, after all pulp manufacturing starts from good wood and good quality chips, which are selected, screened, and managed for successful production and product quality. Therefore, at present times, there is more developed technology and better management in the areas of wood preparation for the manufacturing process. As an additional advantage, as many mills developed biomass fuel based energy generation, defective chips and woods can supply power boilers instead of digesters.

Eucalyptus: forest and industrial success for pulp and paper production

Another technological change that took a long time to happen, having finally appeared a few years ago, was the introduction of a real chip pre-impregnation vessel in the modern digester designs. As a result of it, the different wood qualities present in the chips can be, at least, decently impregnated by the cooking liquor before temperatures above the delignification point are reached. A great technological success, having allowed gains in quality and yields in kraft pulp manufacturing.

In spite of all these evolutions and technological changes, the basic fact remains unchanged: "<u>the wood entering the digester, regardless of which digester and in which forest it was produced, is variable in quality</u>". This variability is the sum of the natural variability of the wood and of the variability added by man in the management of the supply and the wood conversion itself.

In short, we have:

<u>Natural wood variability</u>:

- Differences in quality inside the tree itself and among the trees of the forest;
- Presence of defective woods attacked by pests or diseases;

- Presence of knots or residual parts of branches joining the bodies of the trees;
- Presence of bark attached to the logs;
- Etc.

<u>Variability caused by man</u>:

- Management of the wood blend (mixture of species, clones, forest ages, chips from sawmill residues, etc.);
- Wood storage management (moisture, decaying, deterioration, etc.);
- Chip production and screening;
- Etc.

When the market pulp consuming industry began to purchase pulp obtained from planted forest woods to manufacture paper, it noted that variability was substantially lower. The papermakers were enchanted with the opportunity to have more uniform pulp, with lower ranges of variation with regard to the most important properties and characteristics of these pulp fibers.

The same kind of expectation occurred among the pulp manufacturers. They began to believe that life would be much easier when having as raw material the woods originating from single species or single clone plantation forests. Soon, within a short time, these expectations decreased. It is obvious that variability is lower when consuming woods from clones or woods originating from a single species at the same forest harvesting. However, the dreams of having highly uniform woods, and consequently, the same situation for the pulp fibers, are far from becoming a reality. It is even possible that they will never materialize, because "*wood is wood*". Woods are formed by living beings and mostly consist of the bodies of these living beings. They have different types of anatomical elements formed in different ambience and physiology situations. Then, this variability, its causes and its consequences, must be well-understood and its minimization striven for.

Since we are speaking of variability, it should be mentioned that another serious problem which the sector coexists with is that it got used to work with measurements of mean values (averages) and is little concerned about the size of the variation range. I will give you in the following some examples of what I am speaking about:

Example 01: Basic density of wood

Control procedures are always based on the mean values of the basic densities of the woods from trees, forests, and chips. For example, if the basic density of five samples of chips collected from a rather non-uniform chip stack (mixtures of chips of different species) is determined, it is quite possible that the values obtained are close. For instance, between 0.48 and 0.52 g/cm³.

Let's suppose that the individual values of each sample have been:
Sample 01: 0.51 g/cm³
Sample 02: 0.49 g/cm³
Sample 03: 0.52 g/cm³
Sample 04: 0.50 g/cm³
Sample 05: 0.48 g/cm³

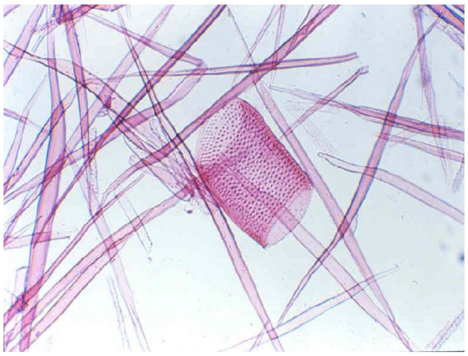
The mean value would be 0.50 g/cm³. The laboratory reports that the average basic density of the wood chips was 0.50 g/cm³ and that variation in this density ranged from 0.48 to 0.52 g/cm³. However, if we determine the basic density of each little wood chip collected on these 5 samples, we will obtain values that quite possibly will range from 0.40 to 0.60 g/cm³. Based thereupon, it should be considered that we do not succeed in perceiving the limits of our variability, we just concentrate ourselves on mean values of this population and on the variation in average values.

Example 02: Fiber coarseness

Nowadays, fiber coarseness is one of the most measured fiber characteristics. Its mean values range from 5 to 11 mg/100 meters for the *Eucalyptus* pulps. All will depend on the *Eucalyptus* species, on the age of the trees, on the improved cloned, etc. The same mill, when using a controlled wood mix, almost always ends up obtaining similar coarseness values, for instance between 6.5 and 7 mg/100m. Once more, we are just considering the mean value of the population. There are very thick-walled fibers mixed with flexible thin-walled ones. There are also longer fibers, twice as long as other ones. And we do not know these proportions and ranges of variability.

Example 03: Resistance properties of the pulp sheets

The laboratories use to collect composite pulp samples during the day (or the week), in order to mix them and run refining and resistance/physical tests of sheets produced in the laboratory itself. It is obvious that almost all refining results will lead to similar values. The spot variations in quality that occur end up being concealed by the way of mixing all samples collected and working with those so-called "composite samples". When reporting an average value for pulp handsheet tensile strength, for instance, they are just providing us an estimate for this pulp test, but they will not inform anything about the variability among the distinct lots of pulp.

For these and other reasons as well, papermakers always tend to "complain" about the consumed pulps. They do not know their properties and the causes of their variation. They have little visibility of their raw materials. In this respect, pulp manufacturers use to behave in the same way as papermakers: they are always fearful of the woods which are to enter the process, even if the average quality parameters do not indicate any difficulties.

For example, the fact that a new clone entering the industrial process causes enormous unbalance in the operation has been frequently mentioned at *Eucalyptus* pulp mills. This is common even if the new clone presents lignin values in the wood and basic density similar to those of the clone being replaced by. We will speak further about this matter in another section of this chapter.

We know that in Nature, as well as in our operations, we will never come across wood and pulp situations like those described in the following:

- Extractive-free;
- Ash-free;
- Lignin-free;
- Contaminant-free;
- Ranges of variation equal to zero for the quality characteristics.

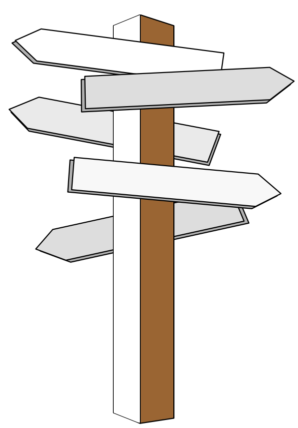
Therefore, we have to learn to get along with variability, to understand it better and to try to know the extremes of this variation, not only the mean values and the means of the averages. Extreme values are those affording us differentiation in the trees, woods and in our products, as it will be seen further ahead in this chapter. They can also explain better our process and operational difficulties.

The concept of minimum values is also put very much into practice by the sector, thereby guaranteeing a comfortable minimum, but there is no concern about knowing the amplitude above that minimum. Some examples are even pathetic, as below:

- Minimum pulp brightness of 87% ISO – Well, I wonder whether the customer will be happy to receive pulps in bales at 87% and other ones at 92%. I wonder whether this variation will not result in papers with different shades, and complaints on the market.
- Minimum basic density of 0.50 g/cm³ in the wood - Well, I wonder whether the chipper and digester operators will not notice any differences when receiving wood with basic densities of 0.50 and 0.58 g/cm³.

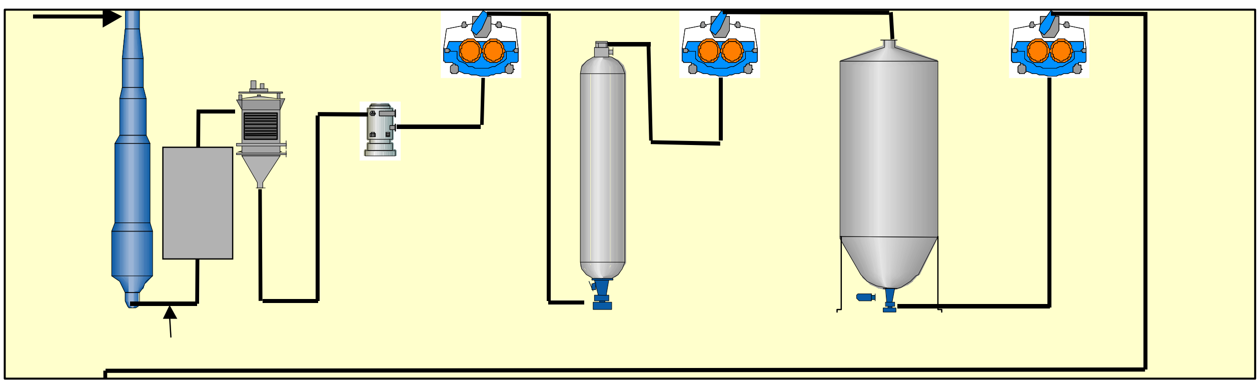
As a function of all these arguments provided here up to now, it becomes easy to understand some well-known phenomena in the sector, such as:

Phenomenon 01: "<u>Different companies present different wood or pulp quality specifications to manufacture the same final product</u>"



Qualities and qualities: what characterizes that considered to be "ideal" ?

The companies specify the raw material quality as a function of the performance they get at their machines, as well as of the end product quality. As each company has its peculiarities within its industrial design (in its chippers, digesters, washers, bleaching line, liquor evaporation and recovery systems, refiners, paper web drying machine, etc.), the production bottlenecks (or restrictions) will be the factors that will dictate the raw material specifications. For example, if the paper mill has low drying capacity (web drying dimensioning and steam availability), the specification will be for pulps with excellent drainage capacity on the wet-end and dewatering at the presses. It will not tolerate any pulps requiring much refining to attain the specified strengths, as thus it will lose runnability. This means to lose productivity, to reduce machine speeds, etc. If that mill purchases pulp on the market, it will want pulps with lower fibrous population, higher coarseness, and higher hemicellulose content. If it is an integrated mill, it will probably prefer denser woods (denser wood species or clones, or older forest harvesting age). It will also prefer woods with higher hemicellulose contents (pentosan, for instance), for reaching faster the pulp strengths development in refining. In its industrial process, it should endeavor not to generate further rejects in cooking and not to remove too much the hemicelluloses in cooking, in oxygen delignification, and in the alkaline bleaching stages.



Pulp production: continuous technological evolutions are favoring or putting pressure on wood quality

A pulp or paper mill often carries out an important upgrade in its industrial process, so that a previous bottleneck or restriction ceases to exist. At that moment it ends up modifying its raw material specifications, as a certain previously limiting factor ceases to be so. When this occurs and is communicated to the wood supplier (forest area) or the market pulp one (pulp supplier), their reaction is not always positive. These supplying areas, which worked for many years developing a special wood or pulp for that customer, perceive that all of a sudden everything changed. The process changed and the raw material specifications changed accordingly. The tendency is to complain very much, to say that the customer is volatile, he does not know what he actually wants, and so on. It is only a tuned and sound dialog between suppliers and customers that will allow confidence and trust between the two parties, as well as suitable productive chain optimizations.

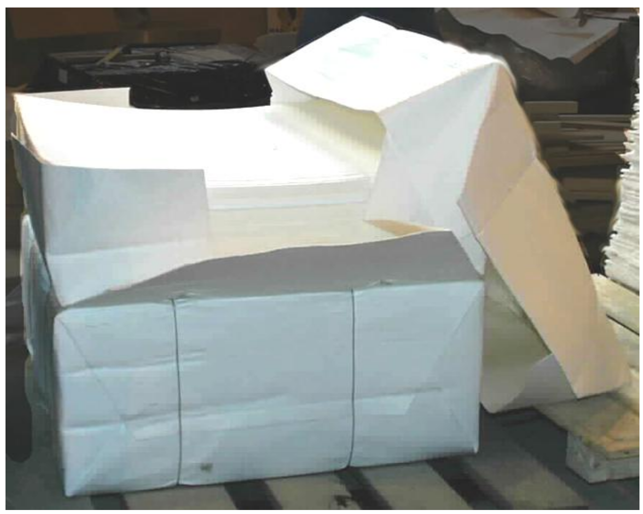
In other cases – and such a situation is even comic (or sad) –, technological changes made for mill upgrading eliminate the bottlenecks and restrictions dictating the raw material specifications, but the technicians do not even notice it. They go on demanding the old obsolete specifications, sometimes involving much suffering and high costs to be met. It is common to have specifications like: low content of extractives in the wood, "light-colored" wood (without the presence of mature heartwood). At present, as a result of oxygen delignification stages in two reactors, more efficient pulp washing, use of surfactants, etc., this extractives-related problems are largely minimized. Then, why go on limiting certain woods to the process, when this is unnecessary?

In other cases, wood specifications are also defined by the wood chipping area, with its obsolete chippers and classification screens. For example, logs with 35 cm as maximum diameter and basic density lower than 0.50 g/cm³ may become required as a function of their obsolescence. When the chipping line undergoes a technological upgrade, these specifications may lose their validity, or become other more flexible ones. However, in case of changing the log chipping specifications, your chip customer at the mill fiberline sector will notice the change. The paper manufacturing area may be also impacted. This situation will require once more the parties involved to enter into continued dialogs, and constant technical arguments to be provided for better decision-making process.

Wood chip piles: the hidden-face of the wood variability

For all these reasons, do not be surprised at the contradictions about the "optimum qualities" of woods or pulp fibers. They end up being unique and specific to each situation. Definitely, there is not such thing as a universal *Eucalyptus* wood or pulp quality. The corresponding specifications vary as a function of paper grade, pulp or paper production technologies, and the way the operational and technological management of the company in question is put into practice. Therefore, there is variability even as far as these aspects are concerned: in terms of management, machines, and ideas.

Phenomenon 02: "Different commercial *Eucalyptus* pulps present distinct papermaking performances"



Market pulp: commercial success of the *Eucalypti*

Close and intimate relationship between market pulp consumers and producers should be very common. The purchaser always looks for the pulp offering him better production performance: fewer breaks, higher machine speed, higher productivity, better drainage, better dewatering, lower steam consumption in the drying process, lower chemical consumption, lower costs, etc., and allowing him to obtain the desired paper qualities. Evidently, there is another series of properties that he considers to be a supplier's obligation to provide: brightness, brightness stability, cleanliness, etc., while there are some other properties he is not even interested to know, because they are neither among his concerns, nor cause him any nightmares.

In most cases the pulp supplier does not understand this. He does not know much about his customers' technologies and tries to sell the pulp only based on laboratory analysis certificates. Most of those certificates are based on average data of some analyses, almost all of them peripheral for the user. These low-interest-to-the-user properties lack as well on amplitude values. Most are meaningful, don't add value to the buyer or user.

It is clear to me that there should be a change in the market pulp suppliers' technical and commercial attitude. We are by no means expecting the market pulp supplier to go to the customer's company, to teach him how to use the sold pulp best. It would be a great audacity and a great prepotency to wish changing the customer, asking for him to adapt to the pulp being offered. In the areas of chemical product supply, the suppliers have already learned to improve this relationship. Any supplier of antifoam agents, anti-pitch chemicals, mineral fillers, etc., uses to assign an experienced technician to the customer's company, to follow the performance of its products, in order to help optimize it. Such a technician uses to know very well the products he sells and knows how to adapt them to the customers' conditions for optimum performance. His role assumes paramount importance in this technical/commercial relationship.

However, on the market pulp supplier side, it is more difficult for acting in this way. The area is short of qualified and versatile technicians, the geographic distance uses to be a key-issue, and often the papermaker "does not want to disclose his game with regard to his magic recipes". As a function of all these problems, low interaction, little dialog, and only sporadic visits to some sort of happy hour end up occurring. It is a pity and a waste!

In an attempt to improve this relationship, I suggest to all market pulp producers offering technical services to their papermaking customers to try to obtain from them the answers to the following four questions:

- What is the main attribute intended for the paper where the *Eucalyptus* pulp is being used?
- For which reason does the customer use *Eucalyptus* pulp?
- What are the main attributes that this specific market presents? Are these attributes similar to those of competitors' pulps? Which are better or worse? Why?
- What are the operational bottlenecks in the manufacturing process of this papermaker who is purchasing the pulp in question? What is causing him trouble? How these troubles may impact the pulp specifications?

Starting from these answers, it becomes much easier to offer the customer a technical service having much more quality, don't you think so? Are you already doing it? Had you ever thought about it?

To avoid surprises, it is very common for each user of market pulp to have a preference for the pulp from a certain supplier. Much confidence and quick and effective communication must permeate this technical and commercial intimacy. In case this does not occur, at any more drastic change in wood as raw material used at the pulp mill the impacts on the pulp customers may be significant. Each more significant change to occur in the technologies or raw materials should be negotiated, explained, and agreed upon with the pulp consumers. For example, a change in the bleaching sequence may seriously affect the market pulp performance. If the pulp customer is not duly prepared and enlightened, he may disapprove the "new quality", even if we believed that it would be better for the customer. Many pulp suppliers do not understand this. They think that this is an undesirable interference by the part of the customers in their productive processes and their fibrous raw materials. Therefore, it is of paramount importance that not only the pulp supplier assigns experienced technicians to help optimize paper manufacturing, but also the papermaking customer send own technicians to the pulp mill and the forests, to understand the interrelations between the forest processes and the pulp and paper manufacturing ones.

At present, with the quality management system certifications, the suppliers' audits are common. Nevertheless, these audits are far from characterizing a customer/supplier interaction. They are documentary evaluations, of adherence to the ISO 9000 standards, of data reliability, and of observance of procedures, rather than anything else. As a matter of fact, there is no real objective to optimize the operations in the customer-supplier relationships.

Then, also here and once more, we come across another great truth: "<u>pulps produced by different fiberlines present specific peculiarities</u>". This may even occur inside a single mill possessing two digesters of different technological ages, or different bleaching sequences. These peculiarities are a result of the used woods and the technological characteristics of each fiberline. They may be more or less significant. This must be very well understood: the why's and the how's? Sometimes, it is due to a specific peculiarity, or some peculiarities, among other ones, that the pulps are preferred by the customer. Do we actually know which ones? Do we actually know the customers' limitations and the reasons why our pulps perform better or worse precisely because of these limitations?

Therefore, there is no universal *Eucalyptus* pulp performing well and uniformly for all papermakers and all paper grades. Paper mills are also peculiar and unique, each of them with its truths, myths, limitations, bottlenecks, beliefs, and preferences. All this fits into the expected tendency for mills designed and operated by human beings. Therefore, when *Eucalyptus* pulps are referred to as commodities, just the commercial side, the relationship between the prices being influenced by the supply-demand relationship is being referred to. If a certain pulp is differentiated and appreciated by some niche customers, it loses this commodity label, even though its price may also come to vary as a function of pulp availability on the markets, although at other levels.

As a matter of fact, the value network of paper is much wider than the forest, the pulp mill, and the paper one. We have thousands of users of paper, paper recyclers, those relying on other fibrous products, etc., etc. A huge productive network, so little studied as network and much more studied by focusing on each knob of this network.

It can be said that there are millions of studies on *Eucalyptus* trees, forests, and woods, many of them easy to locate at present by means of the searching tools on the Web. Millions of researches and bulletins about pulp and paper qualities and uses of these products can be also found. In the graphic area, in that of packaging, of hygienic products, etc., the same abundance of information can be observed. Now, with regard to interactions, dialog and optimizations, as far as this value network is concerned, there is still much to be done. This lack of interaction does not only occur among different companies, but even within the same company, between its various operational and technological areas.

In the present chapter of our **Eucalyptus Online Book** I have as target to navigate and discuss some critical points of this value network, showing which are the disagreements and the possibilities for integration, which are the opportunities for optimization and what must be clarified for the players of this network. I consider this chapter to be rather a kind of primer for everyone wanting to produce better trees, woods, paper grades, and pulps from planted *Eucalyptus* forests. It is my purpose to present several myths and to question some people's positions I have been finding in the sector with regard to the qualities of woods and pulp fibers for the paper industry. Therefore, it will not be plenty of science and techniques; on the contrary, I hope that it may have an enormous practical applicability. In other chapters, I will try to develop with more scientific details some of the topics addressed herein. My goal is to communicate to you a holistic vision of someone working in the sector for over 40 years and consequently having some experience in these subjects.

There is a long way to go, be it in wood, pulp, or paper production, be it in paper use and recycling. Different players are standing along this way, each of them with their interests, motivations, limitations, dreams, and vanities, why not? In spite of the effort of many technicians to try to increase this integration into the paper value network, the result till now is far from being ideal. I believe that when beginning to read this chapter, and already in this introductory part of it, you should have perceived that it is being written to help, to challenge, to show difficulties, to present what is more relevant, and also for you to be able to better perceive the opportunities. The mutual cooperation, the understanding of the limitations, the vision of opportunities, and the integrated effort may help improve our sector through a global optimization, instead of just a specific niche in the network.

The *Eucalyptus*-based pulp and paper industry grows at the same enrapturing rates as the trees of our planted *Eucalyptus* forests

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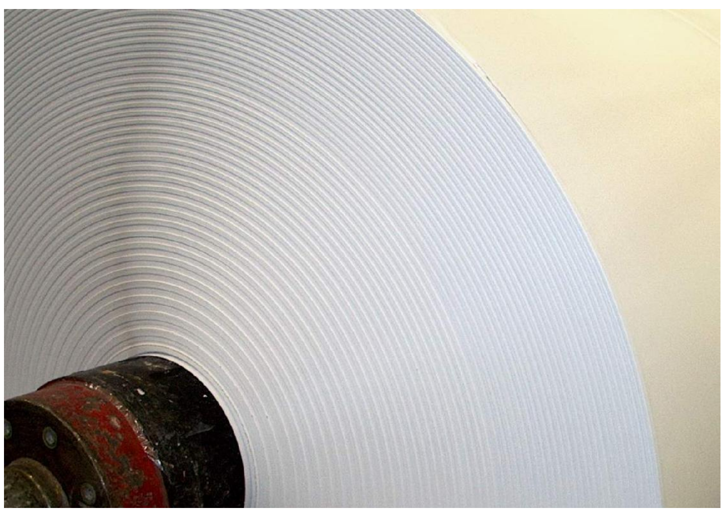
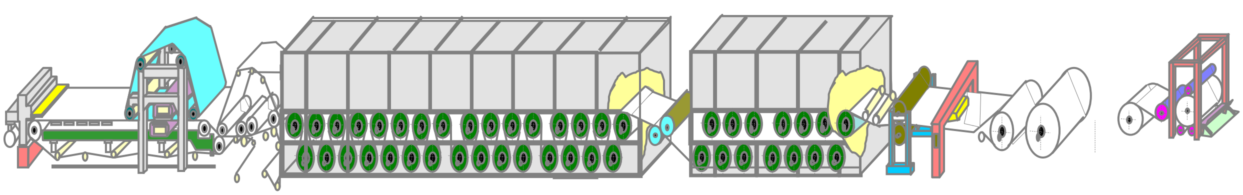
TECHNOLOGICAL CHARACTERISTICS OF THE PAPER GRADES PRODUCED WITH BLEACHED *EUCALYPTUS* KRAFT PULPS



I will begin to discuss the value network of *Eucalyptus* for white paper production starting from what is aimed at in the paper by using these pulp fibers. The papermaker, when choosing to use *Eucalyptus* fibers, has some objectives in his operations and for his products.

The first of these reasons, and maybe of paramount importance, is the lower price of the short *Eucalyptus* fibers, as compared to the long softwood fibers. This price relationship is perfectly understandable and justified. Much less wood is consumed to produce one ton of *Eucalyptus* pulp than one ton of softwood pulp. This is a function of the lower basic density and higher lignin content of softwood, as compared to those of *Eucalypti*. Secondly, the same kraft pulp mill, when operating its fiberline with *Eucalyptus* (at the unbleached pulp line), manages to be much more productive than if it operated with softwood. This means that when feeding the same volume of chips into the digester, much more pulp is produced when *Eucalyptus* chips are concerned, as compared to softwood chips. In further processes along the fiberline, such as bleaching, drying, etc., we will have to suit the mill dimensions to the *Eucalyptus* pulps, since more pulp will be discharged from the digester. A great advantage offered by the *Eucalypti* is that for the same capital expenditure on the brown line (and kraft liquor recovery line) much more unbleached pulp (25 to 40% more) is produced.

It is also important to mention that regardless of the paper grade being manufactured, all papermakers have what I use to call "basic physiological requirements". The latter are indeed similar for all papermakers, and also occur among pulp manufacturers. The main ones are as follows: productivity, operational efficiency, quality, and production costs. No matter which is the mill, the process, the geographic location - these physiological aspects are vital.



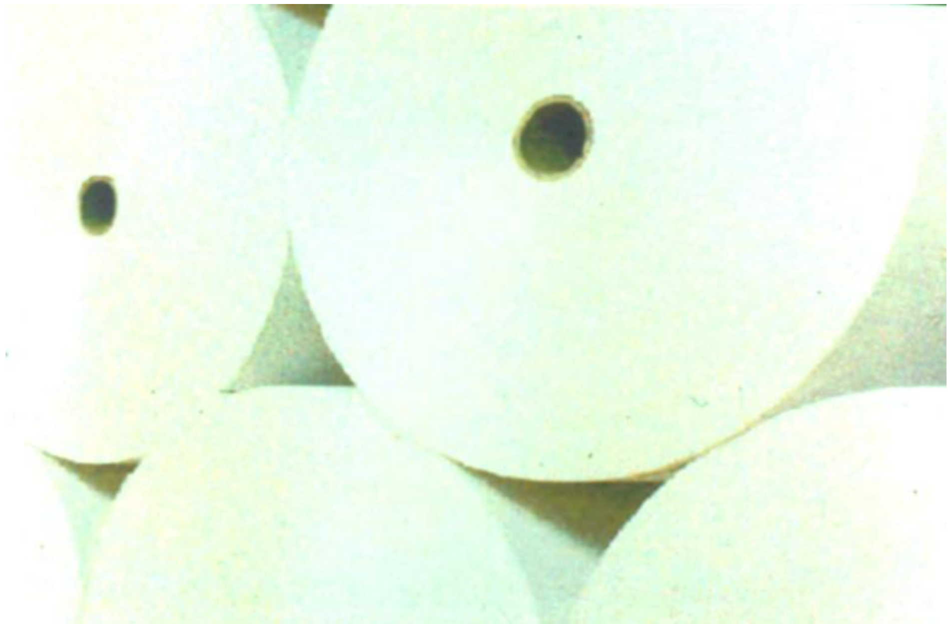
Drawing source: Carvalho, Pinto, Massaferro; 2004

As far as paper manufacturing is concerned - Productivity requires high speed on the papermachine, quick drainage on the wet-end, high consistency after the wet presses, minimum number of web breaks along the paper manufacturing process. Quality implies maximum percentage of paper meeting the specifications and minimum generation of broke. The optimum operational efficiency of the papermachine is the dream of any paper manufacturer. They dream about their machines working aligned, at maximum sustainable speed, without web breaks and succeeding in attaining the desired quality and required by their customers. The direct consequence of this is that all Specific Production Costs, both variable and fixed costs, will be optimized. Therefore, there is no doubt that the good pulp is the pulp which will afford this happiness to the papermaker, whose dreams of productivity, quality, efficiency, and costs are intimately connected with the pulp he is using.

Some properties of pulp are considerably connected with these operational performances. For this reason, the papermakers are always very attentive to them. Some of these properties are due to the wood quality, while other ones depend on the process of wood conversion into pulp (cooking, bleaching, drying), or on the interaction between wood and pulp manufacturing process. Following can be cited among them: viscosity, carbohydrate chain degrading, individual fiber strength, fiber bonding capacity, anionic groups in the fibers, hemicellulose content, content of fines, etc. Other vital characteristics depending very much on the fibers in the paper production process are as follows: WRV – Water Retention Value – and WWS – Wet Web Strength. Unfortunately, these characteristics are hardly controlled in paper manufacturing and seldom included in pulp fiber quality improvement programs. But they should be, and to a great extent.

Another vital pulp property which depends on both wood and industrial operations is the corresponding content of fines. Wood fines are preferentially parenchyma cells, but in the kraft pulps they also include: fiber fragments and vessel elements, fibrils, gels, etc. Many pulp and paper mill operations generate fines in the pulps: wood chipping, pumping, dynamic pulp stock mixture, pressing, refining, sheet cutting, etc., etc.

Knowing that pulp fibers have differentiated and often unique characteristics, it is important to know "for which reasons papermakers want to have *Eucalyptus* fibers in their magic recipes". *Eucalyptus* fibers are particularly appreciated for manufacturing some high-quality grades of tissue paper (sanitary, handkerchiefs, and facial towels), for writing and printing and coating base papers, and for some types of specialty papers (decorative, cigarette, for instance).



The most important and acknowledged qualities that *Eucalyptus* fibers offer to the paper quality are as follows:

"The eleven vital qualities of the papers manufactured with *Eucalyptus* fibers"

1. Paper sheet formation

The short *Eucalyptus* fibers form small flocks when in aqueous suspensions. This result in good paper formation, without the well-known clouds on the paper webs (poorly formed sheets), when they are looked at against a source of light. Deficient formation causes variations in paper sheet basis weight and caliper. This impairs subsequent operations, such as calendering, coating, printing, etc. When calendering a poorly formed paper, dark spots are formed on the paper, gloss is irregular, and often there appear transparent spots (due to fiber bundle wet pressing). Paper formation is one of their vital properties for some fine paper grades. *Eucalyptus* fibers are acknowledged as very favorable to this property.

2. Paper bulk

Bulk is the inverse property to sheet density. It is connected with the capacity of a certain paper to show higher or lower volume (or thickness) at a certain basis weight. Bulky paper sheets can be obtained by using the short and rigid *Eucalyptus* fibers, especially at the initial levels of pulp stock refining. This property is closely associated to paper porosity. It interferes with numerous characteristics of paper use.

A higher bulk makes it possible:

- To save pulp fibers, in order to manufacture papers of same caliper, thus reducing the basis weight;
- To produce thicker books for the same number of pages ("sale of encyclopedias by volume, not by contents");
- To produce tissue papers for facial or hygienic purposes, presenting high volume for the same paper weight or area. This transmits a remarkable sensation of material fluffiness to the user;
- To produce papers requiring high porosity, like those demanding ink or resin impregnation (decorative papers, industrial filters, cigarette paper, etc.).
- Etc.

However, a high bulk also presents some disadvantages. Bulky sheets present lower fiber bonding and may bring about sheets having slacker and weaker structures. Such structures have low surface strengths. Thus, fibers, fines, and vessel elements can escape from the paper network, when handling and using the paper. Hence, the need for better surface sizing of *Eucalyptus* printing papers. A way of mitigating this problem is to look for pulps offering high bulk values, but having a higher hemicellulose content.

3. Porosity / Air resistance

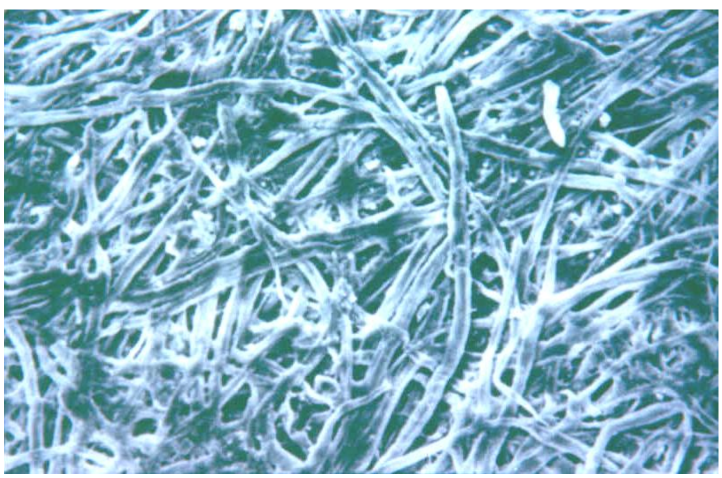
This is a property closely associated with paper bulk. It corresponds to the paper sheet ability to be crossed by an air flow. It should not be misunderstood as liquid permeability, which is another paper property. The slacker and loosened the paper structure, the higher its porosity, but at the same time the lower its fiber bonding and resistance. Porosity can be expressed by its inverse property, which is the air resistance. The higher the air resistance, the less porous the paper sheet. Then, the difficulty for the air to cross the paper sheet is measured as air resistance, not its easiness.

4. Liquid absorption by the paper web

Paper sheets produced with poorly refined *Eucalyptus* fibers present high capacity to quickly absorb and to retain water or inks by micro-capillarity. For this reason, *Eucalyptus* fibers are very much used to manufacture tissue and printing papers. The printing inks impregnate more easily the sheets. In case of decor papers, phenol or melamine resins also penetrate more easily into the paper body.

Now, it is important to tell you that there is a big difference between Klemm test of water absorption by the paper (capillary penetration into the sheet) and that of water retention by pulp fibers – WRV or Water Retention Value of the pulp – (adsorption and retention by the micro-capillarity and ionic groups). They indicate different things and cannot be confused, even because their results move in opposite directions. To be easily penetrated by capillarity water, a paper sheet must have been produced with low WRV pulp, otherwise the fibers hydrate, swell, and close up the web, and the capillarity is lost.

5. Paper smoothness

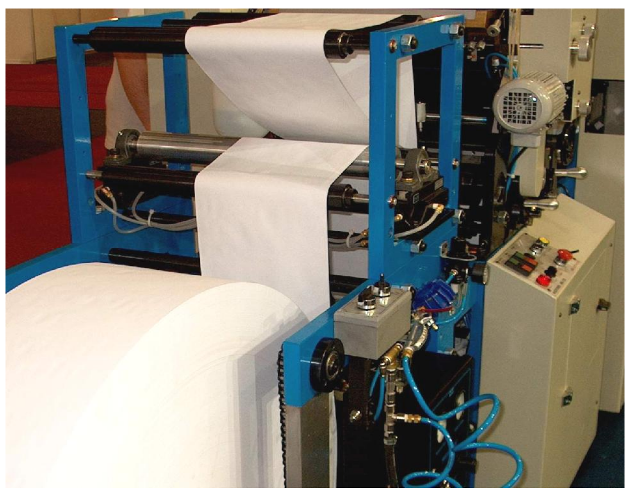


The short *Eucalyptus* fibers are also narrower in their diameter (or width). This favors a better surface distribution of anatomical components, with a higher surface smoothness. Smoothness correlates very well with the fibrous population of the pulp. Smoother papers are ideal for printing and coating, as they allow savings in terms of printing inks or coating formulas. However, suitable smoothness levels, allowing good contact between coating equipment and paper web surface, should be always striven for.

6. Paper opacity

Opacity (paper capacity to be crossed by light) is strongly influenced by the high fibrous population of *Eucalyptus* pulps. The higher the number of fiber elements there are in the paper sheet, the better the web formation and the more difficult for the light beams to cross it. This is due to the fact that the potentiality of light refraction and reflection on the paper body increases. As a result of it, a large part of light is deviated and does not cross the entire paper caliper. This property is vital for writing and printing papers, as well as for decorative papers. The more opaque the paper, the higher its capacity to hide what is under it.

7. Sheet printability



The combination of the properties of smoothness, liquid absorption, and opacity favors printability of the paper sheets manufactured with *Eucalyptus* pulp fibers. This situation is so advantageous that many papers or boards are produced in multi-layers, the surface layer (that to be printed) being manufactured with 100% of *Eucalyptus* pulp.

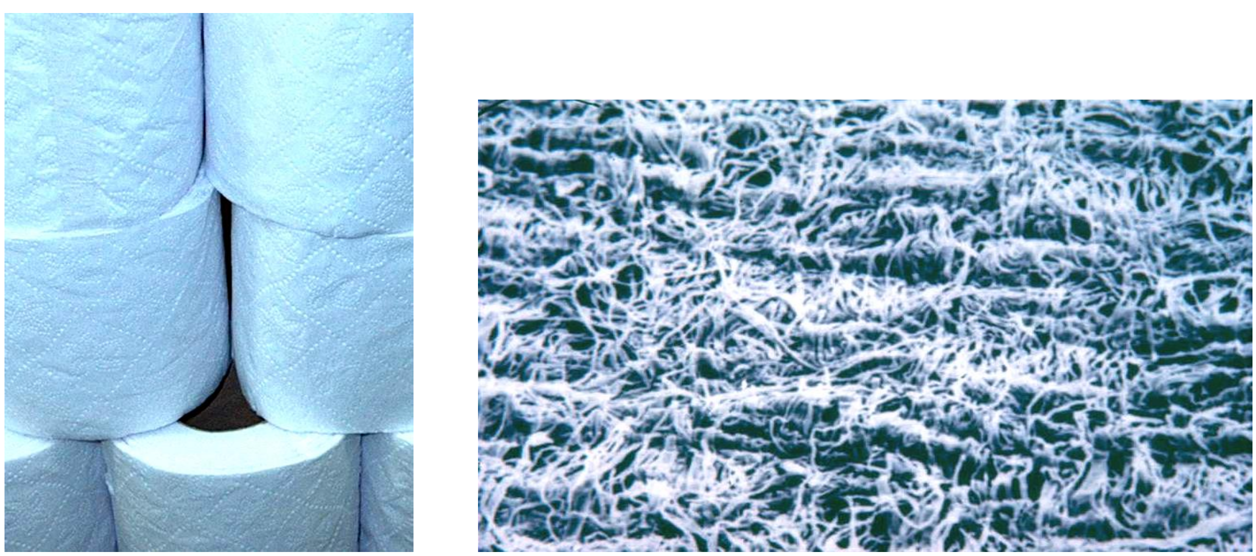
8. Dimensional stability

Dimensional stability is a very important property required by printing papers. This property is excellent in paper sheets manufactured with the short refined *Eucalyptus* fibers. Dimensional stability is strongly influenced by processes involving water (hydro-expansion and swelling) or drying (shrinkage and contraction). The higher the refining applied to the fibers, the worse the dimensional stability, as fibrillation, swelling, and the content of anionic groups (carboxyl's) in the pulps increase. Also, the higher pulp hemicellulose content favors the interaction of fibers and water, which may impair dimensional stability, especially when the pulp is refined more than it ought to.

9. Tissue paper softness

The feeling of softness, or tactile softness, is one of the properties mostly desired in the nobler papers of the tissue grade. There are two kinds of feelings in consideration: the one corresponding to stroke the paper surface (surface softness) and the other felt when compressing / crumpling the paper with one's hands (structural softness).

A paper is felt as soft when touching a paper made with short fibers almost without refining. Sheets made with refined fibers develop strength, but the sheet "closes up" and the sensation of softness is lost. For this reason it is said that to be soft the paper must be made with little or even no refining. Long fibers transmit rather a feeling of roughness, while the unrefined or scarcely refined short *Eucalyptus* fibers offer an excellent tactile sensation of softness and smoothness. Therefore, there are serious conflicts between web strength (either dry or wet, but dependent on fiber bonding) and softness requirements.



Sanitary papers and their creped (artificially micro-wrinkled) surface

10. Paper surface gloss

Calendering the smooth surfaces of paper sheets manufactured with *Eucalyptus* fibers improves very much the paper sheet gloss.

11. Suitable dry and wet web strengths

The short *Eucalyptus* fibers require refining to provide web strength, both to the dry and to the wet web. However, excess of refining impairs practically all those properties of the paper which are favored by the short and rigid *Eucalyptus* fibers. Furthermore, refining impairs water drainage on the wet-end, as well as wet web dewatering by pressing. Thus, the web will tend to leave the papermachine wet-end with a lower consistency value. This is a poison, as consistency is directly connected with wet web strength. Then, a conflict arises for the papermaker. If he chooses to increase the paper web strength by refining, in order to reduce the number of breaks or meet the strength specifications made by the customer, he will be negatively affecting runnability-related properties, such as dewatering, drainage, dryer section steam consumption, increase in vacuum required at the vacuum boxes, etc. Moreover, he will be increasing the hydro affinity of the web and impairing the dimensional stability of the finished paper. The dry sheets may curl to a greater extent, consequently increasing the broke amount at conversion.

For the above-mentioned reasons, every papermaker using *Eucalyptus* fibers knows that attention should be paid to refining, as well as to the runnability of his process. It is no use purchasing a *Eucalyptus* pulp on the market, aiming to gain softness, porosity, bulk, absorption, etc., and later making a mess of everything as a function of excessive or unsuitable refining. For all this, the papermaker using *Eucalyptus* pulps in his papermaking stock should pay maximum attention to his machines with regard to:

- Suitable wire and felt design;
- Suitable clothing (wires and felts) cleaning, as well as of the whole papermachine system;
- Refining with refiners (disks and conditions) suitable for *Eucalyptus* fibers;
- Suitable wet pressing, to avoid losing important properties of the paper (porosity and bulk);

- Technological papermachine design to avoid web breaks when the web is still wet and weak;
- Knowledge of the sustained production capacity of his paper manufacturing line with regard to machine speed, generation and dosage of broke, etc.

The dry sheet or wet web breaks are not only connected with tensile strength or tear. Many breaks are due to contaminants, stickies, dirt spots, shives, and other manufacturing process impurities. I have already known a lot of papermakers who regularly blamed the fiber and even the wood quality, while their inefficient operation was basically due to their incapacity to keep the papermachine clean. A naivety, innocence, or even an incompetence of them!

Another reason for web breaks is related to drainage and dewatering difficulties. Too much swelled and hydrated pulp does not dewater well on the papermachine wet-end, nor does it in the wet presses. Consequently, there are wet webs that are too wet, with low consolidation level, which is a poison for WWS – Wet Web Strength. This applies to any paper grade. The responsibility for these facts is often attributed to the pulps, but the responsible persons forget to look at what is happening at pulp stock preparation, refining, fines and white water recirculation, broke stock dosage and preparation, etc.

In short, my friends, before blaming your raw materials, have a walk through the mill, to see what is happening there to your machines and operators. Try to understand better the limitations of your process and the existing interactions. Next, try to carry out the due optimizations. You may spend a lot of work on changing pulp fibers to discover later that the problem was yours.

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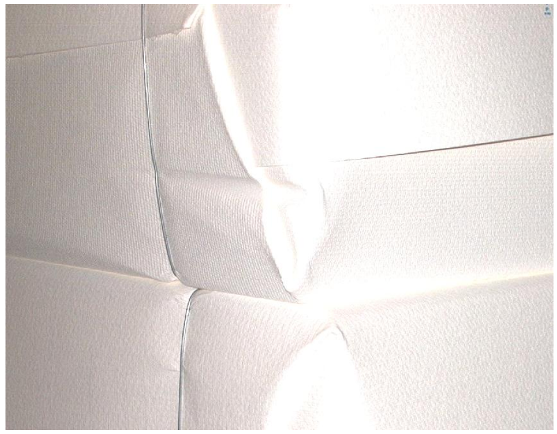
TECHNOLOGICAL QUALITIES DESIRED IN *EUCALYPTUS* PULP FIBERS



The terms fibers or pulp fibers have been commonly used to refer to the mass of anatomical elements that have been individualized from the wood after the pulp manufacturing process. This mass consists of much more than just fibers, as in the anatomical constitution of *Eucalyptus* wood there are other types of cells: radial parenchyma, axial parenchyma, fibro-tracheids, vessel elements, etc. The presence of phloem cells, sclereids, etc., is also common, due to wood chip contamination with a certain amount of tree bark, which is almost inevitable. Nevertheless, considerations are always made about the fibers and many determinations end up considering this mixture of anatomical elements as "fibers". Fines (minute elements – in general parenchymas and fiber fragments) and vessel elements are the most abundant constituents after the fibers. Even so, their proportions are far below those of the fibers. The latter are predominant in the pulps, their proportion in weight ranging from 88 to 95%.

Numerous indices and mathematical ratios were developed for the anatomical elements of the wood, in order to evaluate their papermaking potential. Many quality measurements were also developed, in order to monitor pulp quality. Some of these properties are vital, fundamental for the good pulp performance on the papermachines, as well as for the good quality of the products manufactured therewith. As there are many quality indicators, and as they are based on very similar principles, many of them end up presenting very significant correlations between each other. Therefore, there is definitely no need to measure so many things, unless an academic thesis is intended and data are required to enrich it with fundamental considerations and scientific arguments.

It should be also taken into account that each paper grade has a quality demand, and so have the machines manufacturing this paper grade...

for example, for the manufacturer of extremely high quality magazines the superficial gloss of the printed sheets is the most important characteristic. For the decorative paper manufacturer, the sheet capacity to be penetrated by the resins is vital, while tactile softness and smoothness are critical for the manufacturer of tissue paper – facial handkerchiefs. In other words, "there is no such thing as a most important pulp fiber property valid for all paper grades". There are properties typical of each product and they are often slightly different for the different manufacturers of the same product, because they may have mills and machines of different technological ages and the specifications vary according to the restrictions (bottlenecks) found in manufacturing, do you remember this fact?

It is important for the technicians to know well the relationships between the final properties of the paper and some vital characteristics of the fibers or pulps, either from the fiber suspension or from the wet web or dry paper sheet. Based thereupon, it is even possible to establish relationships with the qualities themselves of the woods supplying the pulp mills. Thus, the technology developed allows engineering the trees, as far as their genetics and the planted forest management are concerned, in order to obtain the best qualities for each type of product or manufacturing process.

The best way of doing this is knowing which characteristics can and must be engineered. They must be vital for the pulp and paper processes and present genetic heritability.

This chapter of our **Eucalyptus Online Book** will show you a holistic vision of the wood and pulp quality, as already mentioned. If you want to have a more detailed vision of the vital characteristics of *Eucalyptus* pulp fibers for paper manufacturing, read what we have already written in chapter 03: "The *Eucalyptus* fibers and kraft pulp quality requirements for paper manufacturing", at the following web or internet address: http://www.eucalyptus.com.br/capitulos/ENG03_fibers.pdf

Our purpose in the present chapter is to show the forest/wood/fiber/paper relationships, as well as the characteristics that can or must be included in the forest improvement and genetic breeding programs. Those I am going to present to you are and should be fully understood by all players of the paper production chain, from the planted forests to the paper manufacturers and users. Therefore, my friends in the forest planting and pulp and paper manufacturing areas, close attention should be paid from now onwards. I consider everything I will be telling you to be very relevant to allow a more efficient optimization of this value network, or of the "productive chain" as a whole.

The evaluations of the papermaking abilities of pulp fibers and woods are very much studied and have generated thousands of articles in the technical and scientific literatures, which can be found all over the world, not to just speak of papers concerning *Eucalyptus* fibers and woods, which are also very abundant. Someone desiring to learn really a lot about this theme has just to navigate on the Web or to access those papers I selected for you in the section of literature references and suggestions for reading, as well in the present chapter 14, as in chapter 03.

Now, I will try to present to you what I consider to be most relevant to evaluate and why. Likewise, I will try to explain the action of each of the vital characteristics of fibers and woods on the vital properties of the papers manufactured with *Eucalyptus* kraft pulps. I will also tread the inverse path, speaking of how the properties of the papers and pulp fibers depend on some vital characteristics of the woods, both with regard to end products and machine performance.

It should be also remembered that the properties of the paper sheet are affected by the characteristics of the pulp fibers and by the paper mill operations (refining, web forming, headbox, drainage on the Fourdrinier wet-end, pressing, drying, etc.). The web structure, the fibrous network, its consolidation and stability, the paper quality and its performance at the customer's house are included in this box of knowledge. Some properties of *Eucalyptus* wood are so important, that they impact on the conversion of wood into pulp, on the quality of that pulp, on the paper operations and quality, and finally on the performance of this paper at the paper users' factories. This is the case, for instance, of fiber length and width, and cell wall thickness. Fortunately, these fibrous characteristics end up being expressed by a simple measurement, which is the fibrous population, or by the fiber coarseness. Good luck for us.

In the following item, I will introduce to you all characteristics of the pulps, which I will call "<u>vital technological characteristics of the *Eucalyptus* pulp fibers</u>", dedicating this section to them. There are many pulp quality indicators, even too many. I will restrict myself to what I consider to be vital and relevant. As I already told you, many of these vital properties correlate with numerous other important characteristics. For instance: the fibrous population of a pulp correlates wonderfully with: coarseness, fiber length, cell wall thickness, wall fraction, Runkel index, basic density of wood, surface area of fibers and fibrils, paper's absorption of water, sheet opacity, bulk, sheet porosity, etc., etc., etc. Therefore, the characteristics I have selected for you are those I consider to be vital for the *Eucalypti* and which can be easily measured by everyone.

Therefore, also here there is, by coincidence, a list of eleven vital characteristics, just as we listed eleven vital properties of the papers manufactured with *Eucalyptus* pulps. I guess we will play the "eleven game" in this book chapter, wait to check.

"The eleven vital characteristics of *Eucalyptus* pulp fibers for paper manufacturing"

They are as follows:

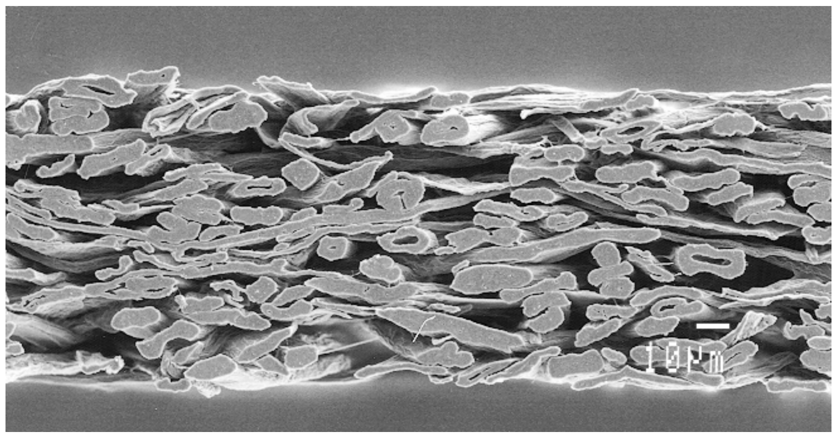
1. Fibrous population (millions of fibers per dry gram of pulp) and the immediately correlated property "fiber coarseness" (mg/100 meters);
2. Fiber wall fraction (connected with fiber collapsibility);
3. Fiber length (not expressed by the arithmetic mean, but by the weighted value with regard to length or weight);
4. Hemicellulose content (expressed either as pentosan content or as pulp solubility in caustic soda solution at 5% concentration, at 20ºC);
5. Content of fines (measured by the dynamic drainage jar, please);
6. Vessel element population and dimensions;
7. Intrinsic fiber strength (expressed either by Zero Span test or by tear strength at a low refining level and a fixed value of bulk);
8. Fiber bonding ability (expressed by tensile strength at a low refining level and a fixed value of bulk);
9. WRV – Water Retention Value (connected with fiber hydration and swelling ability);
10. WWS – Wet Web Strength (connected with the operational efficiency of the papermachine)
11. Fiber deformations (expressed as "curl", "kinks", etc.)

The above-mentioned eleven vital characteristics of pulp fibers correlate extremely well with all those eleven properties desired in the papers manufactured with *Eucalyptus* pulps, such as: formation, bulk, porosity, opacity, smoothness, tactile softness, water absorption capacity, dimensional stability, dry sheet and wet web strengths, etc.

As already mentioned, an extensive revision of these relationships is presented in Chapter 03 of the **Eucalyptus Online Book**, a good reference for readers in English and in Portuguese languages. See how to find it at the section literature references.

In my opinion, these two lists of eleven properties and vital characteristics (paper and pulp fibers) are fundamental for all main players of the paper production chain: from forest breeders to technical experts of the pulp and paper areas. As a matter of fact, they are the foundations for the operational performance and productivity of paper mills, as well as for the quality of the pulps to produce these same papers. But do not forget it, do not stick only to mean values of each of them, but also and above all to their variability's and ranges of variation.

Let's now make some considerations about each one of them:



1. <u>Fibrous population (millions of fibers per dry gram of pulp) and the immediately correlated property “fiber coarseness” (mg/100 meters)</u>

The fibrous population is measured by the number of fibers above a minimum length (in general 0.10 to 0.25 mm), counted per gram of oven dry pulp. Values below these limits are considered as “fines”, not as fibers.

Now, coarseness can be defined as the total weight of a 100 m long fiber line (arranged following each other).

These properties depend on the individual length of each fiber, on the cell wall thickness, on the fiber diameter, and therefore are connected with the average weight of each fiber.

In general, for fibers of similar lengths, the coarseness-fibrous population ratio is direct and negative. However, when the fiber length varies among the samples, this type of linearity may be either lost or slightly altered.

These two combined properties are perhaps some of the most vital ones among those we have available. Also, it is extremely easy to measure them. They allow taking due steps in anticipation of changes in wood quality and market pulp performance. They correlate very well with the basic density of wood, with the wall fraction of fibers, with their length, and with many characteristics of operational performance (refining, drainability, drainage, dewatering, drying, hydration, etc.) and quality of the papers (porosity, bulk, opacity, etc.).

The serious risk we run is not to know how to use these wonderful vital characteristics as tools to improve our operation and quality. When we forget that we should concentrate on understanding the abnormalities, instead of just the daily mean values, we commit the greatest of sins and cannot perceive anything, because we run the risk of only seeing similar values, within a narrow range of variation in mean values. We even forget that these characteristics change due to the production process itself (they are affected by wood chipping, pulp refining, etc.). As everything "seems to be similar", we end up seeing no usefulness for the figures, which is a pity.

Coarseness and fibrous population are the vital characteristics responding most to changes in *Eucalyptus* wood quality. For this reason, whenever you notice an alteration in the standards of industrial behavior of wood (at the pulp mill) or pulp (at the paper mill), an interesting procedure would be to evaluate the respective values and their variability.

As refining affects the fibrous population as a function of reduction in fiber length, this indicator is also useful to follow what is happening in terms of pulp stock refining. Once again, the various fractions of fiber length that the analysis will disclose, variations in wall thickness, etc., should be also observed. All this is provided by the fiber analyzers at the same time as they evaluate the fibrous population and coarseness.

2. <u>Fiber wall fraction (connected with fiber collapsibility)</u>

Wall fraction is the ratio between cell wall thickness and fiber radius, expressed in percentage. The higher its value, the higher the fiber stiffness and resistance to collapsibility. Fibers with high wall proportions are heavier; therefore, the fibrous population will be lower. These fibers drain and dewater very well on the papermachine, but their bonding capacity is lower (fewer points for bonding or contacting). For this reason, it is interesting to associate this characteristic with the hemicellulose content and the content of fines, which promote contacts and help fiber bonding. An optimum balance may happen, as that occurring with many *Eucalyptus globulus* pulps (but not all of them). This species has heavier pulp fibers (lower fibrous population), thicker walls, but a higher hemicellulose content. For this reason it is particularly loved for many users and utilization's in the paper industry.

3. <u>Fiber length (not expressed by the arithmetic mean, but by the weighted value with regard to length or weight)</u>

Although *Eucalyptus* fibers are small, they present a certain variation with regard to the average. Then, it is necessary to know how is this distribution among ranges of fiber length. It matters to know not only the average length, but also the frequency of fibers in lengths such as: 0.0 to 0.25 mm (fines); 0.25 to 0.50 mm; 0.50 to 0.75 mm; 0.75 to 1.00 mm; 1.0 to 1.25 mm, for instance.

The knowledge of these variations allows better understanding the fibrous population and makes it possible to better understand the share of fines in the pulps. This characteristic is also vital to control pulp refining and papermachine runnability.

4. <u>Hemicellulose content (expressed either as pentosan content or as pulp solubility in caustic soda solution at 5% concentration, at 20ºC)</u>

Definitely, this is one of the most vital characteristics of *Eucalyptus* pulps and woods, because this content controls or interferes with a series of operational and qualitative performances in pulp and paper manufacturing. A high hemicellulose content may be either good or bad, or even indifferent. Everything will depend on the paper grade being manufactured, on the relationships with other vital properties, and on the manufacturing process restrictions/bottlenecks.

Hemicelluloses not only help pulp refining, but they also interfere with characteristics such as: fiber bonding capacity, hydrophilicity and swelling, ionic charges and anionic groups (carboxyl's), WRV – Water Retention Value, WWS – Wet Web Strength –, etc. They may either facilitate or impair web drainability, dewatering, and drying, they may accelerate hornification, etc., etc.

It is very healthy for the papermakers to well know the hemicelluloses, their constitution, crystallinity, free ionic charges, etc. It is something deserving further research in the sector.

Hemicelluloses and their recently discovered derivatives (hexenuronic acids and xylan fragments) are major contributors of anionic charges in the fibers. These carboxylic groups are formed by holocellulose degradation, which occurs more easily with the hemicelluloses. These groups also increase much in content in the initial oxidizing stages of bleaching, but as the acid and alkaline stages keep removing hexenuronic acids and some superficial hemicelluloses (xylans) from the fiber walls, the carboxyl content decreases significantly in the pulps at bleaching last stages. There also exists a relationship between fiber carbohydrate chain degradation and anionic group content. There are anionic charges both on the fiber wall surfaces and inside them.

Hemicelluloses are also important for forest breeders and pulp manufacturers. The objectives are often opposed: sometimes the target is to have high, sometimes low hemicellulose contents. The hemicellulose management also impacts on yields, as after all they are present in the weight of pulps and papers. And these products are sold based on their weights.

The hemicellulose management allows differentiating pulps, gaining or losing production yields, improving or worsening several properties of the paper sheets, etc., etc.

Taking all these aspects into account, it is surprising to consider how little concerned are pulp and paper manufacturing companies about hemicelluloses. Just a small number of companies monitor the hemicellulose content, even by empirical and indirect testing, as pulp solubility in caustic soda at 5% or 10%.

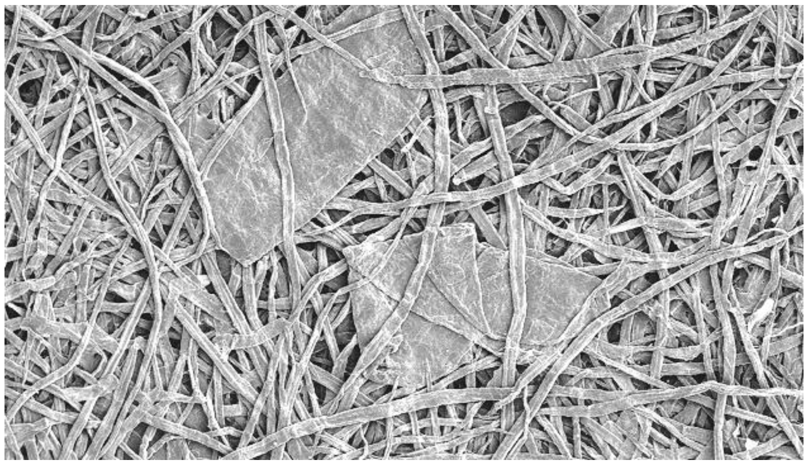
Hemicellulose contents in pulps fundamentally depend on the hemicellulose content in woods, as well as on the capacity to retain them, remove them, or modify them over the course of the industrial pulp production process.

5. Content of fines (measured by the dynamic drainage jar, please)

As already seen, fines encompass parenchyma cells and small fragments of fibers and vessel elements. The higher the content of fines, the more difficult become drainability, dewatering, and drying on the papermachine. Fines cooperate in fiber bonding processes as just a few elements do. In case the fines are removed from the pulp, there occurs a complete change in its properties. Bulk, porosity, and water absorption will substantially increase. As opposed to it, the physical strengths of the paper sheets will drop to extremely low values, all of them.

Not only the content of fines is important, but also what they consist of. Are we speaking of parenchyma cells? Or fibrils? Or very broken fibers? What would be causing this? Wood chipping? The presence of bark on the wood? An excess of refining? Or unsuitable refining disks? Taking all these aspects and the importance of fines into consideration, I will soon dedicate a chapter of the **Eucalyptus Online Book** to them. Please, wait and keep paying attention.

At this point, an afflictive doubt assaults me: if fines are so important in the pulp papermaking performance, why does it occur that practically just a few pulp companies pay due attention to them - to measure them, understand them, and manage them? The most the technicians use to do is to have a look at the results shown by the automatic fiber analyzers, in general calculated based on counting, instead of better determinations, as those carried out by the dynamic drainage jars, with concepts closer to those happening on papermachines. The values of fines measured by the dynamic drainage jars allow anticipating the pulp behavior in the refining operation, on the wet-end, in terms of drainability and pressing, and even in white water recirculation.



Paper sheet surface showing fibers and 2 vessel elements

6. Vessel element population and dimensions

A whole already published chapter of this book was dedicated to the vessel elements and their effects on the papermaking uses of *Eucalypti*. In case of interest, read "Vessel elements and *Eucalyptus* pulps", available at: http://www.eucalyptus.com.br/capitulos/ENG04_vessels.pdf

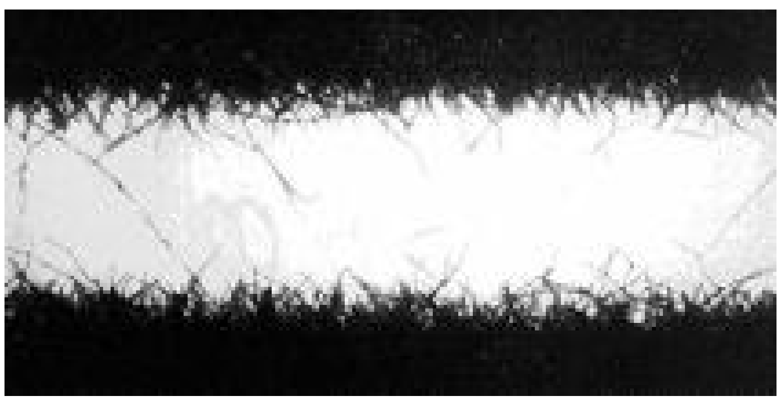
A large number of vessels, as well as large-sized vessel elements, are undesirable in printing paper manufacturing, particularly as far as uncoated and surface sized papers are concerned. These elements make dirty the printing machines, as they are picked off the paper sheet surface. In addition, they spoil the printing quality, leaving marks known as vessel picks. To combat them, the papermaker needs special refining and suitable and more intense surface sizing. For this reason, the *Eucalyptus* species containing smaller and less abundant vessel elements are the preferred ones. Therefore, the number of vessel elements per gram of dry pulp (vessel element population) and the vessel dimensions are vital characteristics of *Eucalyptus* pulps for printing paper manufacturing. They do not cause any major problems in the quality of use for tissue papers, for example, except for the fact that they may produce a larger amount of "dust" in the conversion areas of this paper grade, which requires very little stock refining.

Trying to fit vessel population and their dimensions into a single index, I suggest to calculate the volume of vessels existing per gram of dry pulp (Vessel Index). This might be calculated based on the following formula:

Volume of vessels/gram of dry pulp = Vessel population (Number of vessels per gram) x Average volume of vessel elements

...considering that this volume may be calculated either based on the arithmetic mean value of vessel length and diameter (less correct) or on these same values calculated by weighted distribution within certain classes of frequency for these two dimensions (more correct).

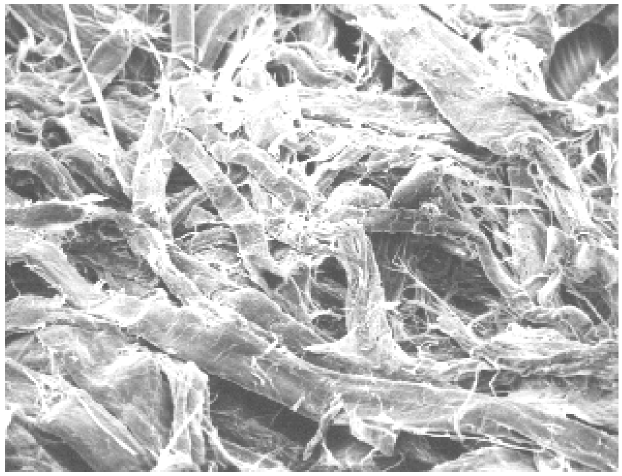
7. <u>Intrinsic fiber strength (expressed either by Zero Span test or by tear strength at a low refining level and a fixed value of bulk)</u>



It is difficult to measure the individual strength of so short fibers as the *Eucalyptus* ones by using dynamometers. For this reason, indirect measurements must be based upon. One of the most used measurements is the Zero Span tensile strength of the pulp or paper sheet.

For those who do not have such measuring equipment, there is always the possibility of estimating that value by the tear strength test, adopting a rather initial refining level and expressing the result at a fixed level of bulk. I suggest it to be 1.8 g/cm³ for sheets prepared according to TAPPI's methodology for test sheet formation.

8. Fiber bonding ability (expressed by tensile strength at a low refining level and a fixed value of bulk)



Fiber bonding is vital for the development of strengths in the paper web , whether it is wet or dry. However, excess of bonding is harmful for certain paper grades, as the paper becomes denser and more compacted. Important properties are lost, such as: porosity, opacity, dimensional stability, bulk, softness, etc.

The fiber bonding capacity is associated with the hemicellulose content of pulp, the wall fraction (collapsibility), the content of fines, the ionic charge, the holocellulose chain degradation and the fibrous population.

An easy way of indirectly estimating the fiber bonding is by Zero Span tensile strength technique, by correlating some of the indices taken at the dry and wet measurements and by varying the span distances. There are those measuring fiber bonding by friction or sheet surface strength, as it is the case of Scott bonding tester, or Dennison wax test.

In case these tests are not available, I suggest you to determine the tensile strength of dry pulp sheets at a low refining level and at a fixed value of bulk, which may be also 1.8 g/cm^3.

9. WRV – Water Retention Value (connected with fiber hydration and swelling capacity)

Pulp and paper manufacturing consists in a series of water insertion and removal steps. In this process there is free water, which is easily removed by the action of gravity and does not cause any operational problems. There are also water molecules retained in the fibers by micro-capillarity inside the cell walls and the fiber lumen, as well as water retained by electrostatic forces due to water polarity and electrostatic forces. This water connected to the fibers, which swells up the pulp, and adsorbs to the cellulose and hemicellulose chains, is precisely this type of water which impairs paper manufacturing. It affects dewatering, drainage, drying, and the qualities of paper usage.

A way of measuring this type of water is through the WRV – Water Retention Value. The WRV consists in the ratio between the amount of water retained and the oven dry pulp weight - in percentage, after submitting the pulp sample to the action of a centrifugal force during a certain period of time. In general, the centrifuge operates between 3,000 and 5,000 rpm, according to the purpose of the tests. Just imagine that even submitting the wet pulp blanket to this enormous G force, there is still a significant amount of water remaining adhered to the pulp. The more water is retained, the higher the WRV.

The WRV is directly associated with refining, fibrillation, the superficial area of pulps (fibers and fibrils), the anionic charge of the fibers, the hemicellulose and hexenuronic acid contents, the fibrous population, the degree of pulp degradation, etc.

Definitely, the WRV is one of the most vital characteristics for the paper manufacturer. It affects too much the performance of his machines, all the more because certain pulps develop the WRV very much at pulp stock refining. When the WRV of the pulp stock is high, the pulp retains too much water - it is said as "fat", the papermakers use to say about them. Drainability on the papermachine wet-end will be very much impaired. Consequently, the "wire side papermachine mirror advances" and the moisture of the wet web leaving the wire will be higher. In order to try to combat this phenomenon, the papermaker tries to alter freeness and vacuum intensity in the vacuum boxes. In case he is unsuccessful, the excess of water will advance towards the wet press sector. As water is incompressible, it will cause quality problems in the pressed wet web, some of them well-known, such as: crushing, creases, folds, bursts, holes, breaks, losses of mineral fillers, etc.

The problems will accumulate both on the wet-end wire side, which will not drain well, and in the press, which may have no capacity to remove this additional amount of water. If the web leaving the press is still too wet, the problem will be transferred to the dryer section. More thermal energy (steam) than gravity (wire side) and pressure (wet press) will have to be used to remove this water. The dryer section often has no capacity available (number of dryers or availability of steam) to do this extra work. The solution left to the papermaker will be to reduce the speed of his machines. Just imagine how he uses to react to this alternative of losing production!!!

A way of drastically reducing the WRV is by pulp drying. For instance, rehydrated sheets of market pulp present much lower WRV than never-dried pulps from integrated paper mills. As far as *Eucalypti* pulps are concerned - market pulps present a WRV ranging from 90 to 120, while never-dried pulps a such between 150 and 190, which definitely results in an enormous difference in fiber behavior in the paper stock. A way of partially solving the problem at integrated mills, when WRV values become too problematic, consists in the more regular control of the dry broke dosage (which consists of a stock previously dried). Another alternative is to use some fraction of dry market pulp. Disintegration of dry market pulp with lower WRV values favors stock drainage and dewatering. In case of using dry broke stock, please do not interpret it as having to generate broke for WRV control. It would be an enormous operational silliness. Even worse than that is that there are people thinking that broke is good for the machines precisely because of such a characteristic. If this silly concept comes to stick, it will cause a big problem for the operational efficiency of the paper mills.

It is incumbent upon the user of *Eucalyptus* pulps to understand very well the relationships of the WRV of his pulps with the different operations, as well as with the remaining characteristics of pulp fibers. It is only in this way that he will be in a position to optimize his process, thus escaping from the perversity of the pulps difficult to drain, dewater, and dry.

10. <u>WWS – Wet Web Strength (connected with the operational efficiency of the papermachine)</u>

This is another one of the most vital characteristics of a *Eucalyptus* pulp. It is curious that almost nobody measures it, an incredible thing! Why do they not measure the WWS to optimize their machines? For lack of equipment? Its measurement is so simple, that it is even possible to make a homemade dynamometer with a burette with water and two light plastic claws to hold the strip of wet paper web.

The WWS is directly and strongly related to papermakers' physiological needs. When the wet web presents good strength, it runs well along the papermachine, it does not break, it does not deform, it does not cause any important problem. However, this WWS is seriously affected by the wet web consistency. The higher the consistency of the same wet fiber network, the better the WWS will be, measured for instance by the tensile strength of a strip of wet web. It is for this reason that it is so important for the papermaker to have a good drainage, a good dewatering, and an optimum pressing of the wet paper web. Thus, the web becomes more break resistant. It can be drawn on the machine without breaking.

Other ways of improving the wet web strength are either by pulp stock refining or by incorporating long fibers into the papermaker's magic recipe. Considering that pulp stock refining increases the WRV and brings disadvantages to porosity, bulk, dimensional stability, etc., more intensive refining may not be the ideal solution. In addition, the additionally refined pulp stock will dewater worse and the wet web consistency may decrease, and, as a result of it, the WWS too. A perverse sequence of things to worsen the papermaker's life.

It is very important to have at laboratory level a suitable and practical method to measure the WWS at constant consistency levels (30, 40, and 50%, for instance). In practice it is difficult to achieve these fixed values of consistency for performing the tests, for which reason we can avail ourselves of graphic interpolations, using curves relating the WWS to the test specimen consistency.

Definitely, it is not possible to compare values of WWS obtained through test specimens at different consistencies when the purpose is to differentiate and select types of pulps or types of stock preparation.

11. Fiber deformations (expressed as "curl", "kinks", etc.)

The changes endured by the fibers due to their transit through the industrial processes (pumping, dynamic mixture, pressing, refining) are important factors affecting their performance in paper manufacturing. These deformations weaken the fibers because they affect their walls, but on the other hand they improve paper properties such as porosity, bulk, softness, etc. The fiber deformations can be artificially induced in the process, in case this is desired. There is very efficient equipment for this purpose, such as shredders and dewatering presses. For some special papers, like high-softness tissue papers, filter papers, and decorative papers, fiber deformations are ways of imparting more quality to the pulp.

Fiber deformations are measured by some indexes, such as: curl index, latency, changes in fiber direction (kinks), micro-fractures and micro-fissures, etc.

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TECHNOLOGICAL QUALITIES DESIRED IN *EUCALYPTUS* WOODS FOR KRAFT PULP PRODUCTION

The pulp manufacturer's motivations with regard to wood as raw material are very similar to the papermakers' ones with regard to pulp fibers. They want to have a wood which will not cause them any problems or insomnia. They want to operate their mills with high productivity, high operational efficiency, a high level of attainment with regard to the quality specifications of the products, and at minimum production costs. To achieve these goals, wood should be as uniform as possible in their quality specifications, so as not to have any significant impacts on the pulping process and the qualitative targets for pulp as product.

Although there is an extremely high number of studies and researches about the quality characteristics of *Eucalyptus* woods, the naked truth is that many sins are still being committed in the forest improvement/breeding programs of the sector, aimed at developing the quality of the wood intended for kraft pulp production. The most terrible of all, as you have already heard my former comments in other chapters, consist in the precarious sampling procedure, as well as the number of replications of the analyses for error minimization in the statistical decisions. This case when statistical tools and planning are used at all for evaluations and decision-making.

Since variability exists (and it is not low, as mentioned in the introduction to this chapter), the sample sizes should be more representative of the populations being evaluated. An extremely low number of foresters working with R&D performs preliminary testing to define the most suitable sample size. In addition to that, sampling itself may be precarious, in case samples are only taken from medium-sized individuals, not from all segments of the forest population. Trees with breast height diameter similar to the forest stand average are not necessarily trees representing the whole population, for evaluating their properties, such as: basic density, lignin content, hemicellulose content, etc., etc. Definitely, the size and representativeness criteria adopted for these sampling processes must be urgently improved, which applies to many parts of the world.

Another recommendation I always make references to the number of replicas for the analyses – the number of times a determination should be carried out, in order to provide a representative population mean value. In most cases, the evaluations are based on averages of two repetitions only, without paying attention to the individual values, or to the standard deviation (how to speak about standard deviation in cases as these ones?). Depending on the accuracy desired and on the maximum error the forest breeder is willing to commit in his decisions, this number of repetitions should be much larger.

I sincerely believe that there are many *Eucalyptus* forest improvement programs being carried out, the only purpose of which is to measure something and to have some data to "fill the spreadsheets with numbers". Most certainly these values will lead to mistakes in decision-making. A program seeming to be apparently charming and interesting may leave a legacy of problems to the next generations of forest breeders and users of woods, because it will be founded on fragile – not to say *rotten* – bases. There are many chances that the forester is accepting as good some genetic materials that in fact are not (this refers to some of the technological properties of woods and fibers). In other cases, the forester may be discarding a good genetic material for an excess of zeal, or due to false interpretations of his fragile statistical analyses. However, such a mistake is less relevant than the previous one.

Up to the present moment, these errors and inappropriate statistical planning on the part of many forest breeders are being concealed or masked by the fantastic gains that tree hybridization and cloning have afforded. When comparing the results of clonal forests with the ancient planted forests obtained from improved seeds, both the technicians and the forest company executives are enchanted with the gains. Everybody believes to be performing wonderfully in their decision-making. The major problem will start appearing when the decisions will begin to involve replacement of clonal materials with other more suitable ones (for additional gains). Many choices that were based on inappropriate technological decisions and evaluations will unfortunately show their face only some years later, when the wood will begin to get ready to be sent to mill consumption.

In past times, when the forests were much more variable due to planting of seedlings obtained from seeds, the chance to find individuals with extreme values for some vital property was much more common. Nowadays, due to genetic base narrowing resulting from cloning same individuals, the prospects for future gains are no longer so impressive, unless a parallel program based on crossings, retro-crossings, and re-combinations through sexual reproduction is conducted and developed. Also in this case, decisions should be made based on reliable data, measurements, samplings, statistics, and analyses.

Now, let's come back to our pulp manufacturer. He is always asking for uniform wood for his mill. He does not like unpleasant surprises. When he asks for uniformity, he is not only referring to close values of basic density of the wood. He includes in his wishes a large number of wood quality parameters which he considers to be very important in the technology of conversion of wood into bleached kraft pulp. For example, he will pay attention to the content of bark present on the wood, to the dimensions and fractions of the chips, to the level of wood deterioration, to the wood moisture, to the presence of knots, of defective woods (attacked by diseases, pests, tension wood, semi-fired wood, etc.), etc. His objective is to have cooking and bleaching operations subject to the lowest possible variability, such that preferably will avoid him nightmares or bad surprises. The final quality of his product must be as stable as possible and within acceptable limits of variation. The process losses, the mill shutdowns, bad quality broke, etc. – all this must be minimized. When standardizing the quality of the wood entering the mill is being aimed at, the pulp manufacturer becomes happy: the only thing he has to care about is regulating quantities and flows, in order to get the desired quality. When the wood quality varies, the pulp manufacturer takes some measures to try to reestablish uniformity, at least mixing "different things" to have a more uniform wood mix. This uniformity is required for him to be sure that the quantities entering the mill in terms of wood weight are not varying too much. To his digesters, where he has to dose up the wood cooking liquors, he must guarantee the control over the amounts of wood feeding them. Thus, our pulp manufacturer believes that he will be making more uniform the mill operations such as: digester pulp outputs, white liquor preparation area, black liquor recovery area, bleaching area, area of generation of oxidizing chemicals for the bleaching process, etc. What he tries to do desperately and first of all is the "<u>management of the quantity of wood feeding the digesters</u>". Digesters are pieces of equipment fed based on the volume of chips, and in most cases they are limited as to their chip feeding and liquor flows, because *Eucalyptus* pulp mills are used to work at their maximum level or above their designed capacities. To avoid abrupt variations in operational performance, the ideal procedure is to work with uniform basic densities of wood logs, and with equally similar bulk densities of the wood chips. The performances and mill continuity in operations are more easily achieved in this way, even if the pulp manufacturer is mixing woods of different basic densities. What is important to him at a first moment is to have a bulk density of the chips which is as uniform as possible. Then, his prime objective is to stabilize the mass flow of wood being fed into the digesters. By doing this, he manages to "stabilize" the rest of the mill, which is, as a matter of fact, not an easy task.

Having guaranteed uniform feeding, the pulp manufacturer's next concern refers to the ways of reducing variability in wood quality. His second goal is to do the "management of wood variability". Having success in doing this, he will reduce the consequent variations in some very important items of the pulping process, such as: white liquor consumption in the cooking process, pulp yield, reject content, specific wood consumption, content of total dry solids generated and sent to the black liquor recovery system, chemical consumption in the bleaching line, end product quality, proportion of off-grade products, quality of operations, employees' stress level, etc., etc.

These two kinds of management – quantities/mass flows and wood variability - may be considered as basic and physiological requisites for any pulp mill. This applies to both integrated and market pulp mills in any place of the planet. The pulp manufacturer will be only interested in the "management of product differentiation" if it is able to facilitate his life and to improve both previous types of management, or if he has full control over these managements of mass flows and wood variability. He wants to have adequacy and conformity in his processes – this is always being requested from him by his quality auditors. Therefore, the wood suppliers should understand these rules very well. In the case of product differentiation, we must understand and help the company's and machine operators' willingness to produce differentiated types of pulp products at the mill, capable of supplying differentiated markets. This differentiation may be connected with the quality of the wood (*light wood or dense wood*); with the *Eucalyptus* species being used (*E.urograndis*, *E.globulus*, *E.nitens*, etc.); with the process conditions (ECF or TCF pulp, pulp dried in sheets or on a flash dryer); or with more recently introduced conditions for marketing differentiation (certified or uncertified wood).

The product differentiation is more easily achieved when the mill has more than one fiber line, which is due to the fact that the mill can operate its production lines with different woods and product qualities. This even allows one production line to absorb some problems and limitations from the other line. By doing so, the mill no longer has to face the need for product transitions, when changing from one type of product to another one.

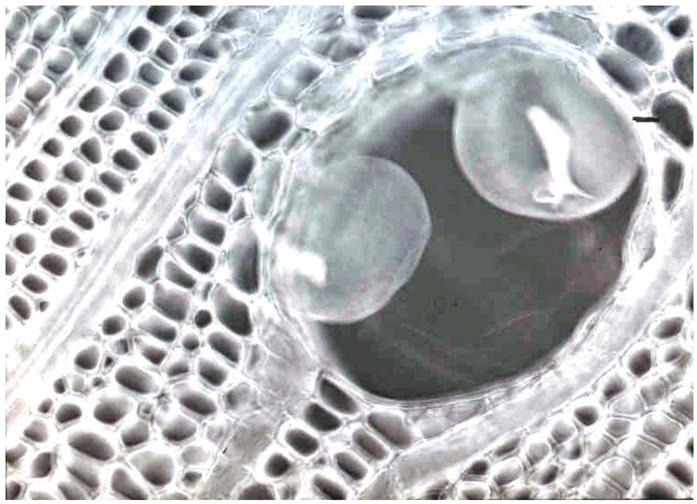
All this I am telling you is very easy to say, but very difficult to implement. Considering that the clonal silviculture is in full development in the current days, the chances to guarantee differentiated clones for differentiated types of pulp and paper are enormous. What in the past was done by varying species or ages of trees, at present is achieved by clone management. Most market pulp companies have already specific clones to produce kraft pulp oriented to tissue, decorative, printing, coating base papers, etc.

For this differentiation to be successful, a very good dialog between the forest area, the pulp manufacturing area, the paper manufacturer and final user, whether they are internal or external, is once again of great importance. In general, it is common for misunderstandings to arise among these areas and players. This is due to the fact that it is difficult for them to understand (or to accept) each other's limitations and restrictions. As a consequence, just a few market pulp manufacturers succeed in offering differentiated products to market niches. Most pulp manufacturers like to produce a single, even universal pulp, which might be delivered to any customer all over the world. However, such a universal pulp does not exist, as you already know very well.

Well, it is much easier to manufacture and to sell a single type of pulp, no doubts about: greater operational efficiency, no transitions, simplicity of logistics and storage, lower costs, etc., etc. Hence the aversion that some pulp manufacturers have to new market demands on quality. They do not like to change their formulations and procedures, even because this requires not only raw materials, processes, and knowledge, but also enormous controls, close attention, and willingness. As the markets are more demanding and competition is more intense, something will have to be done. After all, as the world is changing quickly, those reacting to the change may lose their competitive advantage or their working jobs. In other cases, it is the company that will suffer, since the blind decision-makers are powerful and are not seeing that the customers have new machines and new products and are in need of new raw materials.

Both in case of mills producing a single type of market pulp and those aiming at a product differentiation, it is difficult to define the quality of the wood based on a single wood property. A single and fantastic wood quality parameter being able to optimize the whole mill operation and the quality of the product does not exist either. Although the basic density of wood is one of the most versatile and used characteristics, there are many limitations to adopt it as a universal quality indication of *Eucalyptus* wood. In the next future, a whole chapter discussing this matter will be made available. Nevertheless, I only want to clarify the following: "*Eucalyptus* woods of same basic density values, but belonging to different *Eucalyptus* species, may have completely different technological behaviors in their conversion into pulp and the resulting products may present a completely different quality". For instance, woods of *Eucalyptus saligna*, *E.nitens*, *E.dunnii*, *E.urophylla*, *E.robusta*, and *E.tereticornis* species with basic density exactly equal to 0.5 g/cm^3 will most certainly present differentiated operational and qualitative behaviors for bleached kraft pulp manufacturing. For this reason, those who control wood quality only based on its basic density must at least be working with *Eucalyptus* species which are similar in relation to this property. If working with a widely varied mix of species, the decisions made may be inappropriate. Even if clones are concerned, there may be qualitative and technological performance variations at practically equal basic density levels. And this may be due to the fact that the clone may present characteristics that are similar to the paternal rather than to the maternal species or vice-versa. Something as: some *E.urograndis* clones may have woods similar to the *E.urophylla* one, while others to the *E.grandis* one, is this clear now?

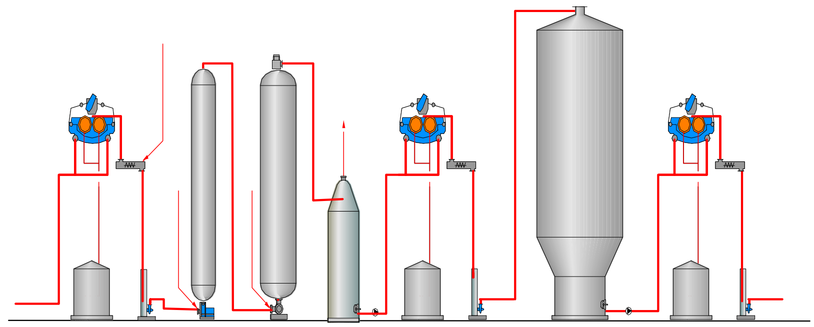
In other cases, the quality of the wood is defined by the pulp manufacturer as a function of the limitations he is subject to in his mill. For example, if he has difficulties with chip impregnation, digester knot recycling, and pulp screening, he will restrict the flow of denser woods and having a higher lignin content getting in; whereas, if he has limitations in terms of digester feeding and needs to increase the daily production of his mill, he will look for denser woods, but having lower lignin contents.



Eucalyptus wood: fantastic anatomical landscapes are hidden by an apparent visual wood chip uniformity

The operational restrictions most commonly affecting *Eucalyptus* wood quality parameters are as follows:

- Chipping and chip screening line capacity;
- Digester capacity;
- Digester liquor flow limitations;
- Pulp washing line capacity;
- Bleaching line design and dimensioning;
- Evaporation capacity;
- Recovery boiler burning capacity;
- Lime kiln and causticising capacity;
- Chemical chlorine dioxide generating plant capacity;
- Pulp sheet drying capacity;
- Contamination level in the pulp (pitch);
- Etc.



In conclusion and just repeating to consolidate concepts: it is the type and intensity of the operational bottleneck that may be defining the "optimum wood quality" for a certain pulp production line. This uses to be the case for mills in operation, having already overloaded process systems. For new greenfield mills, wood quality may be preliminarily defined and materialized in the forest, according to the objectives of the production, technological, and commercial areas. However, these specifications will not last long. Soon after mill start-up, the voracity and anger to increase production, striving for record productions, the usual inattentiveness to forest plantation programs, will lead to scarcity of wood and appearance of some operational bottlenecks at the pulp mill. Consequently, new wood quality parameters will appear. That which was "the heaven or the paradise" is transformed into numerous nightmares in badly slept nights. The positive aspect is only that the *Eucalyptus* pulp sector is experiencing an accelerated growth in production and consumption. Worse than that would be the opposite situation: always excellent wood quality, but the mill operating below the rated capacity; in very good adequacy and conformance, but just a few customers.

The vital pulp mill objectives are well-known: production and productivity, efficiency and operational continuity, production cost, product quality, and little need of investment capital. The pulp mills use to be sandwiched between the forest area and the paper manufacturing customer, which applies to both integrated and nonintegrated mills. Both sandwich sides should know and understand the pulp mill limitations and help it making a good lemonade from some lemons, which are sometimes bitter. Remember, the pulp manufacturer is always in love with his industrial process, he truly loves all this. Therefore, instead of criticizing his demands it is better to integrate with him, in order to optimize his process.

Now I will take the opportunity of presenting to you my list of vital characteristics of the *Eucalyptus* wood quality for the pulp manufacturer, equally in number of eleven.

"The eleven vital characteristics of *Eucalyptus* woods for bleached kraft pulp manufacturing"

They are as follows:

1. Wood cleanliness, soundness, health and moisture;
2. Chip dimensions;
3. Basic density of the wood;
4. Specific consumption of effective or active alkali in the cooking process;
5. Pulp production yield;
6. Specific wood consumption per ton of produced pulp;
7. Dry solids generated for feeding the black liquor recovery line;
8. Wood lignin content and quality;
9. Hemicellulose content;
10. Wood extractives content and constituents;
11. Wood ash content and constituents.

Some considerations I deem to be important will be made on each of them in the following pages.

Chips represent the way wood enters pulp manufacturing: they demand for our focus on, not only to the trees and logs

1. Wood cleanliness, soundness, health and moisture

This is a composite item depending on the tree, as well as on the forest and mill operations.

Wood should be as free as possible from contaminants like bark, leaves, branches, soil. It should also present minimum incidence of defective regions, such as knot insertion, tension wood, wounds caused by pests or diseases, etc. It is no use for the genetic forest breeder and the forest producer to endeavor to obtain the "ideal tree" if later it is spoiled in the forest harvesting and transporting operations.

After forest harvesting, in general the logs are left to undergo a quick moisture loss process, to facilitate and cheapen handling and transportation. Care should be taken to prevent logs and chips from being forgotten or hidden in the processes, so as they may lose much of their quality by decaying. Do not be surprised, this is rather a common situation at mills and in forests.

The kraft pulp manufacturer also knows that some of his operations depend on the moisture level of the wood: chip impregnation, penetration and diffusion of the cooking liquor for fiber individualization, for instance. It is very important to control log and chip moisture, though it is not vital in case of mills having available efficient chip impregnation vessels.

2. Chip dimensions

The chipping lines must be adequate to the type of wood quality, otherwise they will neutralize all gains obtained in the quality management of these trees and woods. Even so dense woods as those of *Corymbia citriodora* or *Eucalyptus paniculata* can be converted into raw materials of excellent quality for kraft pulp production, in case chip dimensions are smaller and suitable for the process in question.

3. Basic density of the wood

Uniformity and the average basic density of the wood are very important for the pulp manufacturer. With them he can better control the management of mass flows and variability of his process. In case of mills having a capacity design which allows using low density woods, the pulp manufacturer may show preference for them, since impregnation is facilitated and cooking is quicker. However, if the digester production is restricted due to incapacity to feed a larger amount of chips into it, the pulp manufacturer will aim increasing production by feeding higher basic density woods, only remaining to find the levels suitable for him. Once again, restrictions may define the optimum quality of the wood. Once the restriction is solved, the optimum quality changes again. This is so simple, but just a few people are able to visualize these interactions, or to understand them!

Changes in wood quality requirements use to annoy forest breeders, because the pulp manufacturer's perspective is the current day, while the forest breeder's one is the long-term. Their ways of acting, as well as behaviors and arguments, suffer great variation as a function of this factor. It is mainly due to bottlenecks and restrictions that some pulp mills prefer to use wood of low (0.40 to 0.45 g/cm³), medium (0.48 to 0.52 g/cm³), or high (0.52 to 0.60 g/cm³) basic density. Such restrictions may be placed by the pulp mills themselves, or imposed by customers or even by forest areas (wood availability). It is for this reason that different market pulp manufacturers end up producing pulps that are not similar in terms of performance or quality.

4. <u>Specific consumption of effective or active alkali in the cooking process</u>

This property of wood is vital for the pulp manufacturer. It is the result of various other characteristics of wood, such as: lignin content, ratio of syringyl to guaiacyl in lignin structure, extractives content, hemicellulose content; besides also depending on the *Eucalyptus* species and the age of the tree. The less white liquor the wood requires to attain the desired degree of kappa number, the happier the pulp manufacturer becomes. In the current days, as a result of modifications to low-temperature and longer-cycle kraft cooking processes, demand for alkali for *Eucalyptus* wood delignification increased. Therefore, in some situations, the mills operate their lime kilns and their causticising process to the limit. For this reason, close attention should be paid to the woods presenting low consumption of effective or active alkali. They will be very welcome to supply the mills.

5. <u>Pulp production yield</u>

This is another vital technological wood characteristic. The higher the amount of pulp one succeeds in producing from the same dry weight of wood, the better the wood quality as to this parameter. This property is very dependent on the content and type of lignin, extractives, and holocellulose of the woods. Pulp mills are primarily built to produce pulp, not black liquor. Therefore, the more pulp a certain wood is able to generate through the same process, the better. It is also fundamental to determine the optimum conditions for its industrial processing. Some woods require certain cooking conditions, while other woods demand different conditions to attain the same kappa number.

6. Specific wood consumption per ton of produced pulp

This vital property is the result of many interconnected characteristics, both of the wood and its requirements in the process of its conversion into pulp: wood basic density, pulp yield, lignin content and type of lignin (S/G), hemicellulose content, degree of wood deterioration, fiber losses in the process, chip quality, chip contamination with bark, etc. In general, it is expressed in cubic meters of wood per ton of air dry pulp. The specific wood consumption per ton of pulp (either unbleached or bleached, each mill prefers one way of determining this) represents one of the most important slices of kraft pulp manufacturing cost. This cost is significant, even for low-cost wood producers. For this reason, it is one of the daily indicators for industrial process quality evaluation. It is also a tree selection parameter for genetic wood improvement for technological purposes. Any characteristics of wood that may impact on wood specific consumption become equally important for pulp manufacturers.

7. Dry solids generated for feeding the black liquor recovery line

This property becomes vital at mills presenting the capacity of their black liquor recovery system as a serious operational bottleneck. It depends on cooking liquor (active or effective alkali) consumption, on pulp yield, on the residual kappa number of the pulp, on the filtrate recirculation flows, on oxygen delignification filtrate recovery, etc., etc. At mills with surplus capacity in the black liquor evaporation and burning system, it is a property that is not even measured. At other ones, presenting serious limitations in these systems, it becomes the daily dream of horror or happiness of the operators and managers of the fiberline and the area of wood supply to the process. For this reason, many people do not understand why the demand for wood quality varies so much from pulp mill to pulp mill. It is only natural for them to vary, is it not?


Photo: Arauco Nueva Aldea recovery boiler

8. Wood lignin content and quality

Lignin is abundant in *Eucalyptus* woods, especially in those being planted in Brazil. While the lignin content is a remarkable advantage for charcoal manufacturing and using wood as fuel, the pulp and paper production area is interested in woods with lower lignin contents. We have come across total Klason lignin contents in wood ranging from 20 to 30%, that is a wide range of variation, for the commercial *Eucalyptus* species. The lignin content directly affects the conversion of wood into kraft pulp, as it impacts on alkali consumption, pulp yield, and generation of dry solids for the liquor recovery system. There exist species with recognized lower lignin contents, and the woods produced from them are very well-accepted by the pulp mills. *E.globulus, E.dunnii, E.maideni,* are outstanding species; whereas other ones, like *E.urophylla, E.grandis, E.tereticornis, E.saligna*, present higher lignin contents, above 25%, in their woods. The hybrid *E.urograndis* is also rather lignin rich in its wood. Understanding the lignification process of these species has been an object of much research since biotechnology may have tools to influence on the path of lignin formation. By controlling lignification, the forest breeder may determine the most correct ways towards developing *Eucalyptus* woods for energy, or production of pulp, or chemical products.

In more recent years the forest breeders have emphasized the studies of *Eucalyptus* wood lignin. Lignin is a vital characteristic for selecting superior individuals for hybridization and cloning.

In general, a reduction of 1.2 to 1.5% in the lignin content of wood corresponds to an increase in kraft pulp yield of 1%. Moreover, the active alkali charge decreases by 0.2 to 0.3% on dry wood basis for this same percentage reduction in lignin content.

There is a long path for the forest breeding to tread in this direction. There are so many natural genes available in the *Eucalypti*, that hybridization and cloning can very well impact very positively on lignin content, without the use of genetic modifications by engineering and transgeny. But these techniques may be also beneficial as to this aspect, since the lignin content and the type of it present good genetic heritability.

While in Portugal the purity and quality of *E.globulus* wood is passionately loved for the low lignin contents it presents; in Brazil the foresters are introducing *E.globulus* genes into the breeding programs through controlled hybrid production. In Portugal, the forest breeding is focused on increasing forest productivity; whereas in Brazil the target is to improve wood quality of the species and clones being planted. In other words, Portugal has good wood quality available with *E.globulus*, and Brazil, forest productivity. Just to remind of, there are situations in which *E.globulus* does not produce the optimum wood, since there is no such thing as an optimum wood for all paper products, do you remember this?

In Brazil, one of the very much appreciated forest indicators is the planted forest productivity, expressed in tons of bleached kraft pulp equivalently produced per hectare per year. This figure ranges from 9 to 16 adt/ha.year. Meanwhile, in Portugal, these values are situated between 6 and 8. Even with low volumetric increments, the *E.globulus* species distinguishes itself in equivalent of pulp produced per hectare.year due to its favorable characteristics of wood, such as: low lignin content, high S/G (syringyl/guaiacyl) ratio in lignin, high basic density, high hemicellulose content.

Speaking of S/G ratio, a lot of emphasis is being placed at present on its study. The molecular path of lignin formation and the environmental factors leading to these values are being intensively investigated. Lignin is a highly complex polymer, difficult to evaluate. It is hydrophobic and its derivatives upset pulp bleachability. For this reason, they must be removed for bleached pulp production. In *Eucalyptus* woods, the predominant groups are syringyl and guaiacyl. The higher the proportion of guaiacyl, the more condensed the "structural molecule" of lignin. These situations disfavor lignin removal by pulping and bleaching processes; whereas fragments and syringyl richer sectors are more easily extracted. Hence the even frenetic search for *Eucalypti* with high S/G ratios. Even within narrow ranges of variation, the S/G ratio offers advantages in the pulping process. Woods from clones or *Eucalyptus* species having a S/G ratio of about 3 – 3.5 are more easily delignified than other ones presenting a ratio value of 2. Unfortunately, *Eucalyptus urophylla* presents low values, of approximately 2, for this ratio, while for *Eucalyptus globulus* this ratio attains in some cases values of 4 to 6, a wonderful situation for cooking and bleaching this material. *E.urophylla* has been the basis of the forest breeding programs in Brazil, as it is a species highly tolerant of or resistant to such diseases (canker and rust) which are typical of tropical conditions. In addition, it is very plastic, so that it can be planted (or its hybrids) in all regions of the country, except for those where the cold weather or the hydrological deficit are very intense. Hence all the efforts are being made to create hybrids between *E.urophylla, E.grandis*, and *E.globulus*. These hybrids are expected to have the potential for volumetric productivity, basic density of wood, resistance to adverse conditions, and good conversion into bleached pulp (due to low lignin content and high S/G ratio). Everything that delights both sight and heart of the forest breeder and the users of the woods resulting from these crossings.

9. Hemicellulose content

The hemicelluloses complement the quality of the woods for pulp and paper production. For pulp production they must be retained in the fibers in order to preserve pulping yield. The lignin must be extracted and the cellulose and hemicelluloses preserved (as much as possible). As the bleached pulps do not contain any remarkable amount of lignin any longer (only some molecular fragments that barely interfere on brightness reversion), the hemicelluloses present are fundamental for pulp performance.

The hemicelluloses are also related to consumption of chemical reagents in the bleaching process, due to the formation of hexenuronic acids during kraft cooking. For this reason, they affect not only yields and performances, but also impact on costs, generate operational bottlenecks, and interfere with the end product quality.

So great an emphasis is placed on hemicelluloses, that they are at present, along with lignin and basic density of the woods, the most frequently analyzed parameters for the forest breeding of *Eucalyptus* trees. Unfortunately, researchers still remain very much on the surface of the whole process involved, rather than penetrating a little deeper. Only empirical methodologies are applied to measure both lignin and hemicellulose contents, informing very little about their constituents. This is something that should be studied further from now onwards, by applying better analytical techniques.

On the other hand, the empiricism in the evaluations also tends to increase, considering the present expeditious and simple techniques to correlate things of different kinds. Thus, almost everyone tries to evaluate close to everything by means of NIR – Near Infrared Spectroscopy – techniques: from lignin to moisture and basic density, as well as pulp production yields. Care should be taken in this respect, evaluating by NIR what can be done at screening level, leaving determinations of higher analytical quality to the properties that will define the quality of the wood of the genetic materials of the future.

10. <u>Wood extractives content and constituents</u>

Wood extractives are undesirable in pulping processes because they directly affect yield in terms of conversion into pulp and may be transformed into contaminants of products and equipment's. The extractives content of *Eucalyptus* woods varies as a function of the *Eucalyptus* species, the environmental conditions, the age of the tree, the forest health, etc. The most common values range from 1.5 to 6%, a huge range of fluctuation. There are several methodologies for extracting these compounds – hence the denomination extractives. They are polyphenolic groups, waxes, fatty acids, resins, soluble carbohydrates, etc. All of them combine to form a very little known soup, which affects not only the pulping process and the quality of products and processes, as some of them have even an environmental impact on effluents and aquatic life. The extractives most commonly determined by expeditious and simple methodologies are those using water, caustic soda, alcohol, dichlormethane, toluene, and ethyl ether as extracting reagents. Now, as related to the structure of these extractives, their composition, and most important characteristics, these are little studied or evaluated aspects. Also in this respect there is a long path to tread in terms of optimization.

11. Wood ash content and constituents

Wood is mineral element rich. Most of these elements belong to the constitution of wood itself, but there are also those contaminating the logs at handling and transportation (soil, sand, clay, dust, etc.). When the forests are harvested, the minerals coming from the soil are exported to the mills. In general, minerals are well-identified in wood, their determination is relatively simple. The ash content is measured (by burning the wood) and the contents of calcium, magnesium, iron, potassium, silicon, manganese, etc., are determined in the ashes. The ash content of *Eucalyptus* woods varies from 0.3 to 1%. As a function of the trend towards water cycles closure at kraft pulp mills, the ash content and its components are becoming also very important, due to the accumulative characteristics of some ions in the manufacturing processes, causing incrustations, dirt, precipitates, etc. The ash content and that of its constituents vary considerably among the *Eucalyptus* species. Therefore, it is an interesting characteristic for optimizing the quality of the wood and processes. So great has been the concern, that wood ions that were not even noticed before became vital at present: iron, silicon, chlorides, manganese, calcium, potassium, etc. Some of these ions are deleterious to the processes, either in the bleaching process, or in the black liquor recovery system. In addition, when they are removed from the soils, the latter impoverish in fertility. Woods with low ash and mineral contents are important to both environment (soil quality) and industrial processes. These mineral elements are known at the mills as non-process elements. These non-process elements deserve pulp producers' and equipment manufacturers' utmost attention. For some users of pulps, they are also vital (especially of pulps used to manufacture chemical derivatives of cellulose).

Fantastic natural mineral elements present in the soils end up turning into sources of problems at the mills and into pollution of effluents, solid wastes and residual gases. At present the mills are working to reduce the presence of mineral elements, both in terms of soil contamination of logs and in the ash content of wood itself - i.e. in its chemical constitution. Tree bark is also very ash rich. When chips are very contaminated with bark, these sorts of problems increase. We have written two interesting chapters for you to read in our **Eucalyptus Online Book**, one of them about *Eucalyptus* tree bark (http://www.eucalyptus.com.br/capitulos/capitulo_casca.pdf), and the other one on the mineral elements present in wood and their environmental relationships (http://www.eucalyptus.com.br/capitulos/capitulo_minerais.pdf). I will feel very happy if they will be useful to you. They are in Portuguese, but translations to English, when become available, will be posted at: http://www.eucalyptus.com.br/available.html

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QUALITIES DESIRED IN PLANTED *EUCALYPTUS* FOREST TREES

Thanks to the excellent technological development and to much R&D in countries like Brazil, South Africa, Portugal, Spain, Chile, Australia, among others, *Eucalyptus* trees attained the status of super-trees and the planted forests either. At a first technological moment, some decades ago, the effort resulting from genetic improvement was applied, all of it, to develop wood volumes in the plantations (productivity in volume of wood). Right after there occurred a migration to weight of wood, associating volumetric productivity with basic density of the woods. Many researches have been conducted to improve the forest seed quality, the silvicultural variables, the forest environment, and the forest interactions. Thanks to the development of technologies for gains in productivity, the planted *Eucalyptus* forest based industry became competitive and victorious in several regions of the world.

At a second moment, a new technological jump was made by the planted forest sector from the ’80s onwards. The combination of hybridization and cloning techniques on a large commercial scale afforded quick and persistent gains - not only in volume and weight of the trees - but also in numerous technological characteristics of wood. Those characteristics were much more difficult to optimize by the traditional techniques of selection of superior individuals and controlled crossings for seed production in orchards.

The history of *Eucalyptus* plantation forestry drastically changed a little longer than 2 decades ago. The unit costs of wood production were reduced and the trees became more productive and uniform. In Brazil, the average productivity expressed in m^3/ha.year increased from 20 - 30 to approximately 45 - 55 in very few years. The variability of the forests in their main indicators also narrowed, although there are potentialities for additional gains in terms of uniformity, as already mentioned in this chapter.

Thanks to the sum of high productivity rates in the forests and better wood quality, the *Eucalyptus* forests became victorious and admired in the forest world. They conquered a position as producers of quality wood for numerous uses: pulp, paper, saw-timber, wooden panels, furniture, plywood, structures for civil construction, posts, etc., not to speak of the unquestionable energetic use and additional potentials (firewood, biomass, and bio-fuels).

Definitely, the plantation forests and *Eucalyptus* woods have improved significantly over an extremely short period of time. New gains are now expected due to genetic engineering technologies and forest biotechnology. Objectives and evaluation methodologies are becoming more and more sophisticated, the *Eucalyptus* genome is practically disclosed, the relationships between genetics and environment are becoming better and better known, and the techniques of safe gene transfer as well. In sum, the moment is very appropriate, there are no doubts left that much was conquered. However, there is even much more to be done, including some difficult tasks.

When looking for superior *Eucalyptus* trees for the forest breeding and wood quality programs, the forester focuses his attention on some vital characteristics in order to be successful. He intends to orient his trees for commercial purpose and therefore he focuses his attention very much on productivity, efficiency, and quality, more or less as pulp and paper manufacturers, each of them in the respective area of influence.

Every year the companies introduce new improved genetic materials for commercial planting. They want their forests to show superior trees in several vital characteristics, both in terms of forest and technological development. We have already seen what it is aimed at in *Eucalyptus* papers, fibers, and woods. Everything considered to be vital was displayed in the lists specifying "<u>the eleven most vital characteristics</u>" of papers, pulp fibers, and woods. Now there remains to present to you the list of the eleven vital qualities of the planted forest trees.

"The eleven vital characteristics of *Eucalyptus* forests for commercial production of wood"

It is easier to present this list to you, as it is self-explanatory with regard to its items:

1. <u>Commercial volume of the trees</u>: resulting from a combination of tree dimensions, such as breast height diameter (BHD), commercial height, and shape factor of the trees.

2. Commercial weight of the trees: a direct relationship between commercial volume of the tree and wood basic density.

3. Percentage of bark on the trees: represented by the volumetric relationship between bark volume and the commercial tree volume. The bark percentage may also be defined as weight ratio between the same items.

4. Silvicultural quality of the tree: represented by its shape, trunk (stem) uprightness, architecture of the crown, leaf area index, type and size of branches, etc.

5. Plant resistance or tolerance to pests and diseases: it is important to find genotypes capable of offering resistance or even showing some tolerance to pests and diseases, since they represent loss of productivity, or even leading to forest lack of viability in a given region. After detecting the resistant or tolerant individuals, even if they are not productive, there are good chances to transfer these resistance genes to productive individuals. Many techniques are used, including the inoculation, to check whether or not the resistance to the pest or disease has been incorporated in the improved genotypes.

6. Tree resistance or adaptation to climatic and geographic conditions: the following stand out: hydrological deficit, cold weather and frost, strong winds, flooding and excess of water in the soil, declivity, altitude, etc.

7. Efficiency in using water and nutrients: they refer to the capacity of the trees to produce more wood with lower water and nutrient consumption (nitrogen, phosphorus, potassium, etc.). In general, this is expressed as weight of wood formed by weight of mineral present in that same wood. Or by water lost by evapotranspiration. At the forest hydrology side, other water consumption indicators are in full development.

8. Photosynthetic efficiency and capacity to allocate organic matter in the part of interest of the tree (trunk, for example)

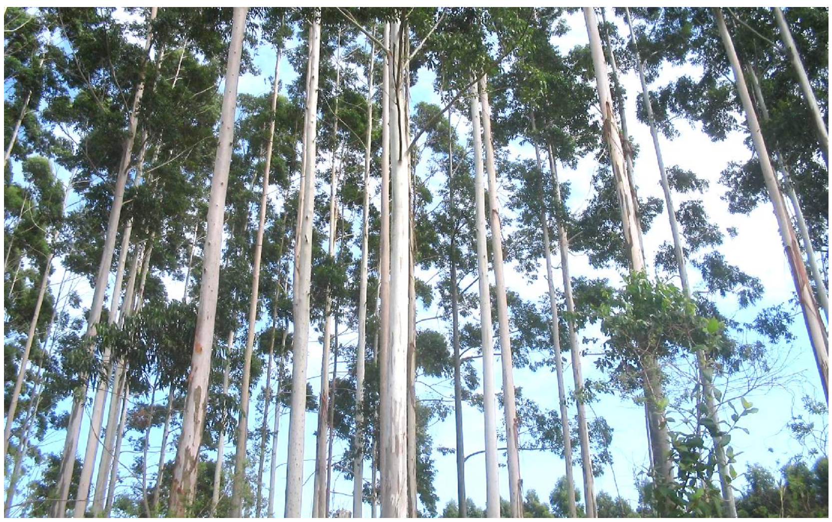
9. Typical forest qualities: accelerated seedling initial growth, weed competition overcoming, adaptation to slope lands, capacity of occupation of the physiological available space, etc.

10. Rooting ability of cuttings, to allow efficient cloning multiplication

11. Clone ability to overcome the challenges of growing as clonal forest stand

The combination of these variables has allowed the forester to develop some indicators of technological efficiency for his forests. Some of them are very appreciated by the investors. Among these indicators the following ones stand out: productivity in m³/ha.year; productivity in tons of wood per ha.year; productivity in equivalent tons of air dry pulp per ha.year; number of trees to compose one solid cubic meter of wood; number of trees per air dry ton of pulp.

These indicators are carefully followed by forest breeders, operational managers, and by a wide entrepreneurial public (executives, bankers, shareholders, etc.). The attention paid to *Eucalyptus* forest performance is complete, in special to the forests being developed by the sector leading companies. Leaders are use to be admired, but also copied and imitated, is it not so?



Eucalyptus forests and *Eucalyptus* forest products impart, most of all, competitiveness to the industries using these raw materials. After all, a new and modern "greenfield" pulp or paper mill can be acquired on the supplier market and set up in any place of the world. The large suppliers of technologies and machines are ready to sell it, regardless of where the mill will be established. The required capital can come from shareholders, government financing agencies, from stock exchanges, etc. Such a mill can be constructed and operated in Brazil, Indonesia, Spain, Uruguay, Chile, etc. Result of this simple competitiveness evaluation: the forest base is one key issue - its productivity, the quality of the wood, and the costs of that wood are definitely the factors guaranteeing the pulp mill's competitiveness.

Eucalyptus trees are nowadays the most popular and victorious raw materials for pulp and paper production. Besides the outstanding technological properties of the trees, woods, pulps and papers, they all have potentials for even further improvements. There is a wide-ranging improvement process in development, but often there still remains the need of improved dialogue and understanding in the various areas involved in this valuable network. With this chapter, I hope to help improve this between-parties understanding, as well as the dialog among them. With the network optimization, some of the advantages can also be transferred to the end customers, not only in terms of prices, but also as to the qualities and operational performance variables. All this is very positive and relevant, but nothing of it was or will be achieved for nothing. A lot of effort was made in terms of R&D, innovation, courage, determination, and willpower. And a lot more will be.

To enable you to understand a little more what these technological forest gains have represented, we will show you a simple table, comparing those previously mentioned vital forest indicators. The differences in chronology only correspond to a range of 30 to 35 years. I, on my part, had the privilege and the wonderful opportunity to be present and to participate in this whole process during these few decades, since I got my academic degree in silvicultural agronomy from ESALQ/USP in 1970, which is the year in which the following little table of mine begins.

Commercial forest stands - planted *Eucalyptus* forests	**1970 - 1980**	**2000 - 2010**
Productivity (m³ wood/ha.year)	20 - 30	40 – 55
Productivity (t dry wood/ha.year)	10 - 18	20 – 30
Productivity (adt pulp/ ha.year)	5 - 7	10 – 16
Number of trees/m³ wood	6 - 12	2.5 – 4
Number of trees/adt pulp)	30 - 40	10 – 18
Total hectares of effective *Eucalyptus* planting to supply a mill producing 1 million tons of pulp a year (in 1,000 ha)	145 - 200	75 – 100

More productive trees are physiologically more efficient and they lead to better performance in the forest operations. The higher the volumes of the trees, the better and more efficient the operations, and the operational costs of production will be lower. In addition, when forests grow more they allow savings to be made in: number of seedlings/hectare (as a function of the increased spacing), lower agrochemical consumption, higher productivity rates of the machines at forest harvesting and transportation, higher ratio of solid wood m³ to stacked wood m³, etc.

More productive trees are also much more efficient in terms of water and nutrient consumption. They manage to produce more and better with the same given quantity of these inputs than trees of worse forest performance. The sum of all these eco-efficiencies ranks the planted

Eucalyptus forests as of low level of environmental impact per unit of produced wood. This applies both to consumption of natural resources per unit of wood and the need for a much smaller area to be planted in order to produce the same amount of wood to supply a pulp or paper mill. Hence, my friends, the importance of the forest technology applied to *Eucalyptus* trees – it has been the key to success by opening the doors to the companies of the sector at global level.

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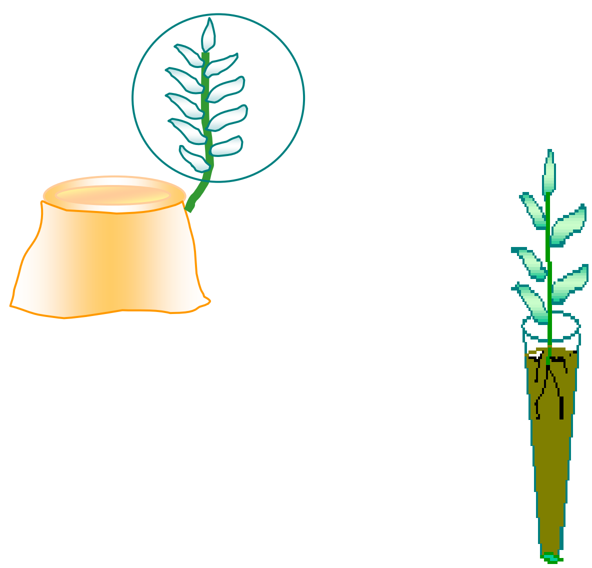
MAJOR TECHNOLOGICAL FACTORS TO CONSIDER WHEN OPTIMIZING THE *EUCALYPTUS* PAPER PRODUCTION CHAIN "FROM THE FOREST TO THE PAPER"



Source of drawings: VCP, 2005

Striving for the continuous optimization of the value network (starting in the forest and ending in the use and recycling of paper) demands a lot of study, knowledge, attention, and work. Numerous are the opportunities for improvements, and there are many links to work on. In case there is no suitable coordination, numerous types of conflicts may occur, among which the most usual ones are those involving interests and vanities. When the optimization is striven after only within each network knob, there exist numerous chances that much of the work carried out is in vain or lost. For example, if the forest breeder does not know what the papermaker needs in his products, he may choose new clones to introduce into his forest planting program, which will throw down the whole optimization work the papermaker was doing with his present pulp raw material. This kind of situation is unfortunately common: each one caring about one's own "nook", with no concern about considering the whole network. This fact indicates once again the need for approaching and dialog among the involved and interested parties.

Taking into account that numerous are the factors affecting this whole and intricate network of interrelations, I dare to report the eleven items I consider to be vital to be observed and monitored, evaluated, and optimized, when the target is the continued, jointly and concomitant improvement of *Eucalyptus* forests, woods, pulps, and papers.

"The eleven vital items to be optimized in the *Eucalyptus* paper production network – "from the forest to the paper "

With a directed focus to the *Eucalyptus* forest to paper value chain, I consider as fundamental the doubled (or tripled) attention to the following eleven items:

1. *Eucalyptus* species*;*
2. Clone (intra or inter-specific) being vegetatively multiplied;
3. Forest harvesting age;
4. Silvicultural and forest management practices;
5. Main defects presented by the woods;
6. Deformations and fines present in pulp fibers;
7. Supply of wood to the pulp mill - (wood blend or wood mix);
8. Supply of pulp (pulp fibers) to the paper mill – (pulp blend or pulp mix);
9. Type of paper mill (integrated or non-integrated);
10. Industrial pulp manufacturing processing conditions;
11. Industrial paper manufacturing processing conditions.

Our **Eucalyptus Online Book** and our **Eucalyptus Newsletter** will still contain several further chapters and technical mini-articles which will be specific about several themes interrelated with the above eleven topics, among which:

- Anatomy and quality of *Eucalyptus* pulp fibers;
- Quality and anatomy of *Eucalyptus* wood;
- Abnormal or defective *Eucalyptus* woods ;
- Role of fines in paper manufacturing;
- Pulp fiber drying and effects on paper quality;

- Silvicultural and technological characteristics of the main *Eucalyptus* species;
- Mixtures of pulps;
- Etc., etc.

In this specific section, I will focus on some key and vital points, which you should stick to in your improvement and optimization programs. You should also understand their variations and inter-dependencies. Thus, and to carry it out, the technological evaluation areas should have suitable human resources and testing equipment, otherwise there will be innumerous chances to operate below the optimum conditions in the processes and with poor performances of the raw materials. This will increase wastefulness, inefficiencies, ineffectiveness, and costs.

In the following pages you will find some fundamental considerations about these eleven main items:

1. *Eucalyptus* species

The decision about which *Eucalyptus* species should be used in our plantations may add competitiveness to or subtract some of it from the whole network in question. The initial decision on the species to plant is ruled by merely silvicultural criteria, or those of adaptability to a certain region (climate, soils, pests, diseases, etc.). Some typical characteristics of each species in its resulting woods and pulps are sometimes forgotten, such as: lignin content, S/G ratio in lignin, basic density of the wood, frequency and dimensions of vessel elements, hemicellulose content, specific wood consumption per ton of pulp, content and type of extractives, fibrous population of pulp fibers, etc. We may be able to have excellent and adapted species, marvelous forests and trees, but a pulp which is little attractive to the paper customers, which is perhaps not a failure on the market, but it will have to fight fiercely to conquer and keep customers. In situations like that, in which a technologically not very suitable species is defined for planting the forest and there is no way of getting back, it is better to focus very well on what pulp mill we need to get the most from the woods, in order to try to minimize the impacts of wood quality.

There are several examples of *Eucalyptus* species with well-differentiated characteristics in woods and pulps, which may interfere with both pulp and paper manufacturing processes.

Have a look at some cases:

- *Eucalyptus grandis, Eucalyptus saligna*, and *Eucalyptus nitens*: these are species that in general produce woods of low basic density (0.40 to 0.48 g/cm³) in the forest plantations. Without a suitable genetic improvement they will end up requiring high volumes of wood as specific consumption to produce one ton of pulp. The pulps produced will present high fibrous populations, which may impair stock drainability and dewatering at paper mills. However, this favors opacity and fiber bonding, as we already know.

- *Eucalyptus deglupta*: a species showing a very low basic density in the woods of plantations and presenting a high proportion of vessel elements of larger dimensions.

- *Eucalyptus urophylla*: a species with lignin rich wood (practically 30% of the weight), low S/G ratio in lignin, high adaptability to climatic, especially tropical conditions. Ideal for energetic uses and hybridization in forest breeding programs.

- *Eucalyptus globulus*: a species with high hemicellulose and low lignin contents in its woods, besides a high S/G ratio. Due to its higher basic density in the wood and easy delignification, it is a raw material pulp manufacturers appreciate very much. Paper manufacturers also appreciate its pulps due to easy drainability and good web strengths at low refining levels.

- *E. paniculata, E.cloeziana, Corymbia citriodora*: species acknowledged by the high density of the wood, for which reason they require special conditions in the chip preparation area.

- *Eucalyptus dunnii* and *E. maidenii*: species of good growth in southern regions, with woods of medium density and low lignin contents.

As mentioned earlier, each species has woods with own forest and technological characteristics, which must be known in order to be able to carry out the intended optimization. By means of the hybridization techniques and controlled crossing, followed by cloning of the selected superior individuals, one species can transfer genes to these hybrids. This allows excellent combinations in the characteristics of forests, woods, pulps, and papers. This agrees with the ancient Chinese wisdom: "each option may be a threat or open up an opportunity".

In view of the large number of *Eucalyptus* and *Corymbia* species, amounting to over 600, the options for optimizing the network extending from the forest to the paper markets are fantastic. In addition, there are still ecotypes, varieties, subspecies, etc.

Evidently, by varying the species we will get enormous chances to vary the quality of the wood and the operational conditions of pulp and paper mills. What we need is to tame all this variability in our favor: to reduce variability, increase uniformity, get the advantages offered by each species, and optimize the manufacturers' vital physiological requirements (qualities, productivity rates, and costs).

We have already seen that there are several vital characteristics to define the qualities of woods and pulp fibers for paper manufacturing. Each of these characteristics and the combination among them may be more adequate for a certain manufacturing process or paper grade. A single characteristic is hardly sufficient to define the quality of a raw material. Hence the need to know well each one, as well as the interactions between them.

With regard to the *Eucalyptus* species, it is well-known that:

- Each species has forest and pulp and paper production potentials which are sometimes hidden and which must be found.
- Each species also has significant limitations as to some of its vital characteristics. For instance, we will hardly come across *Eucalyptus urophylla* woods with total lignin contents around 20%. Or else, *E.grandis* woods with basic densities of 0.60 g/cm³ at 7 years of age, or *E.grandis* natural trees resistant to canker (aggressive disease under warm climate conditions).
- Each species may present some relevant vital characteristic, which can be incorporated into forest breeding programs;
- New and continuous gains may be obtained and safely introduced from other species, provided that heritability and variability of these characteristics are well-known.

Most *Eucalyptus* species have short, narrow, and rigid fibers, and their woods are easily delignified and converted into pulp, as a function of which the manufactured papers use to acquire some properties which are vital for their use (porosity, bulk, water absorption, etc.). Hence the need to know well each material.

The differences between the species allow the genetic base for the *Eucalypti* to enlarge. We are far from using the whole of this forest and wood potential offered to us by Nature. As a complement to this fantastic genetic base, we have technologies allowing us to take advantage of the best characteristics, as many of them present proven heritability and are propagated in the cloned trees.

It is curious that the following question always arises: "which is the best *Eucalyptus* species for pulp and paper production?" Some more hurried persons answer quickly that it is the species used by them, or their favorite clone. The answer should not be immediate, as it depends on numerous local factors, industrial processes, and end products and users. There are no doubts that some species are successful and may still offer even better hybrids. The following ones distinguish themselves among them: *E.globulus, E.grandis, E.nitens, E.saligna, E.dunnii, E.camaldulensis, E.viminalis, E.urophylla, E.maidenii, E.regnans,* etc. The most successful inter-specific hybrids are in Brazil: *E.urograndis, E.urosaligna, E.uroglobulus, E.urocamaldulensis,* etc. It should be taken into consideration that these just mentioned names of hybrids are fancy names. The correct way would be to say for example *E.urophylla x E.grandis*, and even so the order of the names depends on which species had the mother tree (ovule donor – firstly) and which had the father tree (pollen donor – secondly). Then, a hybrid obtained by controlled crossing using *E.urophylla* pollen and *E.grandis* ovules should be called *E.grandis x E.urophylla*.

It should be also remembered that when obtaining heterosis or hybrid vigor by hybridization (mainly for growth in volume), variability of phenotypic expressions is also increased when the plants are propagated by hybrid seed planting. For this reason, plantations of seedlings from hybrid seeds are made to select the best individuals, which after clonal testing can represent genetic materials for new clones to be vegetatively propagated (cloning technique). It is this technological stage that the sector of planted *Eucalyptus* forests dominates and uses very well. Enormous efforts are made in terms of generation of new clones (hybrids, and in some cases intra-specific - within the same species).

However, not all hybridization leads to positive heterosis or improvements in quality. There may even occur values of some qualities at worse levels than the values of the paternal generation. This is due to genetic abnormalities in the crossings.

Anyway, what matters is that the limits of variability presented by many species force the forest breeders to search for extreme values for certain characteristics in other species. After finding them, they try to introduce them into the traditional species. In this context, inter-specific hybridization and cloning have cooperated to do what Nature alone would have many difficulties to carry out. Of course, a species may have little chances to cross and hybridize with another one (due to geographic location, *E.urophylla* and *E.grandis* would hardly have crossed in a natural way). Controlled crossings only allow doing in a natural way what Nature would be able to do, but which might take centuries, or maybe never happen.

A successful case in terms of hybridization was that obtained by crossing *E.grandis* and *E.urophylla* species. This combination has always distinguished itself by providing individuals superior in growth (positive heterosis) and presenting resistance or tolerance to serious diseases of

Eucalyptus trees in tropical or semitropical regions. For this reason, it represents at present the dominant material being planted in Brazil, serving as foundation for the vast majority of the forest companies in the country. However, this "sameness" awakes a certain discomfort to me due to the excessive narrowing and flattening of the genetic base and of the offer of new individuals with extreme and favorable vital characteristics.

Many mills are located in certain regions and grow too quickly in production capacity. In many cases they are not able to obtain in that place the wood of their dreams in the required amounts - they are obliged to obtain a part of their supply on the market. In such a case, they end up having to get along with species being planted by third parties, which were not exactly those desired for their processes. Other mills are established in regions where the traditional species are not perfectly adapted due to situations such as: hydrological deficit, cold and frost, too poor soil, pests or diseases, etc. They are also obliged to look for other species or genes allowing them to adapt their forests to those uncommon conditions. Therefore, this kind of turbulence with regard to species and genetic materials being used by forest planters will always exist, so that this is something we should not find strange!

It is easy to understand that situations like these ones affect the quality of the wood and its performance at pulp and paper mills. Then, it is also easy to understand why there is not an universal *Eucalyptus* pulp, as well as why pulps from distinct manufacturers are somewhat different in their papermaking performances.

2. <u>Clone (intra or inter-specific) being vegetatively multiplied</u>

There have been many surprises in the forest and industrial performance of apparently similar genetic materials. Even if working with clones obtained by crossing two same species (*E.urograndis*, for instance), the pulp and paper making and forest-related behaviors may be rather different among clones. When a certain pulp mill suits its process to the wood of a given clone, it tends to find it strange when the clone in the supply of its woods is changed. The operational conditions must be realigned and readjusted and sometimes this causes difficulties and contrarieties. The most usual situation is that complaints are made whenever the wood of a new clone enters the process. The new clonal wood ends up "being blamed" for the losses of production or the appearance of new bottlenecks. This occurs until the time that new magic recipes and potions are reestablished and recreated. For this reason, there should be a very suitable analytical service of pre-evaluation of the wood quality of each clone, even before it is propagated and commercially consumed. Then, these procedures should be carried out both at the moment of clone selection and a little before its commercial use (by means of forest harvesting and sending the wood to the mill). Thus, the mills will have relevant information about what should be adjusted in their process, such new situations as: higher basic density of the new wood, higher lignin content, lower hemicellulose content, etc. If this is very valid for the pulp manufacturer, it should be equally valid for the papermaker - at the moment they will receive pulp from a different clone or genetic material. Then, it should be observed that the decisions made in the forest area impact on the whole paper production network.

Which would be the characteristics to be assessed by these preliminary tests? We have just shown you in this chapter the lists of the eleven vital ones for paper, wood, and pulp fibers. Some of them are more relevant for certain mill designs and pulp or paper grades. Then, we need to well know which are our wood and pulp fiber customers' main requirements. Which are their production objectives? Which are the vital properties required in their products, in order to value them? Which are their operational bottlenecks hindering the better performance of their raw materials? Has this become clear? I am repeating it in order to better clarify any eventual doubts.

3. <u>Forest harvesting age</u>

The age of the trees on the occasion of forest harvesting is one of the most efficient ways of differentiating wood and pulp quality. Practically, numerous vital characteristics of woods and fibers are affected by age, by the aging of the trees. The tree, as a living being, grows and passes through various periods of juvenility, until reaching the grown-up and mature age. Commercial *Eucalyptus* forests, especially in Brazil, are being harvested at earlier and earlier ages (at 6 years, more recently). At that stage, the xylem is still young, the wood has not yet reached the best development of important vital characteristics, such as: fiber length, fiber wall fraction, basic density of the wood, lignin content, etc. In such situations the fibers collapse and hydrate more easily. They are (each of them) less heavy due to the facts of being shorter and having a thinner cell wall. This will impact on the fibrous population, fiber collapsibility, and papermaking performance. We may compensate this by selection of clones which achieve better results at earlier ages - this is feasible possibility.

Another way of improving some properties of the pulp fiber is by lengthening the forest rotation (period of time between planting and harvesting). By letting the trees grow older we will be favoring paper web drainability and dewatering, bulk, porosity, softness, water absorption, etc. On the other hand, as in every matter there are always pros and cons, strengths depending on fiber bonding, as well as opacity, will be impaired.

One thing is absolutely certain: the foresters and the companies would like to see their forests growing at dizzying rates and to be able to harvest the forests as early as possible. To advance earnings and sales is the undertakers' and managers' dream. Forest productivity with sustainability is the forest engineers' dream. This short rotation forest model is very good for cash flows and wood supply, but not so good for certain wood and fiber quality requirements. If we go on working according to this line of reasoning, we will be soon harvesting infantile forests, under the age of 5 years, for pulp manufacturing. The impacts on wood and fiber qualities will be certainly great, as well as on forest soils, on the environment, and on biodiversity.

Genetic breeding, hybridization, and cloning are able to minimize this kind of impact on wood quality, by working with genotypes leading to trees of denser wood, even at infantile ages.

Based on my thoughts and ideas, I see the age of the tree as a forest-related, environmental, and technological opportunity. To postpone planted forest harvesting in Brazil to the age of 8 to 10 years may help improving several vital properties of wood, pulp, and paper, both as far as product qualities and operational performances are concerned. I am not speaking about senior, very old trees, I am just referring to such ages of theirs when their woods will be at a possibly optimum level of their pulp and paper making characteristics. Then, we are speaking of optimizing the technological quality of woods and fibers, and at the same time the productivity and cost indicators, among which the following can be highlighted: productivity in tons of air dry pulp per hectare.year; forest plantation costs; wood production cost.

The use of over-mature trees should be avoided, as their woods may become much richer in extractives and mineral salts, their wood may present high basic density and low water permeability, making it difficult for the cooking liquor to penetrate. The chipping, cooking, and bleaching conditions may be definitely impaired. Therefore, we are only speaking of "avoiding the extremes of 5-6 (too young ones) and 12-15 (too old ones)", for Brazilian most frequent cases. When doing this, the forest area can be still contemplated in a very qualitative way.

There are very few research articles showing what happens to the *Eucalyptus* wood quality at intermediate ranges of age, from 7 to 10 years, as far as Brazilian conditions are concerned, not to speak of woods of second and third cycles, for which research work is almost non-existent. If something exists, I have no knowledge of it.

One thing I can guarantee you: "the optimum age for pulp production must depend on the species, on the place it is being planted, on the production process and its bottlenecks, and on the quality desired for the end product". With a sound economic and technological evaluation we will be able to better understand and decide which is the optimum age. However, it is important to focus the by network, instead of only the forest area. Often the forest area itself forgets that later harvesting entails avoiding competition among the trees at early ages. This is achieved by increasing tree spacing. The fantastic results that Veracel Celulose manages to obtain from its clonal *E.urograndis* forests, planted on the basis of 4x3 m spacing, which results in 12 square meters per plant, are very well-known. Much less is spent on planting (less soil preparation, fewer seedlings, etc.), and excellent volumes are obtained at later harvesting ages (500 to 550 m^3/ha at 10 years of age). Curiously, people know, but few are copying this successful model.

I am also concerned about the exaggerated emphasis placed by some beginners in forestry on reducing the forest harvesting age. It may seem fabulous as a business, but this is very dangerous for the pulp, the paper, and the environment. I have recently written a mini-article about this subject, calling it "Managing *Eucalyptus* Plantation Forests for Enhanced Sustainability". If you want to make me happy, read it at one of ours Eucalyptus Newsletter: http://www.eucalyptus.com.br/newseng_jan09.html#quatorze .

4. Silvicultural and forest management practices

The tree, as a living being, responds very well to silvicultural treatments over the course of its development. Practices like fertilization, irrigation, control of light and useful space per plant, pests and diseases combat, weed competition control, etc., are reflected in more vigorous growth and higher forest productivity. Growing healthier, the tree gives birth to a larger volume of more uniform wood. Although there are references that all growth speedup practices may cause a loss of basic density of the wood, this fact can be counter-balanced by choosing genotypes for cloning presenting appropriate basic density in the wood and at the same time suitable levels of forest growth. It should be also remembered that basic density is not the only factor to be monitored and optimized.

Well-cared forest stands may yield excellent increments in volume, weight, uniformity, costs, and technological quality of the wood.

There are not many articles in the literature showing the influences of silvicultural treatments on *Eucalyptus* wood and pulp quality. But this does not disturb the forest breeding programs, as when monitoring the basic density, other properties it correlates with can be estimated as well.

Now, the type of forest management (clear-cutting in coppiced stands at an early age, or multiple purpose tree management with intermediate thinnings) may considerably affect the qualities of the woods. The first one generates a sole product, two at the most: wood for pulp and thin trees and short logs for energy; while the multiple purpose tree management generates differentiated assortments, with woods obtained at different ages. Something that complicates the wood quality management a little further. It is up to the managers and technicians to make adequate choices to optimize the demand of the different interested parties for the different wood qualities.

5. Main defects presented by the woods

Logs abandoned in the forest – Decayed and inappropriate wood for the mill

The user of the wood is often far from it, from its origin, and from its intimacy. Such a distance may be geographic, or characterized by the manager's complete lack of presence to look at and talk to that wood. Many technicians do not follow with due care the life of the trees and the way in which their bodies are formed in the forests. The same problem occurs at the mills, the logs are stored and just a few technicians take a little bit of time to see them and "talk" to them.

Many defects result from this absence of the managers, other ones from carelessness with the own wood. Following are the main types of defects in the woods:

- Wood from trees that suffered the action of fire (forest fires);
- Defective woods due to the incidence of diseases or pests (rust, canker, boring insects, termites, etc.);
- Decayed wood due to long periods of inadequate storage. Unfortunately this is a very common defect at mills and in woods stored in the forest. The problem may happen both at logs and wood chips levels.

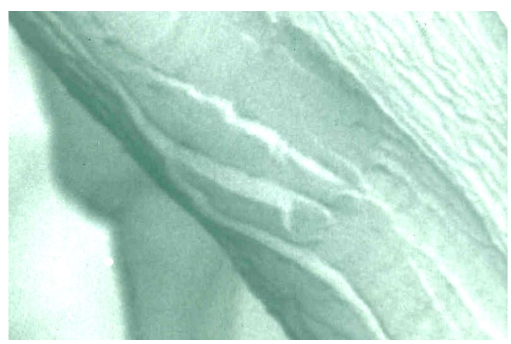
- Tension wood caused by strong winds, by pronounced slope in the location where the forest was planted, etc.
- Wood with resin exudation due to wounds of several kinds (mechanical or diseases);
- Wood from thick branch insertion into the stem (also known as "knots");
- Etc.

Defective woods present irregular performance, which is in general worse in pulp and paper manufacturing. The most usual alterations occurring in the process are as follows: cooking and bleaching difficulties due to increase in extractives or lignin content; pulp yield losses; paper web strength losses; drainage difficulties on the papermachine due to the high proportion of tension wood, etc., etc.

In case the technician responsible for wood quality control is not paying due attention to the condition of the wood entering the mill, he may be surprised at the low quality, higher variability, and generalized aggravation of the pulp and consequently paper quality indicators, in addition to the losses in operations, raw materials and costs.

6. <u>Deformations and fines present in pulp fibers</u>

Curled and spun fibers



Cell wall micro-fissures

A lot of attention should be paid to fiber deformations and defects. We have already spoken about this, but this is a topic which became more prominent when washing and dewatering presses were introduced into pulp and paper mills. Curled, spun fibers with fissured walls, etc., present differentiated behaviors at paper manufacturing. Such deformations have little to do with the quality of the fibers in the trees, except in case of tension woods or sick trees (canker, for instance). Almost all deformations originate from the pulp converting and the paper manufacturing processes. The intense movements which the fibers are submitted to are responsible for these phenomena, as well as fiber pressing and crushing. Quick drying, refining, mixtures of chemicals, etc., are also sources of fiber deformations. There exists rather reliable equipment for these measurements.

Deformations impact on the individual fiber qualities and on the properties of the paper. Frequently the technician is not informed about the deformations, tending to associate the papermaking performance of his fibers with the quality of the wood. This may be very malign, especially in decisions that may come to be reached in the optimization process. Thus, we will be attributing to the wood a cause it is not responsible for.

Also the presence of fines accumulating at paper mills impacts on the properties of the produced paper. Also with regard to this problem, variations due to disturbances or process-related causes must be distinguished from those due to wood or pulp fibers.

7. Supply of wood to the pulp mill - (wood blend or wood mix)

Almost always the pulp producer needs to blend woods of different species, clones, or characteristics, in order to supply his mill. This may involve distinct *Eucalypti* woods, but may even concern woods of other genera (*Pinus, Acacia, Mimosa*, etc.).

Therefore, to the question "is it possible to blend different species to manufacture pulp?", the answer is Yes. We started this chapter by speaking precisely about this - i.e. that the pulp and paper sector relies on a wide variety of raw materials. Situations characterized by either a single species or a single clone are just a few.

In Brazil, the *Eucalyptus* pulp production sector is already doing for years the management of the wood mix, in order to try to homogenize its supplies. As many mills are short of wood, the solution found has been to control the inputs, in order to make the process and the outputs more stable and uniform. For market pulp production, the mills bump against stricter and stricter specifications. Therefore, and to avoid surprises, one should try to mix very well-known woods, which are not very different in quality. For example, low basic density woods (*E.grandis, E.saligna*) should not be mixed in the same digester with woods of very high density *(E,paniculata, E.tereticornis, Corymbia citriodora*). If this is done, difficulties will appear and they will be worse if these proportions of woods will vary. In spite of the fact that sometimes the pulp qualities are even interesting due to the blends, the difficulties will appear in cooking, bleaching, drying, etc.

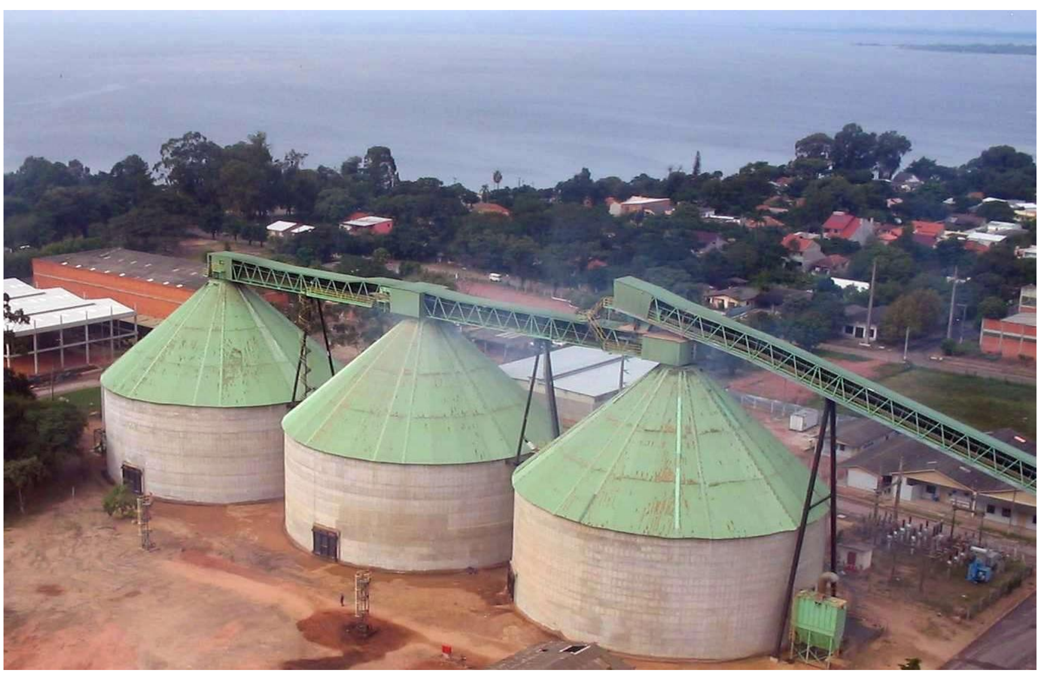
To save the most uniform pulp quality, as well as stability of the industrial processes, people are used to dose a more constant wood mix into the digester. The woods of very distinct qualities must be separately stored and converted into chips, while the mixture must be controlled (either by chip weight or volume control).

The goal is "to make more uniform the lack of uniformity", regarding the differences in clones, species, ages, post-harvesting times, third party woods, and wood conditions (deterioration, diseases, etc.). Such a management is very difficult to be carried out at large mills, as the amounts of logs and chips requiring different logistics are enormous. In sum, there is a good chance of high variability, even controlling the dosages in the mix.

At present, as techniques of GPS, telecommunications, information science, internet, etc., are available, it is possible to better program forest harvesting operations, transports, arrivals and storage of different types of wood.

In order to minimize undesirable surprises and conflicts, it is suggested that each distinct type of wood should be very well-known through preliminary laboratory evaluations. Knowing the peculiarities of each type of wood, the chances of successful mixes increase and even the laboratories themselves may determine the most interesting proportions for these recipes.

Science and the forest business are extremely dynamic areas. While the techniques to minimize the effects of the mixtures are improved, new demands for other types of mixtures are appearing. This is the case of demands for given proportions of certified woods, to be able to obtain the product certification in the chain-of-custody.



Chip silos for suitable wood mix control
(Aracruz Celulose – Guaiba mill)

The log storage and chip preparation sectors must become more specialized and modernized, in order to be able to deal with all these aspects. Chippers, chip stacks, log stacks, silos, classification screens, must be suitable and adjusted to each type of wood entering the mixture. The optimum situation is to have separate chipping lines, adjusted to each type of wood. This fact stresses once more the need for a good and sound dialog among the involved and interested parties, represented by the forest, technological, and pulp and paper manufacturing areas.

Curiously, each company looks for a solution of its own to its wood mix. It is a function of local availability and of the mill's restrictions. For this reason, the discourses on the advantages and disadvantages of the wood blends seem to be antagonistic and conflicting from one mill to the other. The laymen are surprised at such a situation, especially wood suppliers, who end up not understanding what the wood customers really want. In time, sometimes the wood blend makers are also completely lost: their only target is to feed wood into the digester, to prevent the mill from stopping for lack of wood. All the rest and its consequences seem to be no problem for them.

The variations in the proportions of woods in the mixes always cause alterations in the operational performance of the mill and in the qualities of the products. The initial disturbances should be monitored and understood, in order to allow optimizing the new wood blend, so that the whole new "magic formulation" can work well.

It is very common for a mill to change the clone in its wood recipe. Some new wood enters the process and may come to cause complications. The first consequences are operational unbalances, as already mentioned. It is common that complaints are made about this new clone and its wood. Within a short period of time, after adjustments to the process conditions, the mill reaches operational continuity and the operators who had complained begin even to praise the new wood.

In another chapter of this digital book, I mentioned that when *E.globulus* wood was first used in an industrial test run at Riocell, a company which I have worked for, the results were discouraging. The cause was soon discovered: no adjustment to the chippers had been made in order to operate with that wood, denser than the *E.saligna* one, which was being used before. The chips came out too thick and cooking and other subsequent operations were impaired. The problem was corrected in the new campaign with that wood and the gains were noted and acknowledged.

8. <u>Supply of pulp (pulp fibers) to the paper mill – (pulp blend or pulp mix)</u>

Every papermaker proud of himself has as his mission and duty to develop “recipes” that should work well for the performance of his machines and the quality of his products. Such recipes are often “kept under lock and key” and only a few people have access to that so-called “standard formulas”. When working out that formulas, several factors are taken into consideration, such as: type and dosage of chemical reagents (sizes, starches, resins, mineral fillers, etc.), pulp freeness, quality and proportion of reprocessed broke and recycled fibers, and types of pulps from virgin fibers.

In the US, Europe, and Asia, the blend of pulps is a common fact at paper mills. The mission of *Eucalyptus* fibers is to “solve problems” caused by the long fibers. They help improve formation, opacity, porosity, smoothness, etc. On the other hand, long fibers substantially increase web strengths, in both wet and dry condition, especially tear and folding strength. A good match between very different fibers.

In Brazil, white printing paper manufacturing uses to be almost always based on 100% of *Eucalyptus* virgin short fibers. Just a few are the mills using mixtures of fibers, including at the most recycled bleached and purified fibers, and nothing else as fibrous stock. Now, for sanitary and packaging papers, mixtures are more common. There are packaging paper mills which make this mixture in the digesters, mixing *Pinus* with *Eucalyptus* wood chips. Thus, they reduce their production costs and increase their pulp yields.

The great truth is that in the Brazilian papermaking sector, especially that manufacturing offset papers for cut-size use and coating base papers, everyone prefers using 100% of *Eucalyptus* fibers. This dogma is mainly due to the cost and availability of bleached long fibers in the country. As opposed to it, in the rest of the papermaking world, the mixture of pulps is a routine procedure. I wonder whether this Brazilian dogma is a question of principles, costs, a preciosity, or a promotion of the short *Eucalyptus* fibers. Possibly the answer is also a blend of these several causes.

The mix of pulps is very common in manufacturing special papers, boards, card-boards, multi-layer papers, cigarette papers, etc. We will have a whole chapter about pulp blends in this book of ours, just wait for it.

More recently, and sometimes by the power of country or local legislation’s, mixtures of fibers have been speeded up by new demands, as for instance:

- Need to have in the mix of pulp fibers a certain minimum percentage of certified wood fibers;
- Need to prove the origin of the raw materials in the chain-of- custody;

- Need for the mix to contain a minimum proportion of post-consumption paper recycled fibers;
- Need to have limit values of AOX (total halogenated compounds) in paper mill effluents;
- Need for stock fiber coarseness corrections, for a good performance at the papermachine wet end;
- Etc.

Conditions change, variables change, systems become more complex. To manage all this, the paper manufacturer needs more and more sophisticated tools and controls. Those failing to discover this reality and fossilizing, will have to bear sad days in their fossil condition. Therefore, be attentive and quick, if you want to keep pace with the competition and keep your competitive position on the market.

9. Type of paper mill (integrated or non-integrated)

We have already spoken about this earlier, but we will repeat it once again. The behavior of never-dried pulps of the same origin is completely different if this same pulp undergoes a drying process up to or over 80% of consistency. The higher the dryness, the higher the differences. Market pulp mills also manufacturing paper know this very well. It is the case of Portucel, Aracruz Celulose – Guaiba mill, Suzano Mucuri mill, VCP, etc.

The reason is very simple. When drying, pulp endures a physicochemical phenomenon known as "hysteresis". The molecules of cellulose and hemicelluloses, which were swollen and slightly separated by the water in the cell wall, approach so much as the molecules of water are removed, that they begin to attract each other by electrostatic forces – they do not make way any longer for new molecules of water to get in. In the re-hydration of that pulp, water absorption and retention are significantly reduced. This definitely affects paper production, as it impacts on: fiber swelling, fiber bonding, refining, drainability, dewatering, drying, collapsibility, strengths and optical properties of the paper, etc. Therefore, when knowing well these differences, it is even possible to use these differences in order to optimize the mix of fibers. At the time I was working for Riocell (at present Aracruz Celulose - Guaiba mill), the paper mill had special recipes combining dry with never-dried fibers in order to optimize the paper production.

10. Industrial pulp manufacturing processing conditions

Many pulp production process conditions impact on the quality of the product *pulp,* and consequently, also on the product *paper*. I will just report you some more significant ones, for you to focus your attention on them. Following are those I recommend you to pay attention to:

- Percentage of bark present on wood chips;
- Percentage of off-size (unsuitably sized) chips;
- Chip liquor pre-impregnation previously to kraft cooking;
- Type of cooking (maximum low temperature, high alkaline charge, and long cooking time? Or opposite conditions?)
- Sequence, types of oxidative chemicals, and chemical consumption in the bleaching process;
- Pulp washing efficiency;
- Stage of hexenuronic acid removal from the unbleached pulp;
- Pulp dewatering, pressing, and drying;
- Dynamic mixers, deflakers, shredders, etc.
- Etc., etc, etc.

These process conditions affect pulp uniformity, quality, and performance. They may affect several vital characteristics of pulp fibers, such as:

- Individual fiber strength;
- Content of fines;
- Fiber bonding ability;
- Anionic charges in the fibers;

- Content and type of hemicelluloses;
- Content and type of extractives;
- Hydrophilicity and water retention;
- Residual lignin content on fiber walls;
- Hysteresis;
- Fiber collapsibility;
- Fiber deformations;
- Etc., etc.

As the whole pulp production process occurs in aqueous phase, all factors and conditions affecting the fiber hydrophilicity, their swelling, and the individual fiber strengths affect the papermaking performance of that pulp. For example, the presence of hydrophobic extractives and hydrophobic lignin fragments help reducing the adhesive strength and water retention by the pulp. The paper process will feel this difference. As to hexenuronic acids, hemicelluloses, and degraded molecules of holocellulose, they are potentially richer in terms of anionic charges and positively affect hydrophilicity. Things like that are often forgotten and are even difficult to measure. Meanwhile, the quality control laboratory is kept at a hurry, running extra numbers of refining and mechanical tests on the little handsheets, without understanding for which reasons problems are happening in operation.

The really curious point in this whole process of interactions between properties and operational conditions is that statistical relationships can be found therein, which are curious to some extent. For example, it is perfectly possible to find a strong correlation between black liquor viscosity in the recovery sector (at a certain concentration of solids) and tensile strength of the pulp, and this occurs because the black liquor contains lignin, hemicelluloses, extractives removed from the wood, as well as the chemical compounds used for cooking. If these wood components have been removed to the black liquor, they will be no longer in the wood. Then, they will affect the characteristics of the black liquor, as well as the papermaking characteristics of the pulp. The black liquor hemicelluloses are no longer present in the pulp, for which reason the pulp containing a smaller amount of hemicelluloses will behave in a different way. Then, it is curious what statistics reveal!!

In conclusion, everything that can modify the vital characteristics of the fibers will affect the pulp performance on the papermachine, as well as the properties of the paper, is this well-understood?

What we cannot do is to be at a loss, trying to control everything – we have to separate the vital things from the remaining ones. This is what I tried to show you in the present chapter. In case you do not do this, we will end up coming across people trying to control paper quality by controlling the kraft pulp mill black liquor quality, or else, the kappa number of the pulp leaving the digester, which is not so infrequent a procedure.

Then, my friends, I recommend you to be very attentive and to reread this chapter, even though this may be tedious. Draw a comparison with your pulp production processes. Eventually you may even discover some of your process-related weaknesses or faults.

11. Industrial paper manufacturing processing conditions

Numerous vital variables are involved in paper manufacturing, whichever its grade. The more one becomes acquainted with them, measures them, manages them, and optimizes them, the better is the performance of the process and of the pulp fibers being used. For this reason, the technician using or selling *Eucalyptus* pulps must know these important variables very well, as well as their interactions with the vital characteristics of the fibers.

In a previous section I said that the mixture of fibers and the magic recipe developed by the papermaker are important. Any changes in both of them will already interfere at once with the performance and qualities along the papermachine. If these changes are facts situated at non-acquaintance level, or if they are made without a planning of actions, the papermaker will come upon many inexplicable surprises. The responsibility is often ascribed to the quality of the pulp, which is after all the most abundant component in the paper composition.

Whenever a given type of pulp is replaced with another one (a change of *Eucalyptus* pulp supplier, for instance), due adjustments have to be made before judging and comparing the new pulp to the previous one. It is common that a papermaker purchases a new brand of market pulp. Several are the reasons for this new acquisition: curiosity about the brand, third party information, cost reduction, attempt to obtain some advantage inherent in the pulp, etc. If he believes that he will replace the pulps and the papermachine will not feel the change, he is a beginner in papermaking. Any alteration of this significance tends to destabilize the manufacturing process. Even if the changes are expected to be advantageous (for example: better drainability and dewatering), they may result in other impacts in manufacturing (worse tensile strength, pronounced felt marking, etc.). These changes will occur until new adjustments to the vacuum, presses, calender stack, etc., have been made. This may take some time, some days, sometimes weeks. For this reason, mini-tests of new commercial pulps lasting just a couple of hours are fatally condemned to failure.

Out of these considerations about changing the type of pulp in the paper manufacturing process, it is suggested running any test by means of gradual replacement (little by little) and at a considerably longer period of evaluation than those having been performed at many paper mills.

The major causes of variations in pulp performance and paper quality are as follows:

- Pulp refining: separate or mix of fibers refining, freeness level, type of disks, refining consistency, etc.;
- Types and condition of machine clothing: wire and felt design and opening, cleaning, etc.;
- Wet web pressing: shoe press, nip pressure applied in the press nip, etc.;
- Dryer drying curve;
- Pulp interaction with the applied additives (debonder, cationic starch, wet strength resins, etc.);
- Quantity and quality of broke being reincorporated into the stock;
- Etc., etc.

The broke stock is a serious jeopardizing factor of the papermaking performance of any fiber. When replacing a pulp with another one, the tendency at a first moment is to generate more broke (either dry or wet). If the standard procedure of always dosing the same amount of broke in the stock is not followed, this higher generation returning to the process will worsen the machine stabilization process even further. At paper mills, even under normal conditions, there is a wide variation in the generated amounts of broke (between 5 and 25%, in general). There are also several types of broke: conversion broke, wet broke generated at breaks, off-graded paper rolls and reams, etc. If the broke mix, its quality, and its dosage are not controlled, there will be variable effects on the papermaking stock qualities and performances. And ingenuous people will believe that the problem is being caused by the just newly added virgin fiber pulp, since they never had the foresight to do the management of the broke.

These above-mentioned vital operating conditions directly affect some of the most important papermaking characteristics of pulp fibers, such as:

- Fiber length (by cutting) and fiber collapse;
- Fibrillation (it affects the superficial area of fibers and fibrils, anionic charge, fiber bonding, etc.)
- Individual fiber strength;
- Wet web strength;
- hydrophilicity and WRV - Water Retention Value;
- Fibrous population;
- Fiber deformations;
- Content of fines; etc.

WRV – Water Retention Value – is a pulp characteristic very simple to measure and to follow. It is connected with numerous characteristics of pulp fibers. For example, a market pulp sold in the form of dry sheets presents a WRV between 90 and 120; the corresponding value of a never-dried pulp ranges from 150 to 190; a refined pulp stock may have a WRV between 180 and 280, depending on the type of pulp and freeness level. Therefore, as the ranges are wide, the WRV can be used as a very good indicator for operational control.

The anionic charge, expressed by the carboxyl group content, is also a good indicator for paper mills, as it is related to fibers and additives. It is considerably used for wet end chemistry control. As it does not only depend on pulp fibers, it is difficult to use it in pulp stock recipes only for pulp control.

Once more, my friends, try to understand what is happening to your fibers/pulps, as well as the respective variability. When I refer to variability, remember it, I am not only telling you to consider variability with regard to mean values, but also to spot values. A further example to clarify it once and for all: if 10 average wet web consistency are informed for the papermachine cross profile, very similar mean values will certainly result from them. However, the spot values along the profile and for the various sampled materials should vary much more than that. This is precisely the point our attention should be given to.

Or else: when the average length of the *Eucalyptus* fibers in a given refined pulp stock is measured, values close to 0.65 mm will be possibly obtained. This indicates much less than the fiber length distributions in pre-settled length ranges, concerning those values we are interested to control.

At present, the equipment's made available by the automation suppliers to control online and continuously many of the vital characteristics are more than sufficient. I know that this has a high cost, but it can be fully justified, or even more than that, by the equally high benefit. Nevertheless, it is necessary to understand and to know how to interpret the data for more qualified managerial and technical actions to be possible. To just have figures and equipment is not enough; the data should propel people into action.

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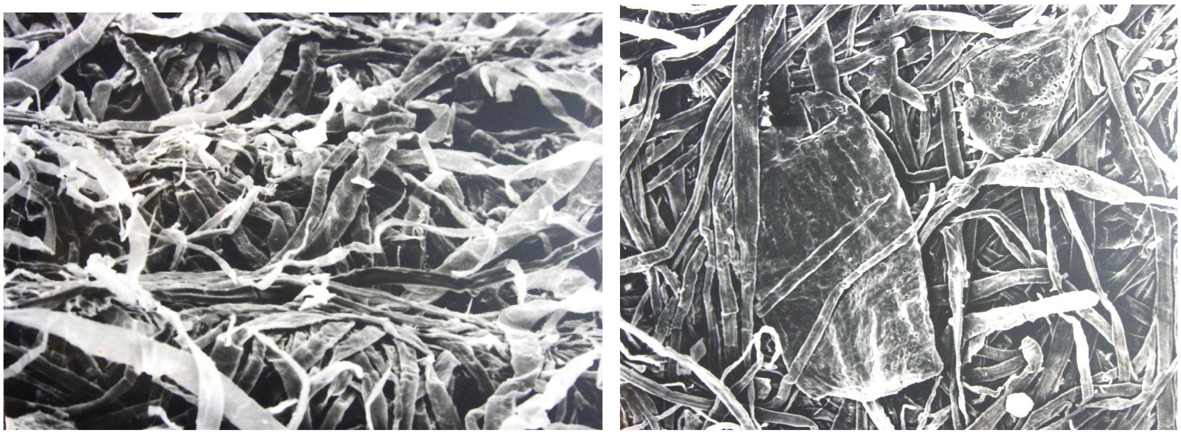
PROPOSING SIMPLE ALTERNATIVES FOR BETTER WOOD AND PULP FIBER PERFORMANCE IN THE PAPER PRODUCTION CHAIN



Surfaces of sanitary (on the left) and printing (on the right) papers

"Simplicity is the ultimate degree of wisdom"
(Khalil Gibran's quote, famous Lebanese-American thinker)

We have already achieved substantial gains in productivity and quality in our *Eucalyptus* plantation forestry. Such gains were mainly made in the past two decades. The next great jump to happen in technological *Eucalyptus* development should be in terms of quality of its woods, as at present they are being destined for numerous and varied purposes. This is a point that must be better engineered, it is a crying need.

There is a lot of potential for the genetic improvement to combine qualitative with quantitative characteristics of several *Eucalyptus* species and clones. Each *Eucalyptus* species, even those little used and planted among us, is a source of genes. For this reason, it should be never said that a given species is bad or poor quality. It may be unsuitable for pulp manufacturing, but at the same time outstanding for bee-keeping (*E.melliodora* and *E.robusta*, for instance). In other cases it has genes making it cold-resistant (*E.dalrympleana* and *E.nitens*, for instance), that may be very well transferred to other commercial species by hybridization or genetic engineering.

Be it by heterosis, be it by additive inheritance of characteristics connected with wood quality, or else by forest biotechnology, the truth is that there are new and powerful tools being used in forest improvement. These technologies present quick development and spreading through forestry. It is enough to pan well to find what is desired among so many *Eucalyptus* species and genetic materials existing worldwide, and to use these forest improvement speedup tools - everything in compliance with legislation and striving for sustainability, is this clear?

I would like to remind you that by additive inheritance one understands the expression of a certain phenotypic characteristic (for example: basic density of wood) in the just born filial generation at an intermediate level with regard to the parental generation. For example, if *E.grandis*, with a basic density of 0.4 g/cm³, is crossed with *E.urophylla,* with a basic density of 0.55 g/cm³, offspring individuals with basic density values between 0.4 and 0.55 g/cm³ will result in generation F1, but ho higher (positive heterosis) or lower (negative heterosis) values should occur. This will only happen due to analysis or sampling errors.

Dominating the different gene transference technologies and finding in Nature the individuals with the extreme values desired, the users of *Eucalyptus* woods and fibers will mostly certainly have new reasons for rejoicing, as well as prospects for great commercial success in the decades to come.

Considering everything said and repeated herein, it is very important to know more – and to know it better – about variability of the vital characteristics of woods and pulp fibers of so large a number of *Eucalyptus* species. Nowadays, most of them are very little researched by science, and even those commercially a little less successful species are neglected by the researchers. It even seems that in Brazil there is only material available for researches on *E.urograndis*, and more recently on *E.globulus*. A boring and worrying "sameness": everyone trying to do the same things with very similar genetic material. Instead of trying to locate new opportunities for gain, everyone keeps trying to make the most of what is already very well-known. In this way, the genetic base is narrowed still further, and the chance to find extreme individuals in some qualitative parameter keeps decreasing. Unfortunately, this occurs at all research levels, researchers always trying to research what is in fashion, what is charming, forgetting that such researches do not lead to any discoveries, just to small gains in terms of continuous improvement.

Just to show you the enormous potential existing for commercial *Eucalyptus* and *Corymbia* species, have a look at the large number of species that are being successfully planted in the *Eucalyptus* world, listed in alphabetical order for each of these two genera:

E.alba
E.benthamii
E.botryoides
E.camaldulensis
E.cinerea

E.cloeziana
E.dalrympleana
E.deanei
E.deglupta
E.dunnii
E.fastigata
E.globulus
E.grandis
E.gunnii
E.maidenii
E.macarthurii
E.melliodora
E.microcorys
E.nitens
E.paniculata
E.pellita
E.pilularis
E.propinqua
E.regnans
E.resinifera
E.robusta
E.saligna
E.smithii
E.tereticornis
E.urophylla
E.viminalis

Corymbia citriodora
C.ficifolia
C.maculata
C.ptychocarpa
C.torelliana

All these close to 40 *Eucalyptus* and *Corymbia* species are considerably planted around the world. Their development as trees, their limitations, and their adaptation to climate, soil, and water conditions are also known. However, almost nothing exists concerning studies of the vital characteristics of woods and pulps of many of these species. *E.saligna*, *E.grandis*, *E.nitens*, *E.globulus*, *E.regnans*, and *E.fastigata* species are even very well-known. As to the remaining ones, there is an enormous vacuum about the technological properties of their woods and fibers. At the most, something is known about the basic density of their woods and the anatomical average dimensions of their anatomical constituents. There is still much to be learned, including to know how to use what one will discover in the programs of genetic improvement of *Eucalyptus* wood quality. Now, that the *Eucalyptus* genome is practically mapped, the new era of forest technology is drawing closer and closer – we are making ourselves ready for it, as well as for the new technological forest and industrial gains. There are new and challenging paths to tread towards additional improvement of the technological qualities of *Eucalyptus* woods, pulp fibers, and papers.

Among the vital characteristics of woods and fibers, we have to concentrate our efforts on the "most vital ones", in order to simplify researches and speed up the choice of materials. Then, which could they be?

Having reflected very much on this theme, I have chosen a smaller number of characteristics, which I consider to be the minimum acceptable for the researches at this new technological moment. If you want to analyze some further ones, please do as you wish, but it will involve more work and take a longer time. If you choose many, you will run the risk of reducing the sample size and the number of repetitions. We will get into that problem of poor quality decision-making. I prefer to analyze fewer, but vital things, and presenting good statistical quality (sampling, precision, and representativeness – with smaller mistakes).

Then, I present you in the following list the "most vital" characteristics of the *Eucalypti* for pulp and paper production:

Wood:

- Total lignin content;
- Hemicellulose content;
- S/G ratio on lignin;
- Basic density;
- Specific wood consumption per ton of pulp;
- Active or effective alkali requirements and generation of Total Dry Solids in kraft pulping the wood.

Pulp fibers / pulps:

- Content of fines (dynamic drainage jar);
- Wall fraction;
- Hemicellulose content;
- Fibrous population and coarseness;
- Individual fiber strength;
- Fiber bonding capacity;
- Hydration and swelling capacity;
- Volume of vessel elements per gram of pulp.

Some of these properties and characteristics are more difficult to measure than other ones. Not everybody has available the equipment required to measure the individual fiber strength or the fiber bonding ability. In some cases, we can look for some simpler property, correlating well with these vital ones. For example, the individual fiber strength correlates with tear strength of the dry handsheet of pulp at initial levels of refining. For fiber bonding capacity we can also evaluate the tensile strength of the dry handsheet of pulp at an initial level of refining. Tensile strength correlates very well with fiber bonding, and tear strength depends very much on the individual fiber strength. As far as *Eucalyptus* pulps are concerned, tear strength is also very affected by fiber bonding. For this reason I believe that the best way of evaluating individual fiber strength is at the initial level of refining, at a low degree of defibrillation, at minimum cutting and collapsing. I suggest to interpolate the values for a fixed level of bulk (1.8 cm^3/g, for instance – TAPPI sheet formation methodology). Sheets with same basis weight and same bulk are ideal, as the same fiber weight is distributed in the same sheet thickness and area.

In reference to swelling and hydration capacity, it may be evaluated in two alternative ways:

- By pulp refining speed - for example, number of revolutions of PFI mill to gain 10° SR (Schopper Riegler). The lower the number of revolutions, the more easily the pulp is hydrated and swollen.
- By the difference in WRV – Water Retention Value – measured first at dry pulp at 10% of moisture, and afterwards measured at wet pulp, refined at 500 revolutions of PFI mill. The bigger this difference in absolute terms, the higher the pulp fiber capacity to swell and to hydrate.

In the following, a nice spreadsheet may be set up by you to classify the selected species, clones and genetic materials. It will be easy, based on the "most vital" characteristics predetermined, to create groups of genetic materials, separated and ranked according to the presented results. These groups may be established according to the technological requirements of the mills and the desired product qualities.

Please, do not forget that the age of the trees affects many of these vital and selected characteristics. I count very much on the tree harvesting age to help this optimization process to become more effective.

As a function of pre-established ranges for each of these properties, it will be easy to make up groups of distinct and to a certain extent unique genetic materials.

Some potential groups to separate these materials according to the quality of wood and pulp fibers:

- Group 1: the great *E.globulus* group and similarly generated clones
  - Low total lignin content (20 to 23%);
  - High S/G ratio (between 4 and 5);
  - High hemicellulose content in the wood (from 17 to 20% of pentosan content);
  - High basic density in the wood (between 0.58 and 0.62 g/cm³);
  - Low specific wood consumption per ton of pulp (about 2.6 to 2.8 m³/adt of pulp in the digester);
  - Low consumption of active alkali in kraft cooking (about 18%);
  - Low fibrous population and high coarseness value (from 8 to 10 mg/100 meters of coarseness, for instance);
  - Etc., etc.

- Group 2: the great *E.urophylla* group and similarly generated clones
  - High total lignin content (27 to 30%);
  - Low S/G ratio (between 2 and 2.5);
  - Low hemicellulose content in the wood (between 13 and 14% as pentosan content);
  - Medium wood basic density (from 0.49 to 0.53 g/cm³);
  - High specific consumption of wood per ton of pulp (about 3.6 to 3.8 m³/adt of pulp in the digester);
  - High consumption of active alkali in kraft cooking (about 22%);
  - Medium fibrous population and medium coarseness value (from 6.5 to 7.5 mg/100 m for coarseness); etc., etc...

- <u>Group 03</u>: the great *E.saligna* and *E.grandis* group and similarly generated clones

These species are renowned by having low to medium basic density and medium values of lignin and hemicellulose contents, low S/G ratio in lignin and high fibrous population, which represents low coarseness values. For this very reason, the specific consumption figures of wood per air dry ton of pulp in the digester are high.

- <u>Group 04</u>: the great *E.dunnii, E.maidenii,* and *E.nitens* group and similarly generated clones

Excellent genetic material group - the woods of which present intermediate characteristics between *E.globulus* and *E.grandis* – very interesting and potential for forest breeding and new papermaking opportunities.

- <u>Group 05</u>: the great *E.tereticornis, E.camaldulensis,* and *E.cloeziana* group and similarly generated clones

Species of higher wood basic density, but with high lignin contents and higher coarseness values than those presented by pulps obtained from *E.saligna* and *E.grandis*.

- <u>Group 06</u>: the great *Corymbia citriodora* group and similarly generated clones

Extremely interesting *Corymbia* species, the crossing of which with *Eucalyptus* species for generation of hybrids is impossible (at least till now), but having nevertheless a very interesting papermaking potential. The woods present very high basic density, low lignin contents, medium S/G ratio (approx. 3), and high pentosan contents.

Evidently, many data to be included in these above-listed large potential groups are still missing. The literature scarcely contains characteristic values for the properties we refer to as vital for the respective woods and pulp fibers. However, it is never too late to start searching, researching, panning, measuring. If we do so, we will certainly find some hidden treasures.

In future chapters of this digital book I intend to dedicate myself more profoundly and deeply to each *Eucalyptus* and *Corymbia* species, from those cited in this chapter, making relevant considerations on their respective virtues and defects, both forest-related and concerning the technology of their woods.

Something I would like to reaffirm is that based on a few vital characteristics of woods and pulp fibers we can easily anticipate and surely estimate their performance at pulp and paper mills. We can also associate forest productivity data with the global performance of the material in the paper production network. These vital characteristics will also allow us to carry out screenings of materials at an adequate level of safety and certainty. At subsequent improvement and optimization stages we will be able to venture into wider and more detailed technological evaluations, trying to meet more thoroughly manufacturers' and market particularities and specifities.

After all, in just few recent years we have already acquired so much accumulated knowledge. Having some more years available and dedicating ourselves to directed and integrated studies, we will be able to do much more. I only ask you to avoid the present "sameness", where everybody keeps studying the same things. In this way, those doing such will be narrowing our *Eucalyptus* genetic bases and leaving us with fewer options for the future.

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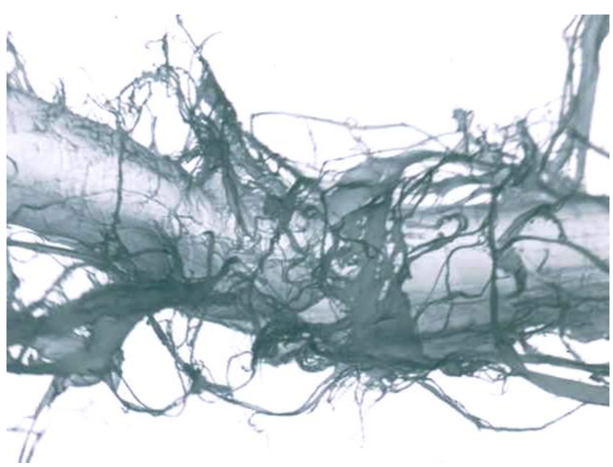
AUTHOR's FINAL REMARKS



Refined fiber and fibril releasing

When planning this chapter of the **Eucalyptus Online Book** I did not intend to write so much, but the theme is fascinating, intricate, and challenging. Things gradually associate with and fit into each other and so do the ideas. The mind runs freely to extremely interesting visions to be shared in writing. The pen runs smoothly and quickly over the sheet of *Eucalyptus* writing paper. I have not yet learned to write long texts directly on the computer - I am a paper-true man, my mind interacts with it to create what I write. I hope that you have liked the chapter, although I am aware of the fact that sometimes I have been too repetitive. However, I did it on purpose, as though I were giving a lesson, where the teacher repeats more than once, for the pupils to understand well the concepts.

My friends, there is therefore a fantastic way of rich opportunities for all users of *Eucalyptus* trees, woods and pulp fibers. In case we succeed in better coordinating the academic and industrial researches, the time required for fantastic technological jumps might be considerably shortened. The opportunities are numerous, just waiting for our action. They do not only take into account the genetics of the trees, but also the silvicultural aspects, the forest age, the technological conditions for pulp and paper manufacturing, and the paper users' wishes and requirements.

Some species are definitely interesting: *E.globulus, E.dunnii, E.nitens, E.benthamii, E.grandis, E.saligna, E.maidenii*. They are appropriate for new genetic crossings and production of inter-specific hybrids, as well as for improvement within the species itself.

The tree harvesting age is a point that will arise with increased emphasis and this will not take a long time to occur. The reasons for changing harvesting age will be environmental and associated with sustainability and differentiated quality of industrial products, rather than connected with costs and productivity.

Finally, our *Eucalyptus* paper production network optimization will lead to the improvement of these exceptional technological virtues of *Eucalyptus* woods and fibers, such as lower lignin contents, higher S/G ratio, higher hemicellulose contents, lower specific consumption of wood at its conversion into pulp, more suitable performance on machines, and adequate properties of paper webs and sheets.

The possibilities are there to be cultivated. Find them and take advantage of doing this wisely, and at the same time, striving for sustainability.

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LITERATURE REFERENCES AND SUGGESTIONS FOR ADDITIONAL READING

Dear friends, in this book chapter section, I'm bringing to you several texts that have straight and direct connection to the covered issues in this specific **Eucalyptus Online Book** chapter. Several of these articles are extremely relevant, and fortunately, many of them may be accessed through the web. Others, from the pre-Internet age, you may only find them in books, magazines or speeches in some well-supplied libraries in the forest-based sector or in libraries of forestry/chemical engineering colleges.

Anyhow, we are making available to you over one hundred highly-valued references to all wondering to learn or know more about the *Eucalyptus* trees, woods and pulp fibers to the manufacture of paper. In two former chapters of the **Eucalyptus Online Book**, also referred in the below cited literature review, it is possible to find more literature references, most of them distinct from the one presented here. Please, also wait patiently, because new book chapters will soon be released in continuation to this issue. Please, have a look at the book chapters 03 and 04, I anticipate that you are to enjoy them.

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