Eucalyptus Online Book & Newsletter

ABTCP
Associação Brasileira Técnica de Celulose e Papel

°Celsius Degree / Grau Celsius

INDUSTRIAL SOLID WASTES FROM EUCALYPTUS KRAFT PULP PRODUCTION

Part 01: Fibrous organic residues

Celso Foelkel

www.celso-foelkel.com.br
www.eucalyptus.com.br
www.abtcp.org.br

Sponsored by:

BOTNIA

ARACRUZ

June 2007

INDUSTRIAL SOLID WASTES FROM EUCALYPTUS KRAFT PULP PRODUCTION

Part 01: Fibrous organic residues

Celso Foelkel

CONTENTS

INDUSTRIAL SOLID WASTES FROM EUCALYPTUS KRAFT PULP PRODUCTION

Part 01: Fibrous organic residues

Celso Foelkel
www.celso-foelkel.com.br
www.eucalyptus.com.br
www.abtcp.org.br

INTRODUCTION

The eucalyptus wood, one of the most important raw material for the pulp and paper production process, consists of anatomic elements, the most abundant of which are the fibers. When fibers or fiber containing material are lost, valuable and scarce material is being lost and thrown away. In addition, costs also increase, since besides the raw material loss, there is a residue to handle, to transport and to dispose away. This residue is also called pollution. For this reason, generating fibrous solid wastes in pulp mills is a great ingenuousness, impacting on our costs and on nature. Raw material will be lost and pollution will be generated. This altogether also means costs, is such a way that throwing fibrous residues away is throwing money away.

As fibrous residues are raw materials, first of all the origin of these wastes, i.e. where they are being generated, must be looked for. The problem must be preferably solved at its origin. The ways of solving such problems are varied, depend on creativity, operational bottlenecks, values involved in investments, economic value of these wastes, technological solutions, investment payback, management, goodwill and commitment of the people involved. In most cases it also depends on awareness and operational discipline. Developing awareness and discipline is very good, but it is also important to value these losses and their environmental, social and economic impacts. Any waste generates impacts. Often, they are not even noticed by the people causing them. The commonest argument is that it has always been like that, that it is normal to lose something, that all mills must endure this kind of loss etc. When these wastes are valued, it is quite possible that this evaluation will lead the managers to quick action, or else to put pressure on getting quick changes!

A great part of my professional life has been very much connected with looking for the solution of problems related to solid wastes at pulp and paper mills. It is amazing how easily our industry accepts the loss of fibrous materials, either in its effluents or in its solid wastes. Sometimes the managers believe that they have no problems, as they are doing some sort of internal recycling, as for instance sending primary sludge to be burnt in the biomass boiler. Thus, they are not realizing the losses, whether they are too high or not. The problem remains hidden, everybody believing that life at the mill is wonderfully efficient. A great mistake may be occurring instead!

Once, I was invited by the chief executive officer of a large Brazilian eucalyptus pulp manufacturing company to the inauguration of what he called "the largest recycling plant all over the world for recovering solid wastes of a eucalyptus pulp mill". Really, I was sure that the recycling plant was fabulous and said to him at once: "my congratulations and my condolences". He asked me why? Then, I answered that the congratulations were for the decision to recover the losses in the form of recycled products, which demonstrated the concern and the commitment of the company to the environmental aspects; while the condolences were only for the fact that if the company had the largest waste recycling plant all over the world, it should be also one of the companies wasting the largest amount of material in the form of residues, throwing them away to that recycling plant. In most cases, internal recycling blinds us to the problem. The correct solution is mostly to try to solve the problem at its origin, where the residues are being generated. The gains, economic and environmental, will be a lot better.

Losing fibers to the effluents causes problems of high suspended solids and COD (Chemical Oxygen Demand). These fibers will either demand large clarifiers for removing them as sludge, or will go to the watercourses and accumulate in them. They cause pollution and impair the fauna, consuming oxygen from the water. Fibers also accommodate in the gills of fishes, impairing their breathing. They also accumulate in the form of sediments in the river bottoms and may cause fermentation, generating an unpleasant odor. Because of their organic degrading process, they may also have their persistent pollutants concentrated along the time, as it is the case of organochlorinated compounds.

Another great inconvenience of losing fibrous material as pollution is its avidity for water. Any kind of cellulosic material is highly hydrophilic. In the presence of water it hydrates and this water is difficult to be removed by physical means. The highest percentages reached for dryness/consistency in fibrous materials by pressing or by centrifuging range from 35 to 50%. In general, these values are lower in practice, ranging from 17 to 25%. This means that the solid wastes of wood fibrous material are water rich. We will be losing fibers, as well as water. We will be discharging water into the landfills or feeding water into the boilers, when these residues are burnt. Worse than that, we will be paying to transport, to handle and to dispose of this water, which is also a scarce and valuable input.

The economic impacts are enormous and often are not even considered or known by the mill managers. Each ton of dry fibrous waste may carry about 3 to 6 tons of water, increasing the weight and the volume of this residue. Residues are handled by volume and their disposal occupies dumping volumes in the landfills. All this has a cost, which is not at all low. The cost of handling, transporting and disposing of industrial solid wastes from pulp and paper mills ranges from US$ 8.00 to US$ 25.00 per ton or cubic meter. Whichever the way of paying or computing the payments to dispose of these residues, we will be paying for the water thrown away along with the wastes. The most serious aspect is that nearly nobody considers the value of this lost water in their calculations, as though water were a good of absolutely no value. Then, it is incredible how little attention is paid to correctly press these residues, when they are generated. Just a few mills have a moisture specification for their solid wastes. Most intermediate places for disposal of residues at the mills are uncovered, so that the residue is always hydrating with rain or floor washing water. The most incredible is to accept these losses of both fibrous materials and water as if this fact could be something absolutely normal. Moreover, when a residue is lost, water, raw material and the whole economic value added through the process until reaching this phase are lost along with it: they all are simply thrown away. For instance, if wood sawdust is lost, the value as wood is lost and the added value to debark the logs, to chip them, to sort the chips etc., is lost as well.

If fibers are lost, wood is lost, plus the whole economic value added to the process to reach the stage at which these fibers were lost: on the pulp drying machine they have a value; at unbleached pulp washing they have another one, etc. If the fiber loss occurs through the pulp drying machine effluents, the corresponding fibers are almost ready to the market: they have been already individualized by cooking, screened, washed, and bleached. The only cost to add in order to sell them at full price would be the drying cost. This means that much money is lost with each squandered ton of fiber.

When we are losing digester rejects we lose wood, active alkali, black liquor and the heat of these rejects, which might be reused in the process. In addition, we pay the cost of disposal and treatment of the pollution. Digester rejects are problematic residues, as they have active alkalinity, high pH, leachate a dark liquid and therefore have a substantial environmental impact.

Based on these simple examples, it can be understood that losses of fibrous residues are very valuable. More important than that: they happen because we let them happen. Losses of fibrous residues are perfectly avoidable, which is not the case of other types of residues, such as e.g. dregs and grits, which occur independently of our will. We will speak about them in another chapter of this Eucalyptus Online Book.

For all these reasons, it is very important to have these losses of fibrous rejects quantified in the operational day-to-day. Such a quantification should not be made only based on lost tons, but also on the total value of this loss, involving the economic values added in the process and the costs of disposing these losses. The economic value wasted altogether is high, not to speak about the environmental impacts, which are also very high. Taking the large production scale of our pulp and paper mills into account, the solid waste generation may reach thousands of tons per year. They will become environmental liabilities to persecute us forever. I would like very much to be able to see an increasingly great commitment of our industry to eliminate the solid waste problems, not only to treat and to dispose them. We are improving, some day we will have mills with minimum solid waste generation, but there is still a long way to cover in order to get there.

Undoubtedly, solutions exist. They would appear more naturally if our engineers and technical operators would pay more attention to these losses. What we cannot do is to accommodate ourselves to these situations and to the losses. I become absolutely amazed and incredulous when I see managers of our mills accepting fiber loss values of 1% as something normal, saying that this figure is benchmarking for this kind of industry. Let's understand, my friends, that 1% of lost fibers just means that from every 100 tons of manufactured pulp 1 ton is thrown away. This can be extrapolated to our forests. From every 100,000 hectares planted with forests to supply our large mill, nearly 1,000 hectares are growing just to originate fibers that will leave as solid wastes or COD in the effluents. These residues, besides meaning important losses, represent treatment, recycling, handling, disposal and other costs. I definitively do not accept, I cannot accept this on any account, even because there are intelligent forms of recovering almost all of these wastes we are losing nowadays. We have to think in a new way, act in a new way, prevent in a new way, even change our mills so that they become even further environmentally friendlier. We will not be spending more money or acting in a more sophisticated way, we will be simply succeeding and performing better. The new eucalyptus pulp and paper mill can generate much less solid wastes – this is the conviction we have to adopt and to pursue. We can engineer mills better, prevent more, find new ways of doing things.

In these chapters that we will be writing about solid wastes our purpose is not a discussion about legislations or about bureaucratic aspects of how to manage residues. We rather want to show the problem under a practical angle of acting in an operational way. We also want to show different forms of looking for the solution of the residues problems at their origin. Our mills must be cleaner, generate less wastes and pollution. They must be also more ecoefficient, using better what they have as raw material. We have improved very much in the recent past years, there are no doubts in this respect, but there is still much room left for new improvements.

Which would be the most important fibrous wastes generated at an eucalyptus pulp and paper mill? There are not many of them in terms of types, but they are bulky, valuable and costly:

- Digester rejects or cooking knots;
- Unbleached stock screening shives;
- Chip screening sawdust;
- Dirty bark from the wood storage and chip preparation areas;
- Wood rests (loglets, pallets etc.);
- Rests of organic matter from gardening (grass mowing and pruning of trees).
- Fibers losses with the primary sludge;
- Paper manufacturing broke;
- Paper collected at the mill's selective collection programs.

Considering the dimension of this study, in this chapter we will focus our attention on the first six items listed. In the following chapter we will speak about fibers and paper losses.

The wastes generated quantities and their qualities depend very much on the conceptual mill design, on the technological condition of the mill, on the use of its capacity, on the existing bottlenecks and on the way the operation is managed. To prevent fibrous residues from being generated and to reduce fibrous material losses, these ingredients have to be very well combined i.e. in a wise and committed manner. Now, let's talk a little more on each of them:

- **Conceptual mill design**

When designing the mill, still in its conceptual engineering phase, a series of decisions impact on the higher or lower generation of fibrous material losses. Many things are decided still on the paper, sometimes by engineers who do not know what is to deal with solid residues or what is the value of these residues. Therefore, decisions aiming to simplify the project and to reduce its investment costs may end up generating leakages of thousands of dollars per year. Let's take just one very simple example: we can choose between installing or not installing filters to collect lost fibers from the bleaching effluents. These filters involve an investment cost, but there are recovered fibers in an amount which is not to be neglected. If we do install the filters, we will spend more money on the mill construction as a function of their installation, but this will result in lower costs and investments in primary clarification (wastewater treatment plant). In addition, recovered fibers of high value will be gained therefrom. Decisions in the conceptual phase must be very well balanced by experienced technicians. Residues overload operations and the environment. They generate further costs and the solution for them is often simple and has a quick payback.

Let's consider some other decisions made in the conceptual phase of a mill, that impact on fibrous solid waste generation:

Type of auxiliary fuel for power generation:
When a decision is made to use biomass, with a high-technology and flexible power boiler, decisions as to using, recycling or disposing of some residues are significantly favored, because the biomass boiler can burn many of these residues as fuel, although most of them are very wet. Under these conditions, it is important to have a good control of dewatering and pressing operations and to avoid material rewetting. Biomass boilers can perfectly burn organic residues like primary sludge from WWTP – Waste Water Treatment Plant , pulp screening shives, bark rests, sawdust rests, dirty paper from the selective collection, rests of grass and organic materials from pruning the trees of the mill garden etc.

Using filters to collect fibers from sectorial effluents:
To collect the fibers where they are being lost is one of the best options of investment in a continuous improvement program at pulp and paper mills. The filters used for this purpose are very simple: disk filters or thickener type drum filters with 60 to 80 mesh wire screens. Usual fiber losses occur in the effluents of bleaching, of the pulp drying and the paper manufacturing machines. They are also common in gasket leakages, in tank spills, tank overflows, etc, etc.

Suitable tank dimensioning:
Whenever a tank containing fibrous stock in suspension comes to an overflow, a fiber loss may be occurring. It is very important to know the balance of flows coming to each tank, in order to understand the reasons for overflows and drainages. It is also important to know the qualitative characteristics of each of these flows, which are those containing higher load and which are those more diluted. Knowing these facts, it will be easier to adjust the flows to avoid the excess of liquids coming to the tank.

Project of the wood storage and preparation area:
In general, much more attention is paid in a mill project to the wood amounts in the form of logs or chips to be stored instead to the quality and the contamination of these materials. Definitions such as: log stock rotation, direct log feeding proportion into the chippers, wood yard pavement, chip pile size, chip handling procedure, etc., help to generate a larger or smaller amount of solid residues in these areas. Woodyard may be a great solid waste source at pulp mills.

Log debarking definition:
When debarking is done in the forest field, it is very important to guarantee a minimum bark percentage to follow with the debarked logs. This implies committed management, implies discipline, training and creativeness. All this is valid, both for the industrial and the forest areas. Another area generating bulky bark losses is the log storage yard, both for logs arriving in debarked condition or not. The logs debarked in the forest field may still have much bark in the form of adhered strips, which get loose as the logs are handled. When the logs are debarked at the mill, bark losses always occur either in the log yard or in the log debarking and washing area. The mill design must be such as to favor this bark to get dirty to the minimum possible extent, to get wet as little as possible and to be viable as biomass fuel in a boiler of this type.

Digester knot recycling form:
At present, it is absolutely inconceivable that some new kraft pulp mills are built without a digester knot recycling system. Although the modern digester suppliers argue that the amount of generated knots is very small, as a matter of fact, the total generation is not so little as a function of the enormous production scales. Significant volumes of this dark, dirty, odorous, hot and wet residue having a high pH and still active alkalinity should be avoided. Sending this kind of residue to a landfill is expensive, complex and foolish. Internal knot recycling is important, as well as the ways of minimizing their generation through the suitable wood processing for high quality chip production. The cooking conditions and the kappa number at which the pulp is cooked also affect this generation in terms of a larger or smaller amount.

Wood loglet recovery system:
Debarking may generate significant amounts of broken loglets from the thin logs. The debarker design and log handling devices can help reduce the generation of this residue, or reuse it as process chips or for power generation.

- **Technological mill condition**

Old mills, with digesters, pulp washers, filters, lime kilns, boilers etc. of older technological generation may waste much more raw materials that become residues and pollution. The technological industrial process evolution has led to mills with more closed cycles, with higher efficiency, lower losses and higher internal recycling rates.

Nowadays, the modern chippers generate less wood slivers and less sawdust; the digesters succeed in producing much less knots and shives; the washing presses lose less fibers etc. In other words, the whole technology has been developed for better and higher ecoefficiency. Nevertheless, our pulp and paper industry consists of a universe of mills of very distinct technological ages. There are new state-of-the-art and extremely modern mills, beside other ones of significant use and experience because the age. For this reason, the fibrous residue generating figures vary to a reasonable extent. There are mills generating little or nearly nothing to dispose on landfills, while other ones reach absolutely high and unbelievable values, as approx. 300 to 400 kg/adt of pulp. The latter are e.g. mills generating much sawdust or bark as wastes due to excessive biomass fuel production or because they have another type of secondary fuel (mineral coal, natural gas, etc.).

Conventions adopted in this chapter:
adt = air dry ton
odt =oven dry ton

- **Using the production capacity and coping with the operational bottlenecks**

When the mill operates under normal conditions, within the design capacities of its equipment's, the residue generation is lower. When it exceeds this capacity, working with sections having pronounced bottlenecks, the waste generation raises exponentially. This occurs with any solid waste type, either fibrous or inorganic (bark, knots, shives, sawdust, dregs and grits, ashes etc.).

In the same way, when a new mill enters into operation, during the learning curve phase the residue generation is relatively lower, except for exceptional circumstances, such as accidents or operational failures. During the learning curve period, the mill uses to operate below its design capacity, as it is still in the course of developing these capacities. The whole system is empty of impurities and contaminants. It takes a certain period of time for the system to become saturated with contaminants and stickies and for the latter to accumulate and to deserve removal. Dregs and grits, for instance, are generated in much smaller amounts in the beginning of mill operations. Therefore, much care should be taken to accept as residue generating standards those found in the starting up phase of any new pulp and paper mill. They may worsen much within a short period of time. Any operational bottleneck results in losses, which may be of fibers, wood, black liquor etc. Bottlenecks are terrible to the process and product qualities and to the environment. Even if the loss corresponds to dissolved organic load to the effluent, this will result in higher solid waste generation, since the organic load ends up becoming secondary sludge in effluent treatment.

- **Operational management**

This is one of the main residues generating factors: which are the cares taken by the management in order to prevent wastes from being generated? to measure their quantities? to avoid process losses? not to accept bad operation, etc? Careless, unprepared, evil-minded, ill-trained, ill-oriented operators lose much more, generate much more residues than other ones who are keen, attentive, cautious and committed. Not aware and not committed leaderships also affect this very much, as the operators reflect their bosses' behavior. The increase in solid residues occurs by drainages, purging, lack of attention to the correct moisture of the residues, unsuitable procedures, non-fulfillment of operational indicators, desire to produce at any cost, precarious maintenance, etc. When the management of the area puts pressure on quality and quantity of the generated residues, everyone does their utmost to minimize their generation. However, many managers only care about the manufactured tons of products, paying little attention to the wastes. They do not succeed in seeing these losses and do not know to evaluate these many losses in terms of money. It is our mission to teach them, do you agree? Solid residues mean wastefulness, they mean costs and thrown away opportunities. For this reason the whole management must be very attentive to quantitative and qualitative figures, as well as to the economic values of losses or process residues.

Our proposal to the managers is a very simple one: to specify the quality of each solid waste (moisture, content of residual alkali etc.), the maximum acceptable quantities (in kg/adt or m^3/adt) and the daily economic value lost per each residue (in monetary unit per ton of produced pulp). Based thereupon, managers are recommended to do the daily management of these indicators for each residue generating area, as though it were a product of the mill. All this with goals to be achieved and with explanations for the non-conformities. We will see how to do this in a future chapter of our Eucalyptus Online Book.

==

KRAFT COOKING REJECTS, DIGESTER KNOTS, UNCOOKED WOOD CHIPS OR REJECTS

The well-known “knots” or “uncooked wood chips” are usual residues in wood processing, as it is converted into pulp. The name “knots” is associated with the wood knots, which are the points of insertion of the branches into the trunk. This wood is more difficult to be cooked and for this reason it is somewhat related to the kraft process rejects. However, the rejects do not originate only from these abnormal woods. Some denser, thicker or over-dimensioned eucalyptus chips, or else coming from a defective/abnormal wood, end up not impregnating well, remaining partly delignified after pulping. Thus, their fibers do not individualize well and the rejects must be separated from the pulp to prevent pulp quality problems (cleanliness and bleachability). These rejects exist, they are inevitable in the kraft process. Even with modern chippers or high-technology digesters these rejects after all always come up. Evidently, in the past there was a higher incidence of these rejects, between 1.5 and 4% of the unbleached pulp dry weight basis. Nowadays, this incidence has lowered significantly to 0.3 - 1% of pulp dry weight basis at digester outlet. There is, at present modern digesters, a much better chip impregnation with the cooking liquor. These digesters are able to cook at lower temperatures and at a much longer reaction time. Thus, delignification is improved and the knots reduced in amount, but they still exist, there are no doubts about this. Many people believed that by using more modern digesters, with long cooks at low temperatures, rejects would be virtually eliminated from the pulping process, but after all, they had to admit that they were fully wrong. They soon had to install knots recirculation systems to get rid of the problem related to accumulated pulping rejects. Moreover, it is unquestionable that as soon as the pulp mill begins to exceed the digester design capacity, as a function of the growth of its production, the knot generation increases.

The cooking reject content is also very dependent on the kappa number of the kraft pulp resulting from pulping. In case of a cooking aiming at kappa numbers ranging from 14 to 16 this reject content will be much lower than in case pulping objectives are kappa numbers from

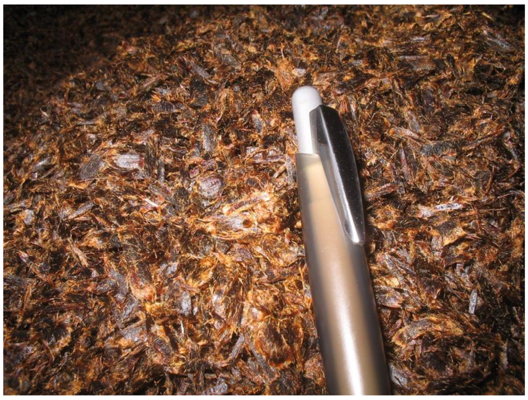
17 to 19. In these usual kappa number ranges, even for the modern high-technology digesters, the reject contents vary from 0.4% to 1% dry pulp basis, depending on the kappa number at which the wood is pulped. Chip quality is another key issue.

Therefore, the definition of the uses for these rejects is very important, in order to prevent them from getting lost as residues, which would include economic, environmental and even social impacts (discomfort for the people in the form of dirt leachate and odor at transportation).

In almost all mill designs the digester rejects come back to the digester for re-cooking, mixed with virgin chips. The form of returning them varies from forwarding to the chip pile, or to the direct return to the chip feeding line into the digester. Recycling is based on reusing the reject knots to separate their fibers, taking the readiness of their re-pulping into consideration.

The knots carry inside themselves a certain amount of residual alkali. They are partly cooked, have already lost a considerable fraction of their wood lignin. As the material is partially delignified, the re-cooking is favored. Low alkaline loads and short cooking times are enough to complete fiber release. This means that the knots may turn into pulp much quicker than the chips inside the digesters. There are continuous digesters, still belonging to another technological generation, which are very sensitive to this differentiated knot ability to turn into pulp. When present in the liquors circulating in the digester, the fibers may cause screen plugging problems during liquor extraction and recirculation. Another problem concerns the way of blending the knots with the chips. If the knots are not very well mixed, they may end up creating pockets of knots inside the digester body (areas having a much higher proportion of knots than of virgin chips). In such an area, the knots turn quickly into pulp, the fibers start being released, the volumes change and the chip column inside the digester may change its displacement. This may even cause plugging inside a continuous digester. In short, knot recirculation is desired and ecoefficient, but it must be carried out in a disciplined and correct way. These problems are common when the knots are irregularly and intermittently handled onto the chip piles by tractor type machines.

In addition to returning the knots to a new pulping step, there are other ways of disposing, recycling or reusing them. The worst of all ways is to send these rejects to a landfill. Other not so convenient procedure is to send the knots for being used outside the mill by someone else. The rejects contain still much black liquor, are difficult to transport, require special vehicles to prevent the roads from getting dirty with the black liquor flowing out, and exhale an unpleasant odor. In other words, a not at all pleasant operation and a not at all good image for the pulp mill. Even storing the knots in the mill area is a problematic procedure. The area must be large, paved, preferably covered. The release of a black liquor leachate is constant, its appearance is undesirable and the odor is persistent. It may also contaminates the ground, the groundwater and the pluvial effluent. In rainy days, the leachate release becomes problematic, overloading the effluent treatment (if the leachate is directed to the WWTP) or the evaporation (if it is treated as spills).




Digester rejects or cooking knots

Larger dimension digester rejects
(which means a higher kappa number and darker color)

Due to all these causes, as mentioned above, a solution must be always found in order to prevent this reject from accumulating either at the mill or on a landfill. The solution for the digester rejects must be preferably found within the geographical limits of the mill.

Aerial view of a huge uncooked knot pile stored in the open air
(in spite of the paved ground and leachates flowing to chemical recovery system, the

The solutions existing for the digester rejects may be the following ones:

- Re-pulping mixed with virgin chips;
- Isolated and captive re-pulping in a small batch digester, specially oriented to this purpose;
- Burning in the biomass boiler as fuel;
- Disk refiner defibration for semi-chemical pulp production;
- Defibration, screening, incorporation into the unbleached fibers of the mill itself and sending to oxygen delignification and later on to bleaching line. The shives from pulp screening may be also defibrated or sent as shives to be used in another way. Within limits, drastic oxygen delignification and drastic bleaching may promote fiber individualization from the shives created by defibration. But at which costs and limitations???

In the following item we will discuss in short and practical form each of these possible utilization's. Fortunately, in my professional life, I had the opportunity of being connected with all these alternatives. Therefore, I can speak about them based on the experience gained from exercising and dealing with each of them.

It is up to each company to decide how the digester knots should be used, as a function of its design, its bottlenecks, its creative thinking and investment capacity.

- **Burning in a biomass boiler**

Bark biomass pile, with cooking knots for burning in a biomass boiler seen in the background

It is rather a viable operation to get rid of the rejects, but it is not a very wise operation from the economical and technical points of view. The knots are very wet, they have already lost much of their lignin. Lignin has a higher calorific value than the wood carbohydrates. The knots have still a significant amount of residual active alkali (caustic soda and sodium sulfide). This is not so suitable for burning and besides, it may generate odor and sulfur compound emissions in the combustion gases. In addition, the presence of stones and sand in the knots is always possible due to the virgin chip contamination itself. At screening for knot separation these contaminants are also separated together. Handling the knots, if it is in an open ground manner, also ends up bringing contamination to them (knot stored on the ground, before they are taken to burn in the biomass boiler). In short, burning digester knots in a biomass boiler results in considerable technical and economical disadvantages. Calorific power is also low, due to the high knot moisture. This practice is just an option to have the mill clean and knot-free. It should be only considered for emergencies, not as an operational routine, where this operation would be carried out on a daily basis.

- **Disk refiner defibration for semi-chemical pulp production**

This is a technically feasible operation, but economically and environmentally unsuitable in many cases. The market value for an unbleached semi-chemical eucalyptus pulp with a relatively high shive content is low. There is really no market for this type of pulp, it should be created. Unbleached short-fibered pulps have little uses in the paper manufacturing process. This pulp competes much more with recycled corrugated board wastepaper than with an unbleached chemical pulp. The price fluctuation and the type of market are very unstable. The market is small and little attractive. Therefore, this alternative of production is not to be considered as the best one, for most of the cases.

Even if technology succeeds in doing well this defibration, it is better for it to occur at medium or high-consistency (higher than 15%), for better effectiveness and economy in fiber separation. Lower consistencies are not recommended, neither for the resulting pulp quality (insufficient defibration), nor for the disk defibrator health. The power consumption to defibrate and pump this pulp is also high and costly at low consistencies.

The semi-chemical pulp thus produced still contains many small shive type rejects between 0.5 and 5% dry weight basis. The kappa number is extremely high, between 50 and 80, and brightness is very low (15 to 25% ISO). The values are also very different, according to the mill run, since the reject quality varies according to the type of wood, the chip dimensions, the screen performance, the presence of fibers as a function of knot washing, as well as of the defibrator performance (disk type, equipment maintenance condition, etc.). Furthermore, the pulp exhales a slight kraft process odor and it is sometimes not recommended for using in cartonboards for food packaging.

With defibration, screening and washing of these knots and the resulting pulp, a very COD and alkalinity rich filtrate is generated, which must be sent to the recovery cycle, overloading the evaporation and recovery boiler. The alternative of sending it to the effluent raises too much the COD load to the WWTP.

I have already seen many companies selling or donating these digester rejects to third parties, to other paper or board companies sometimes doing this defibration under environmentally and socially not at all correct conditions. It is a transfer of liabilities. By law, the company commercializing residues shares responsibility with those who purchase the residues. The one who generates and sells is equally responsible with regard to the one using and polluting with these same residues. For this reason, also here, the residue should be prevented from leaving the mill at which it has been generated. If the option is to defibrate the residues, then there should be through the use of a clean technology and with environmental care, both compatible with such an operation. When the filtrate is sent to be treated as effluent, it will overload considerably the primary treatment with fibers and the secondary one with the high organic load.

A knot defibrating operation may cause several types of inconveniences at a eucalyptus kraft pulp mill, as mentioned ahead. The references are based on the unit weight of the manufactured semi-chemical pulp.

- fiber loss (0.5 to 2% oven dry weight basis);
- filtrate generation, which will leave as a contaminated effluent to be treated (10 to 15 m³/adt of semi-chemical pulp);
- heat loss due to the fact that the hot knots get cool (150 Mcal/adt);
- loss of active alkali as soda, which was impregnating the rejects (50 kg NaOH/dry ton of rejects);
- loss of total sodium sent to the sewer due to generation of effluent contaminated at the operation (10 to 20 kg Na^+/adt)
- loss of COD in the effluents of this operation (70 to 100 kg COD/adt);
- wet secondary sludge generation due to COD addition to the effluent treatment (250 to 300 kg of wet sludge/adt of semi-chemical pulp);
- loss of sodium and COD, which remain in the pulp being commercialized, even after intense pulp washing (0.5 kg Na^+/adt and 1.25 kg COD/adt).

Relatively simple knot defibrator in outsourced operation and washed and pressed pulp generated by defibration

Independently of the technical, operational, economic and environmental problems that this knot defibrating operation may create, the semi-chemical pulp produced may be used for manufacturing several paper grades, such as: corrugated board medium, triplex board central layer, duplex board inner layer, kraft type packaging partly replacing the unbleached kraft softwood pulp, kraftliner, testliner, asbestos cement products partly replacing asbestos and softwood fibers, etc.

The unbleached semi-chemical kraft pulp obtained from eucalyptus wood cooking reject ("knots") defibration has some interesting papermaking advantages. Its physico-mechanical strengths are suitable, its bulk and porosity are excellent and opacity is exceptional. In exchange, it also shows some undesirable properties, such as: variation in shade, in brightness and in color, as a function of kappa number variations; high shive content; high power consumption at pulp refining. The pulp is also more hydrophobic than a normal kraft pulp. The pulp refining requirements are high rather for shive destruction than to develop strengths. As the shive content may be high, the operator tends to radicalize refining in order to release fibers from shives, breaking them. It is the resource available to him, as screening would mean losing fibers and weight of the purchased pulp. The corresponding power consumption is high, ranging from 150 to 200 kWh/adt to reach a Schopper Riegler degree of 35 to 40. Generation of fines is intensified under these conditions. Since pulp is relatively alkaline (pH between 8 and 9), refining is favored. Therefore, the physico-mechanical properties depending on fiber bonding are good.

A company that produced this type of pulp for years was Riocell, where I have worked for 19 years. At present, the company does not produce this type of pulp any longer and the mill belongs to Aracruz Celulose, in Guaíba/RS/Brazil. The company had serious digester bottlenecks. To make feasible a higher production in that digester, it was strategically decided to remove the knots from the process and defibrate them separately. The pulp thus produced was called "filler pulp", for the fact it was sold as "filler" for some paper grades, especially boards and packaging papers. The initial purpose was to cook the knots and the sawdust from chip preparation in a small vessel or digester. Thus, the "filler" pulp would be a mixture of knot and sawdust pulps. The operation became unfeasible right from the starting up for two reasons. The first one was the sawdust and knot generation itself. Both the digester and the chip line were overloaded. Therefore, the amounts of knots and of sawdust were well above the level used in the project designing. Only the digester reject generation was something around 2.5% dry pulp basis. The sawdust generation reached from 2.5 to 3.5% wood dry weight basis. On the other hand, the sawdust was not screened, it was very rich on wood dust. Approx. 15% of the sawdust passed through a 2 mm opening wire screen. That sawdust was alkali avid, the consumption was enormous and the sawdust delignification very difficult, as the cooking vessel was very small. These unfavorable factors have limited the plant performance: generation of large amounts of knots and sawdust and high alkali consumption by the unscreened sawdust. The use of sawdust was abandoned and the mill went over making the "filler" pulp only from defibrated knots, with no complementary cooking at all. The company found another use for the sawdust and the "filler" pulp has sustained as a mill product for about 15 years. It was only discontinued when the company invested in an optimization mill program and opted to recycle the knots back to the digester.

A semi-chemical pulp obtained from defibrated knots involves several problems, such as:

- It is a minor and secondary byproduct, always left in the background in terms of investments and operational requirements;
- The quality is very variable, as it depends much on the quality of the knots leaving the digester. The kappa number, the color, the shive content and the brightness being the items varying the most;
- Defibration requires very good consistency control for this operation. As the amount of knots is small, to be able to operate continuously and have a continuous hydraulic flow, the refiners must often operate at lower consistencies, which affects very much the product.
- The amount of shives in the pulp is very variable (between 2 and 5% of shives bigger than 0.2 mm), which displeases the customers. It is practically impossible to produce a shive-free pulp, unless by over-refining the pulp, in an additional operation.
- The operation generates a large amount of a dark filtrate, which releases from the knots being refined/defibrated. If the evaporation plant has no sufficient capacity, this filtrate must be treated as effluent. If the evaporation plant has sufficient capacity, it will evaporate a very diluted liquid. In both cases, we are talking about technically unfavorable situations.
- When the defibration plant is shutdown for maintenance purposes the knots must be accumulated in a paved and enclosed place, in order not to cause any environmental impact.
- The operation is relatively unstable and complicated, since it involves a lot of labor.
- The market of this pulp is very competitive, as it is a product of irregular quality. The market it competes with is that of corrugated board wastepaper, unless the technical team may be able to develop a special niche.
- The selling price is low, often it is even insufficient to cover the variable costs of wood, power, drying and effluent treatment.

Whenever a company has to opt for an operation of this type, it should do an extensive technical, economical, environmental and social pre-evaluation study, for a better decision making process.

Semi-chemical pulp defibrated from eucalyptus kraft cooking knots
(pulp dried by flash drying system)

View of sheets formed with semi-chemical pulp defibrated from eucalyptus kraft cooking knots
(left-hand sample refined at 30ºSR, presenting less shives and a slight darkening as a function of refining. On the right, a sample of unrefined, only defibrated pulp, where the contaminating shives can be seen)

- **Knot defibration followed by oxygen delignification**

This kind of treatment has been suggested and even practiced in industrial operations. The digester reject defibration originates a dark pulp of high shive content, as already mentioned. The pulp has a high kappa number, as well as a high COD (dissolved organic matter) carry-over. There is still much black liquor impregnated in the fibers and in their wall micro-pores.

The oxygen delignification operations may be carried out in accordance with two procedures:

- The semi-chemical pulp resulting from defibration is mixed with the main kraft pulp of lower kappa number and both of them pass together through the oxygen delignification and thereafter through bleaching.
- The semi-chemical pulp of high kappa number is delignified in a small reactor with oxygen in a captive separate operation. Later it is evaluated and if it has a suitable quality it is sent for mixture either with the unbleached pulp or the oxygen delignified kraft pulp. Both of these pulps will follow later and together to the bleaching line.

The first option it technically poor, resulting in a risk for the quality of the final bleached pulp, as well as in higher chemical reagent consumption, both at oxygen delignification and bleaching. There is also the risk of increasing the amount of contaminants such as bleached shives in the final pulp and of not reaching the desired brightness after bleaching. Depending on the proportion of semi-chemical pulp, the average kappa number of the pulp raises some tenths and a very subtle difference can be noticed. The problem is that this increase in kappa number is false, as the shives cannot react very well at the kappa number determination. The shives react little and consume little permanganate because they have a small surface area in regard to their weight. These shives may be considerably reduced by oxygen delignification, but may still persist in the bleached pulp. There is also a higher demand of oxidative reagents at bleaching (chlorine dioxide, oxygen, hydrogen peroxide). After all, the higher chemical addition increases the concentration of reagents in the medium. Not only the semi-chemical pulp viscosity, but also the chemical pulp viscosity itself are affected. These larger amounts of chlorine dioxide required for attacking the larger amount of lignin and organic carry-over may generate a higher AOX content in the bleaching filtrates, which is an additional undesirable concern.

Although the mechanical strength tests of the pulp do not show any quality loss, the higher consumption of expensive and often scarce chemical products is absolutely another problem. The reject problem is solved, some bleached pulp production is gained without higher productions in the digester, but more chemical products are consumed for bleaching, more AOX is generated in the effluents and the bleached pulp brightness and cleanliness may be jeopardized. The highest risk in the bleached pulp will be the greater presence of shives (although white) and pitch and dark spot impurities.

The option of having a small captive oxygen delignification for this semi-chemical pulp of defibrated knots is technically feasible. But this is from the technical point of view. Economically it does not make any sense to have a defibration and thereafter an oxygen delignification stage. It would be enough to have a captive batch digester for separate knot re-pulping. The resulting pulp would have a very low kappa number, would be clean, without rejects and easily bleachable. The kraft re-cooking advantageously replaced any attempt to defibrate the knots and then to treat the resulting semi-chemical pulp with oxygen. A technology of this type, with defibration followed by an oxygen stage, might even be more interesting for the screening shives (unbleached stock screening shives).

- **Knot re-cooking along with virgin chips**

There are many myths with regard to digester knots. Most of them are deep-rooted in the kraft pulp company technician minds. Some of them believe "that the knots are very difficult to be re-cooked, since they originate from dense, different, defective and extractives rich woods". Others believe "that the knots will be overcooked inside the digester, will turn into a pulp mash, resulting in a very weak and degraded pulp". Due to these two visions, some technicians do not like the idea of recirculating the knots back to the digester for a new kraft pulping.

The truth is very different from these myths. Most cooking rejects consist of big or thick chips, which had no time to complete their delignification and fiber individualization. They can also consist of normal but pourly-impregnated chips, due to liquor flow and temperature deficiencies inside the digester.

My knot or digester reject cooking experience, as far as eucalyptus wood is concerned, shows that the knots or rejects do not disturb the chemistry, nor do they impair the kraft cooking quality. The knots are cooked quickly and easily. They are already pre-cooked. The yield of this pulping is high, ranging from 60 to 70%, depending on alkaline charges and remaining re-pulping conditions. The resulting pulp kappa numbers are low (between 10 and 12), but compatible with the kappa numbers of the remaining kraft pulp (at present, between 16 and 19), even because its proportion is small in that mixture. The knot pulping reject content is low, all knots are practically perfectly cooked, their fibers individualize and do not generate almost any reject at all. The hemicellulose removal is more pronounced. Caustic soda solubility at 5% (S_5) for a normal eucalyptus kraft pulp after the digester ranges from 11 to 13% for Brazilian eucalyptus. For the re-cooked knot pulp this S_5 value reaches 9 to 10%. To be cooked, the knots require a much lower active alkali charge, between 10 and 12%, as NaOH, whereas the virgin chips require from 17 to 21%. Under high alkali conditions, knot cellulose chain degradation occurs and there is some yield loss, but this is far from being dramatic, like many people suppose. Cellulose resists the excess of alkali relatively well, even because at present the cooking conditions are based on higher alkali charges, lower temperatures and longer cooking times.

When the knots are returned back to the digester for joint re-pulping with the chips, their mixture must be made very well, in order to avoid knot accumulation in some digester zones. The digester manufacturers have already created suitable conditions for this knot re-injection into the digester, exactly to avoid such a situation. This was a problem that occurred when the knots were returned via chip pile.

The final pulp quality practically is not affected by this knot reincorporation into the virgin chip cooking process. Although the pulp originating from the rejects has a lower viscosity and a higher apparent bulk, its percentage fraction in the final pulp is so small that the pulp testing results are practically not affected. Because of that, there are no reasons for the knots not to be re-cooked or recycled again. And this can be done in two different ways: either recycling in mixture with virgin chips or re-pulping the knots in a separate captive operation.

Eventually, this type of re-pulping operation may cause some sort of inconvenience for special pulps, which would be utilized to produce some special paper grade requiring high pulp fiber quality homogeneity. The fact of carrying out mixtures of fibers with very different viscosities and hemicellulose contents may jeopardize this type of pulp utilization in some manner. Even thus, this would be exceptionally rare, something to be evaluated case by case. In case the knot re-cooking is carried out in a captive operation, this type of inconvenience can be minimized.

- **Knot re-cooking in captive operation**

Nowadays, many mills operate with overload, with their digesters operating to the limit of their capacity. To return the knots for re-cooking in the same digester means to occupy some digester volume with a material that has already passed through it. We will be failing to feed an equal volume of fresh chips due to the fact that we will be coming back with the knots. This is only valid in case of overloaded digesters, at the limit of their chip feeding supply. In such a situation, the daily production will be slightly reduced, as it will be seen later on. We will see some material balances to prove this.

The alternative for some companies having bottlenecks in terms of chip feeding into the digester is to have a small captive batch digester for knot pulping in a separate operation. This means that this mini-digester is only fed with the knots and it will operate producing unbleached kraft pulp with a kappa number similar to that of the pulp from the main digester of the company (or similar to the oxygen delignified pulp). Both pulps will be very similar, in spite of the great difference in yield when cooking the knots. After the separate cooks, the pulps from both lines (main digester and knot digester) will be mixed with each other and directed to oxygen delignification and bleaching line. Another easy and very feasible alternative is to cook the knots to kappa number 10 to 11 and to send this pulp for direct mixture with the virgin chip kraft pulp, but after submitting the latter to the oxygen delignification. As both pulps will have similar kappa numbers (10 to 11), we may save the passage of the knot pulp through oxygen delignification, thus making more flexible and inexpensive the process.

The separate operation requires a knot deposit or silo, as during the period of batch digester operation the knots being produced will have to be stored. The flows and volumes involved are not large, so that they can be easily managed.

The additional cares for this operation and project would be those concerning the environmental protection, in order to avoid odor exhalation and filtrate loosening in this batch kraft pulping operation.

As the pulp produced would be incorporated into the normal pulp prior to screening and washing, filtrate and pulp stock flows practically would not be affected. The weight and flow differences are very large between these two production lines.

It is important to stress that this separate cooking operation is very interesting for digesters at the limit of their capacity. Thus, an extra production can be gathered for the mill without any considerable investments.

The captive knot re-pulping presents the following characteristics with regard to normal chips:

- Low active alkali consumption;
- High pulp yield based on dry weight of material fed into the digester;
- Shorter cooking times;
- Lower H factors;
- Similar or even significantly lower kappa numbers, due to the readiness of knot cooking;
- Lower reject content in the pulp;

- Lower hemicellulose content in the pulp;
- Lower pulp viscosities (about 20 to 30% lower);
- Higher pulp bulk;
- Slightly lower strengths.

Later on in this book chapter, properties obtained from knot kraft pulps will be compared to those of mini-chips (or pin chips), to coarse sawdust and to normal eucalyptus chips.

It should be also remembered that the re-cooked knot pulp would represent from 0.3 to 1% of the total produced pulp, so that its qualitative influence on the final pulp properties is practically irrelevant.

==

UNBLEACHED STOCK SCREENING SHIVES

At present, pulp stock screening is being very efficient. It succeeds in removing practically fiber-free shives or fiber bundles, even the most minute ones. Screens with very narrow slots (0.15 to 0.2 mm) and hydrocyclones or centricleaners remove very well the pulp impurities at this stage, following the removal of knots and large size rejects.

The removed amount of these small impurities is variable according to the kappa number of the pulp and according to the bottlenecks and technological age of the mill. Modern, state-of-the-art mills, have a low generation of this residue, between 0.15 and 0.30% dry pulp basis. Older mills, with bottlenecks in the fiber line, go as far as to generate over 1% dry pulp basis of this reject.

The separated shives are, in many cases, the sum of the unbleached pulp stock screened by screens and centricleaners. These slotted screens are so efficient, that there are even mills that do not use the centricleaners any longer at this stage of the process.

This reject we are speaking about consists of a mixture of shives, little partly-cooked wood rejects, sand and pitch particles. For this reason, whenever there is an interest in recycling or reusing this reject, the most convenient procedure is to separate the sand and other inorganic rejects from it. That sand and other heavy particles may be perfectly removed to an industrial landfill. The content of inorganic matters in a residue of this type is approximately 5 to 8% dry basis.

Among these inorganic matters there are sand, silicates and impregnating sodium compounds.

In the same way as the knots, it can be tried to reduce their generation by a better chip quality and by better impregnating the chips with the cooking liquor. As far as this residue is concerned, it is also impossible to prevent it from being generated: it is possible to reduce its generation, but not to eliminate it completely. It is inherent in the kraft process.

Although the generated dry pulp basis percentage is low, it is a residue that may accumulate as a function of the production scale factor. To dispose of all this fibrous material to an industrial landfill is costly and environmentally incorrect, because this would mean to throw wood and fibers away. Trees that have grown to turn into pulp end up having a part of their cells scrapped and this is not fair to them.

Considering a net generation of 0.15% o.d. pulp basis and a content of inorganic matters of 8% for a state-of-the-art mill producing 2,860 adt of bleached pulp per day, the shive generation would be around 4.15 odt/day i.e. 3.8 odt of fibrous material and 0.35 odt of sand and inorganic impurities per day of regular mill operation. The bulk or apparent density of this material is low, on average 140 to 160 dry kg per cubic meter. Therefore, the daily generation of a mill like that would be approximately 25 to 30 m³. It is undoubtedly an appreciable volume. Sending to a landfill, burning or re-cooking requires a special logistics.

Shives from unbleached pulp screening

According to the use this material is intended for (e.g. burning or re-cooking), it is interesting to separate the heavy sand. This can be achieved still in the phase these residues are in aqueous suspension in the process, by using a heavy particle collector / remover, a viable and known thing in terms of equipment and process.

In general, these shives are submitted to a good washing and have a rather smaller residual amount of black liquor than the knots. For this reason, the odor is less pronounced and the leachate leaving them is cleaner, although it still contains a high COD content.

Following are the possibilities of using this residue and for all of them it is recommended to have a sand remover installed prior to its use:

- Burning in a biomass boiler;
- Defibration and utilization as semi-chemical pulp;
- Defibration and incorporation into the unbleached pulp stock and forwarding to oxygen delignification;
- Re-cooking together with the knots in a captive batch digester.

• Burning in a biomass boiler

It is a very simple way to prevent this material from accumulating. Costs with sending to an industrial landfill are also saved this way. For this burning, even if the sand is not removed, this would not be a problem, as the bark fuel and the biomass fuel are sand rich and the modern boilers are adapted to this situation. Nor the active alkali content in the residue is a problem, since the biomass is acid and the incorporation of this material into the biomass ends up neutralizing this residue. Anyway, there is not much of this residue. On the other hand, the screened shives are very wet due to their good washing for fiber and liquor separation. They should be preferably collected in a covered area, to avoid an additional rewetting with rain water.


Buckets for collecting shives in sheltered places

The bucket collecting them should have inclined bottom and perforations for liquid outlet. This drained liquid should remain in the residue generating area and be reincorporated into the process by the spills recovery system. Even thus the dryness of this material is low, ranging from 25 to 35%. Therefore, the net calorific value of this material is low: about 300 to 600 kcal per wet kg, but it is still positive. As the generation is not high, several buckets can be left to collect this material in a sheltered place. Thus, drainage is better and the liquid efficiency removal may be higher.

- **Defibration and utilization as semi-chemical pulp**

This is an operation that is almost always carried out by third parties, who purchase this residue and defibrate it for using it in board, kraft paper or cardboard manufacturing plants. As always, there is the legal risk of the shared liability concerning the residue. For this reason, it is very important to choose well and to control the purchaser of the residue. This control should be mainly placed on the human conditions of those people operating the defibrators and refiners and working in the production of this pulp.

The quality of this pulp is better than that of the defibrated knots. As small shives are involved, already with their fibers almost individualized, defibration is easier and the resulting pulp is better and cleaner. The greatest care is really a good sand removal. Otherwise, the refiner or defibrator disk service life will be reduced. The resulting pulp quality will also be worse.

The kappa number of this pulp ranges from 30 to 50 and brightness is between 20 and 25% ISO. The content of shives and small rejects in this pulp is substantially lower than in the defibrated knot pulp. The physico-mechanical properties are good, very similar to those of unbleached eucalyptus kraft pulps. Also, as they are lignin rich pulps, with rigid and more hydrophobic fibers, porosity, bulk and capillary water absorption are favored.

This practice has been often adopted by small board mills, who purchase this residue from kraft pulp mills, in order to convert it into semi-chemical kraft pulp for their own use.

- **Defibration, incorporation into the unbleached kraft pulp stock and forwarding to oxygen delignification and bleaching**

This alternative has some technical feasibility, but it involves risks associated with the higher chemical consumption for bleaching, higher AOX generation in the bleaching filtrates and the higher dirt potential on the final bleached pulp. For this reason, the modern market bleached kraft pulp mills have avoided this practice. The gains in additional pulp tons are considered to be irrelevant and the risks of impairing the end product quality by a higher dirt content are significant. Now, for integrated pulp and paper mills, operating with lower brightness and having pulp shortages to their processes, this is an alternative to be considered.

- **Screening shive re-cooking**

Re-cooking this material is only a feasible alternative in case there is an auxiliary batch digester available, and even thus of the ancient models, in order to allow liquor recirculation without the risk of screen plugging with pulp fibers.

The shives delignify very easily, turning into fibers much earlier than the other materials with which they may be treated together in a digester (sawdust, wooden chips, digester rejects or knots, etc.). In continuous digesters, recycling and re-cooking this material along with the normal virgin chips is inadvisable, exactly due to the facility of having its fibers individualized much earlier than those from wood chips. Thus, it may impair the liquor circulation, even in its minute amounts.

The most viable solution is re-cooking knots and shives simultaneously in a captive batch type digester. Thus, an additional amount of pulp is produced without interfering with the main digester of the mill. In a simple and environmentally correct way, the pulp production of the mill is increased and a very noble use for these fibrous rejects is gained. Even if the gain in production is not significant, at least a suitable use will be given to these wood residues, almost fibers. In addition, there will be no waste disposal costs and no environmental liabilities will be generated.

When an individualized kraft cooking of these little screening shives is carried out, it is important to know their pulp manufacturing quality potentialities: weaker pulps (viscosity and strengths lower than those of normal pulps), with a low hemicellulose content (S_5 between 8 and 9%) are the result. However, these pulps have an excellent sheet bulk, besides good porosity and capillary water absorption. The physical tests may be further impaired if the alkali charge is applied in excess. This increases cellulose chain degradation and reduces the cooking yield. As the material is almost in the fibrous form, alkaline charges of 6 to 8% of active NaOH are more than enough to individualize the fibers and to reduce significantly the kappa number of the stock. The digestion time may be also considerably shorter than that normally used for chips, as well as lower the maximum cooking temperature. H factors of 250 to

300 are already enough for pulp conversion. The resulting yield can vary from 55 to 65%, for kappa numbers between 10 and 15, depending on the conditions adopted for re-cooking. Even under more drastic conditions, similar to those used for normal eucalyptus virgin chips, yields of 55% (kappa number of 8) can be obtained. In other words, this material is very easily transformed into a suitable kraft pulp.

It should be remembered that it is very important to promote a sand removal of the little shives prior to pulping, as otherwise the ash content of the resulting pulp will be too high (above 3%). With a reasonable sand removal, the ash content of the pulp will be between 0.2 and 0.4%, normal for this processing.

In view of all these considerations presented in this item, the individual re-cooking operation of this material is not very probable, due to the low generation of the residue in the process. Nevertheless, due to the similarities between shives and rejects/knots, the joint re-cooking of both of them in a captive batch digester is an interesting alternative to be considered for kraft mills. Residues are eliminated and the wood coming to the mill will be better used. An adequate balance of social, technical, environmental and economic viability should provide important points for this kind of decision.

==

CASE STUDIES FOR DIGESTER KNOTS AND SCREENING SHIVES RE-PULPING

Let’s consider for our case studies a modern and state-of-the-art bleached eucalyptus kraft pulp mill. That mill should operate 350 days a year, with an average daily production of 2,860 adt of saleable bleached pulp. This corresponds to about 2,760 odt/day of screened pulp at the outlet from the unbleached pulp area, where a continuous digester of latest technological generation is operating. This mill has a yearly design production of about one million air dried tons of bleached market pulp. For this production, the chip supply should be about 5,208 odt/day, which corresponds to approx. 31,565 m³ of chips and to 10,416 m³ of eucalyptus wood logs.

Let’s consider initially 4 situations for our material balances. They will involve different ways of re-pulping the knots and the unbleached stock screening shives. Following are the cases considered:

Case study # 1: Knot recycling without loss in feeding the normal wooden chips (the mill maintains the same supply for the virgin chips, since the knot recycling should not affect digester feeding).

Case study # 2: Knot recycling, but with loss in feeding the normal wooden chips (lower chip feeding = 112 m^3 chips per day), because it was assumed that chip feeding was experiencing a bottleneck and when recycling back the knots, the latter was taking room of virgin chips in the digester.

Case study # 3: Separate knot re-cooking in a captive batch digester, to allow a knot equivalent wood chip feeding into the digester, thus avoiding loss of chip feeding in digester bottlenecked situations.

Case study # 4: Separate knot and screening shives re-cooking in a captive batch digester, in order to allow normal chips to be fed without restrains . The amount of virgin chips was not impaired and the mill eliminated all fibrous screening rejects, converting them into pulp.

Summary of the situations:

Case	1	2	3	4
Cooking	Chips plus knots in the main digester	Chips plus knots in the main digester	Chips in the main digester and knots in a separate captive digester	Chips in the main digester and knots and shives in a separate captive digester
Situation	Normal chip feeding was maintained	With small limitations in chip feeding	Normal chip feeding was maintained	Normal chip feeding was maintained
Wood consumption in m^3/day	10,416	10,378.5	10,416	10,416
Net solid wood specific consumption in m^3/odt of pulp	3.7620	3.7617	3.7605	3.7578
Unbleached pulp production in odt/day	**2,768.7**	**2,759**	**2,769.8**	**2,771.9**
Total Dry Solids from digesters tons TDS/day	3,610.5	3,597.4	3,608.9	3,610.1
tons TDS /odt of unbleached pulp	1.304	1.304	1.303	1.302

TDS= Total Dry Solids

Conclusions about the 4 evaluated cases and their detailed description:

In case the mill manages to maintain the designed wood feeding, independently of knot recycling, situation 1 is more feasible and opportune. It is more practical than carrying out a re-cooking only of the knots in a separate digester (case 3). However, in case the mill is limited in terms of chip feeding and in order to recycle the knots it will have to reduce feeding of virgin chips in the same proportion of the re-introduced knot volume (case 2), it will lose production. Thus, it will be better for the mill to adopt the solution of case 3, which would be to have a small captive and separate batch digester for the knots. Thus, the mill would succeed in recovering its virgin chip feeding and would not lose any production due to this fact. This difference in production for mills with the mentioned chip feeding bottlenecks may correspond to approximately 0.35%, like the hypothetical case presented herein. This loss will be the higher, the larger is the amount of rejects generated in the cook.

Considering that the mill chooses to have a captive batch digester for the knots, then it can also re-cook the screening shives (case 4) in it. Thus, it achieves the most ecoefficient solution considering the 4 case studies, with lower specific wood consumption per ton of produced pulp. In addition, the mill does not generate any longer two important and problematic solid residues. The small batch digester will yield an additional daily production, besides reducing the environmental impacts of the mill.

This additional pulp production due to the joint cooking of knots and screening shives in a separate captive digester is not only interesting from the environmental and technical standpoints. Also valuable is its contribution in terms of financial results. By way of exercise, let's effect a simple valuation of this additional economic result arising from the shives cooking. To do it, we will consider that the shives, when being re-cooked in our case 4 , will be adding 2.1 odt of unbleached pulp per day to the mill production, without any new expenditure in wood. After converting it into bleached pulp, this would represent about 2.2 additional adt of bleached pulp per day. In one year, this would mean over 750 adt of bleached pulp for the mill. Furthermore, the company would not dispose any longer of the fibrous part of these shives as garbage (22.3 m³/day or 7,800 m³/year). Something to look carefully at, there is no doubt: too large amount of residue and money to be taken to an industrial landfill.

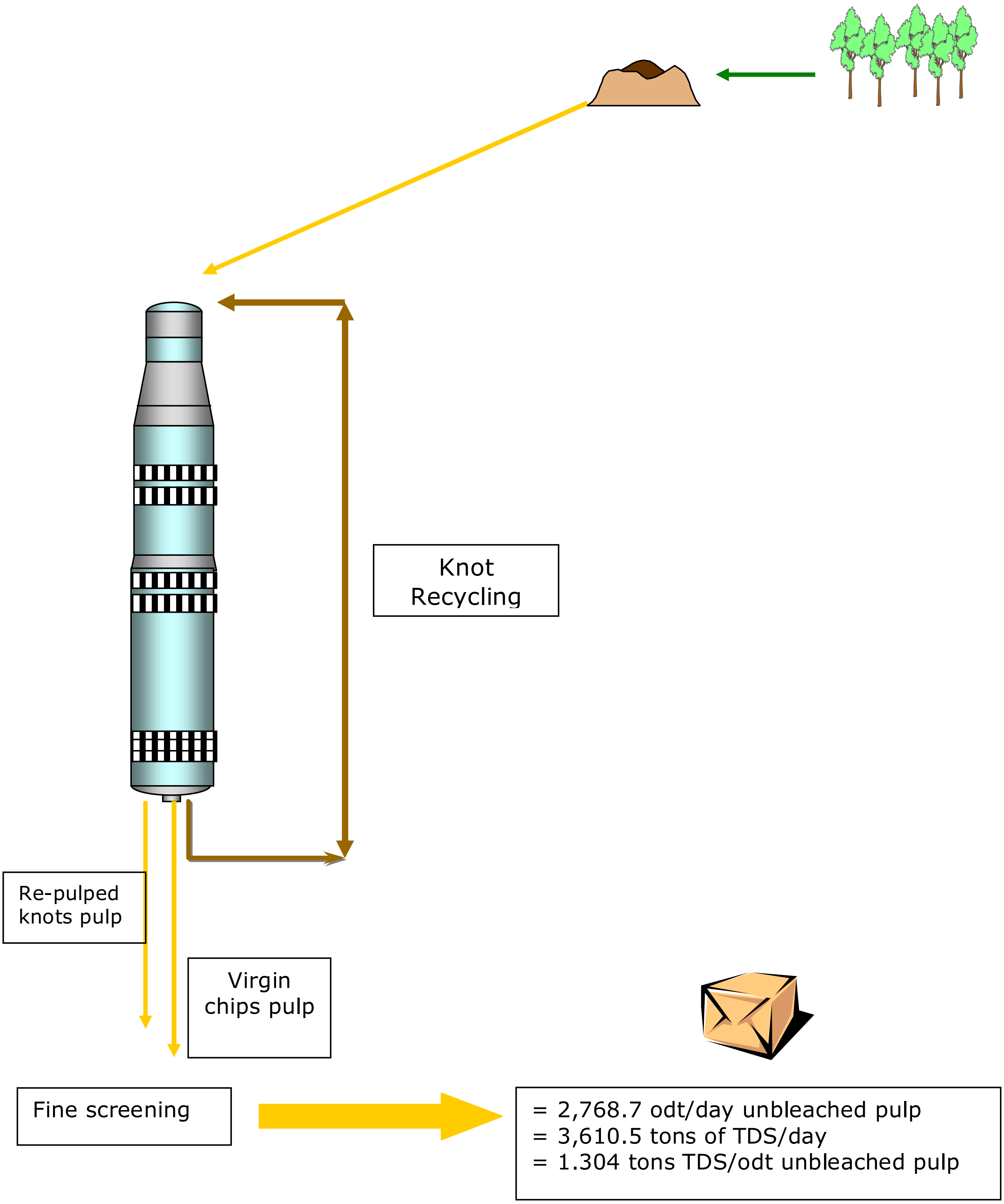
In addition, when knots and shives are cooked under suitable conditions, in a dedicated digester, the knots as well, may provide a better yield than that offered by them when they are cooked along with the virgin wooden chips in the main mill digester. For this reason, the interesting and important production differences between cases 1 and 4 are detailed later on.

For all these reasons, it is very interesting to calculate the additional value of this option 4 in a simplified way, as follows:

- Daily unbleached pulp production of case 1: 2,768.7 odt in the digester
- Daily unbleached pulp production of case 4, with knots and shives re-pulping in a captive batch digester: 2,771.9 odt in the digester
- Generation of TDS/day in case 1: 3,610.5 dry tons
- Generation of TDS/day in case 4: 3,610.1 dry tons
- Additional pulp production of case 4 with regard to case 1: 3.2 odt/day of unbleached and screened pulp
- Additional production of saleable bleached pulp: 3.38 adt/day
- Additional production of saleable bleached pulp: 1,180 adt/year
- Specific economic value of this additional pulp (Net selling price minus cooking, bleaching and drying costs) = 500 US$/adt
- Annualized added value of this additional production: US$ 590,000/year
- Reduction in residues to dispose of in a waste landfill: 7,800 m^3/year
- Unit value cost of disposing of industrial solid waste in a landfill: US$ 15/m^3
- Annualized value of disposing of shives in a landfill: US$ 117,000
- Yearly economic result, comprising the sum of pulp production gains and reduction in solid wastes of case 4 with regard to case 1: **US$ 707,000/year**

Therefore, a small captive batch digester for re-pulping knots and shives may be of great technical, economical and environmental value. This will not affect the final pulp quality, will not affect the amount of dry solids to the recovery boiler, will involve lower wood costs per ton of pulp, higher mill productions and lower environmental impacts. It is everything our sector needs, in order to be even more ecoefficient. Everyone will profit therefrom: company, society, and nature.

Case study # 1: Knot recycling without loss in feeding the normal wooden chips (the mill maintains the same supply for the virgin chips, since the knot recycling should not affect digester feeding).



- For the situation of case 1, the mill would feed 5,208 dry tons of eucalyptus wood chips into the continuous digester. This would correspond to 31,565 m^3 of chips, taking a chip density of 0.165 dry tons per cubic meter into account. This amount of wooden chips would correspond to 10,416 solid cubic meters of bark-free wooden logs.

- The virgin wood chip pulp yield was admitted to be 53%, while a yield of 60% was admitted for the knots.

- The daily amount of rejected knots was 20.84 odt, which means something like 0.75% of knots with regard to the unbleached pulp produced. For a knot bulk density of 0.185 odt/m^3 there will be an equivalence of 113 m^3 of knots generated per day.

- The active alkali charge consumed by the virgin chips corresponds to 18% as NaOH. The white liquor activity was assumed to be 80%.

- The active alkali charge consumed by the knots was assumed to be 12%; also a white liquor activity of 80% was assumed.

- The virgin chips resulted in 2,760 odt of unbleached pulp and the knots in 12.50 odt/day of unbleached pulp. Then, the sum of both fine unscreened productions (carried out in the same digeste) was 2,772.5 odt of raw pulp, plus the quantity of separated knots (20.84 odt/day).

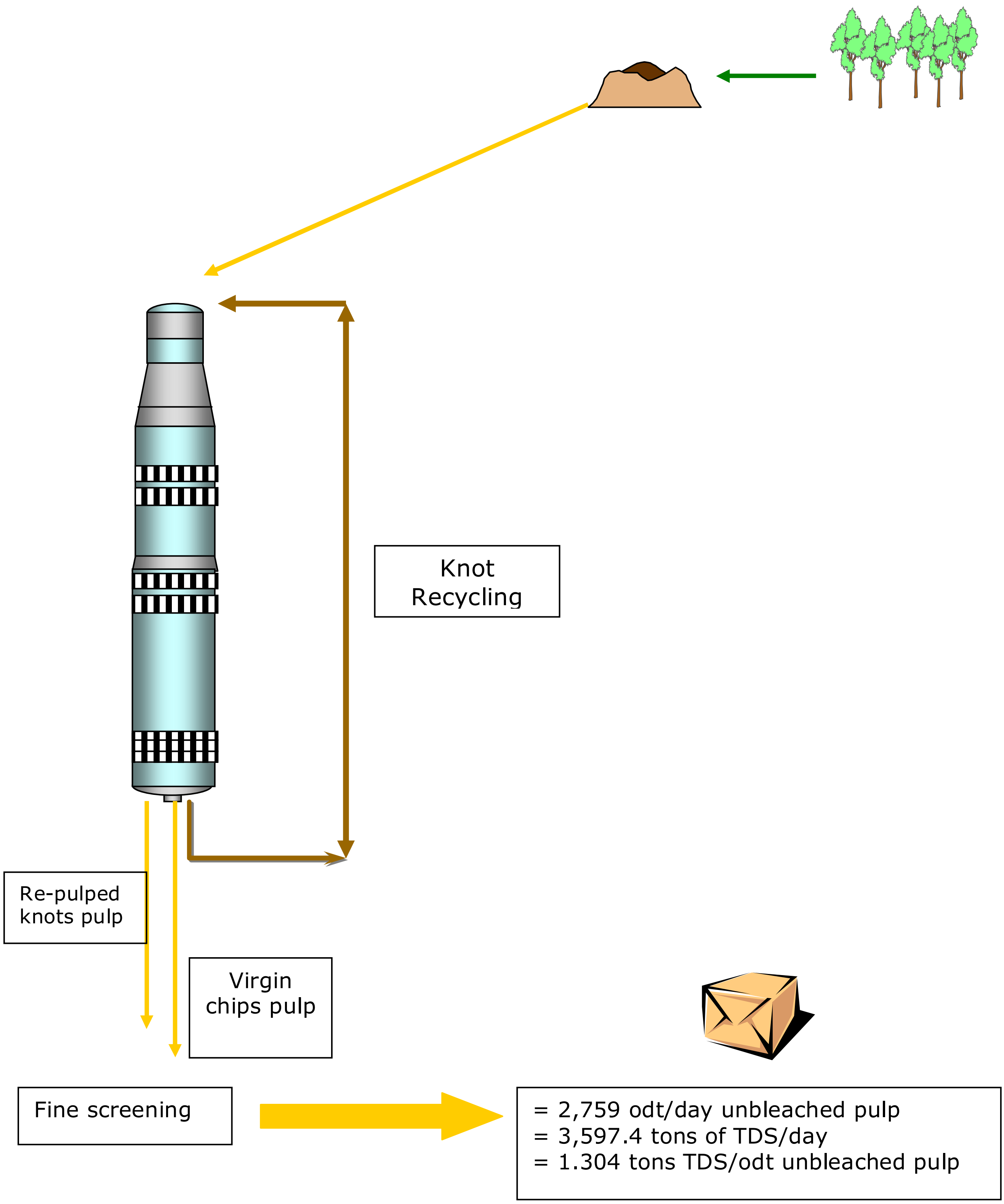
- Fine screening eliminated 3.80 odt/day of shives from the unbleached pulp stock. These shives were assumed as discarded in this case 1.

- The daily production of unbleached and screened pulp in case 1 would be 2,768.7 odt.

- The virgin chips resulted in 3,599 tons of TDS (total dry solid) per day and the knots in 11.45 tons of TDS/day. Then the sum of both amounts of dry solids for evaporation and recovery boiler would be 3,610.5 tons TDS/day.

- Then the resulting tons TDS/odt pulp ratio was 1.304.

Case study # 2: Knot recycling, but with loss in feeding the normal wooden chips (lower chip feeding = 112 m³ chips per day),



- For the situation of case 2, the mill would feed 5,189.4 dry tons of eucalyptus wood chips into the continuous digester. This would correspond to 31,450 m³ of chips, taking a chip density of 0.165 dry tons per cubic meter into account. This amount of wooden chips would correspond to 10,378.5 solid cubic meters of bark-free wooden logs.

- The virgin wood chip yield was admitted to be 53%, while a yield of 60% was admitted for the knots.

- The daily amount of rejected knots was 20.75 odt, which means something like 0.75% of knots with regard to the unbleached pulp produced. For a knot bulk density of 0.185 odt/m³ there will be an equivalence of about 112 m³ of knots volume per day.

- The active alkali charge consumed by the virgin chips corresponds to 18% as NaOH. The white liquor activity was assumed to be 80%.

- The active alkali charge consumed by the knots was assumed to be 12%, also a white liquor activity of 80% was assumed.

- The virgin chips resulted in 2,750.4 odt of unbleached pulp and the knots in 12.45 odt/day of unbleached pulp. Then the sum of both productions carried out in the same digester was 2,762.85 odt of unscreened pulp, plus the quantity of separated knots (20.75 odt/day).

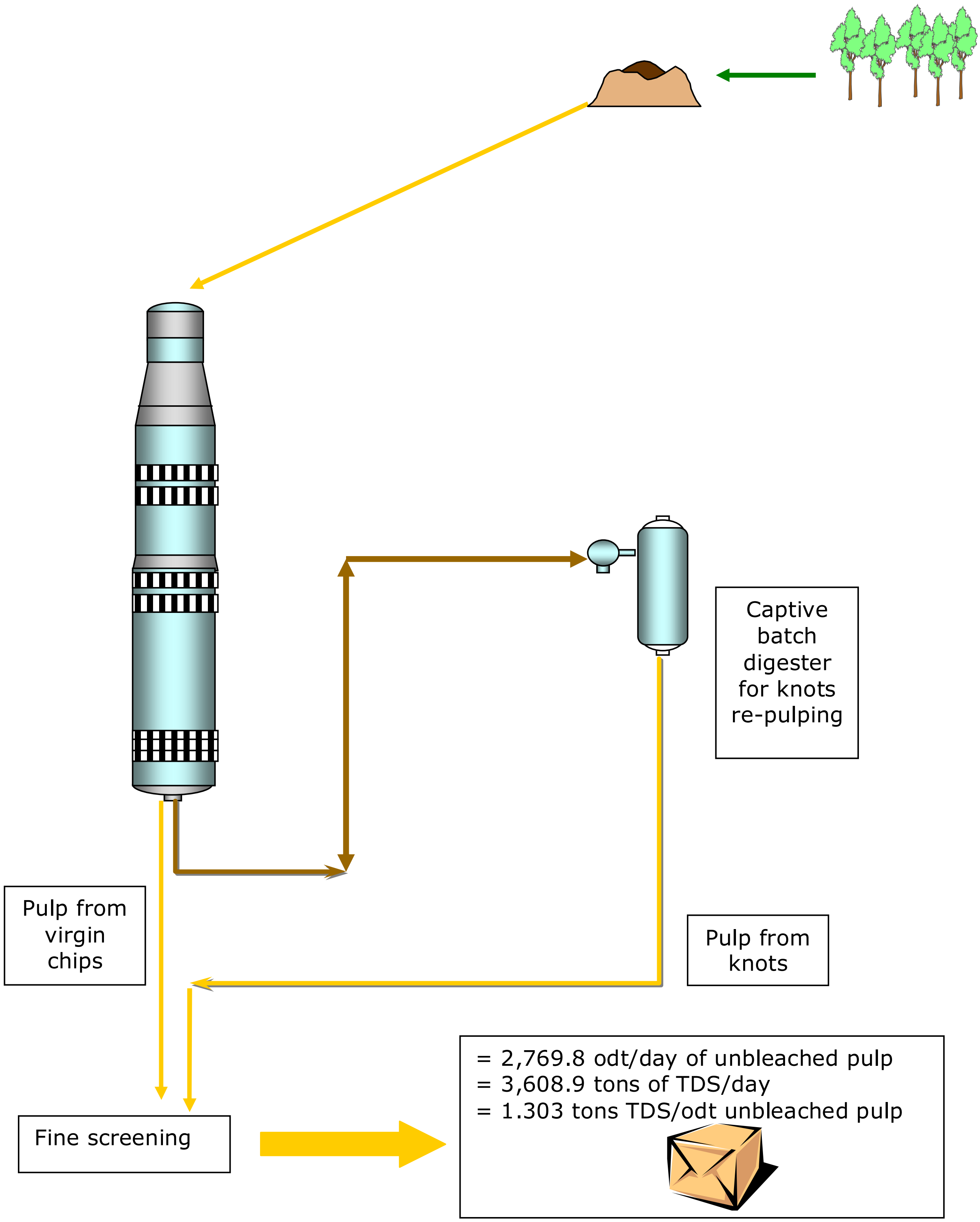
- Fine screening eliminated 3.80 odt/day of shives from the unbleached pulp stock. These shives were assumed as discarded in this case 2.

- The daily production of unbleached and screened pulp in case 2 would be 2,759 odt.

- The virgin chips resulted in 3,586 tons of TDS (total dry solid) per day and the knots in 11.41 tons of TDS/day. Then the sum of both amounts of dry solids for evaporation and recovery boiler would be 3,597.4 tons of TDS/day.

- Then the resulting tons of TDS/odt pulp ratio was 1.304.

Case study # 3: Separate knot re-pulping in a captive batch digester



- For the situation of case 3, the mill would feed 5,208 dry tons of eucalyptus wood chips into the continuous digester. This would correspond to 31,565 m³ of chips, taking a chip density of 0.165 dry tons per cubic meter into account. This amount of wooden chips would correspond to 10,416 solid cubic meters of bark-free wooden logs.

- The virgin wood chip yield was admitted to be 53%, while a yield of 65% was admitted for the knots, due to the fact that in the present case the knots are cooked under more suitable conditions for them.

- The daily amount of rejected knots was 20.84 odt, which means something like 0.75% of knots with regard to the unbleached pulp produced. For a knot bulk density of 0.185 odt/m³ there will be an equivalence of about 113 m³ of knots volume per day.

- The active alkali charge consumed by the virgin chips corresponds to 18% as NaOH. The white liquor activity was assumed as 80%.

- The active alkali charge consumed by the knots was assumed to be 10%; also assumed white liquor activity as 80%.

- The virgin chips resulted in 2,760 odt of unbleached pulp and the knots in 13.55 odt/day of unbleached pulp. Then the sum of both productions carried out in separate digesters was 2,773.6 odt of unscreened pulp, plus the separated knots (20.84 odt/day).

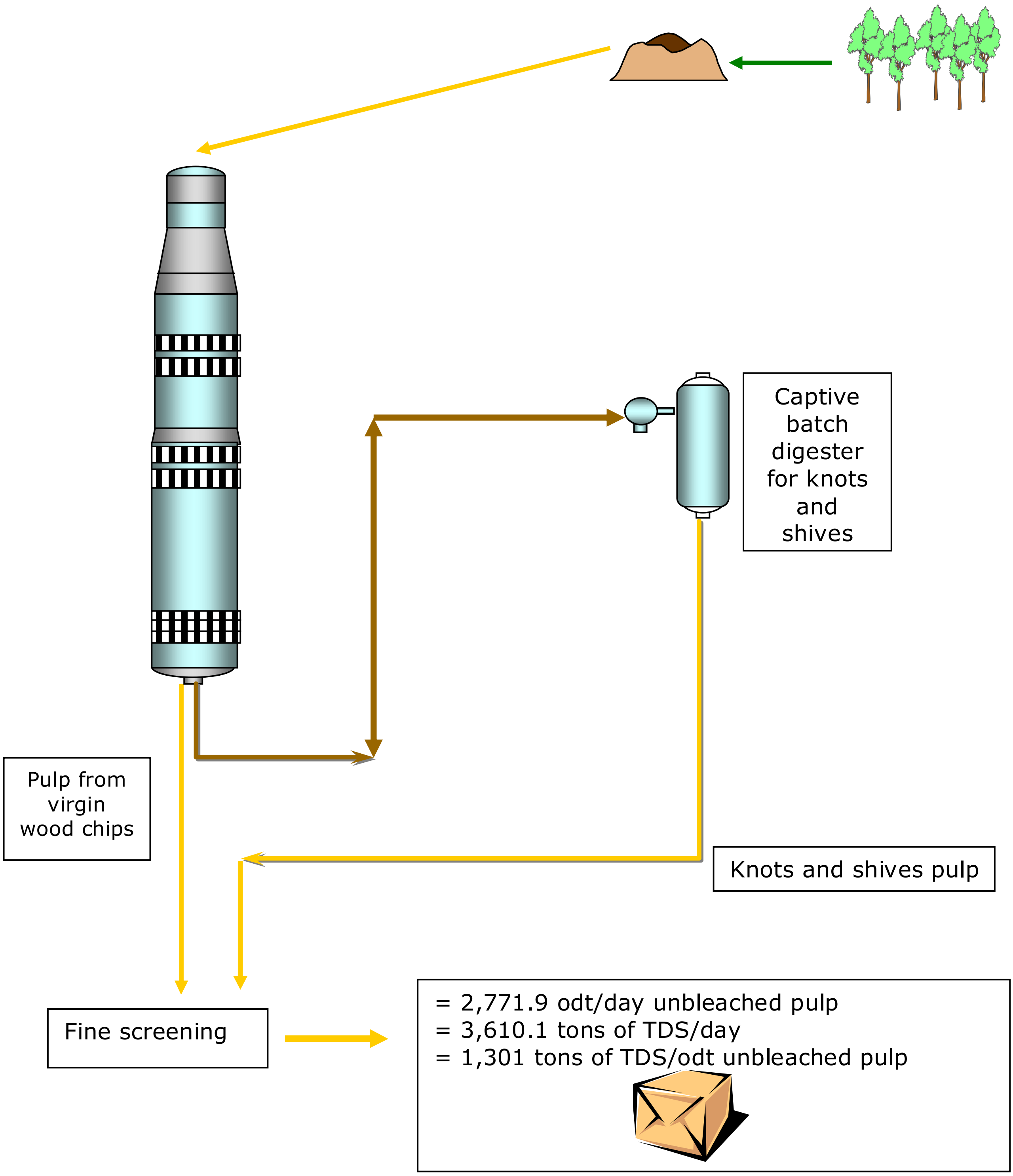
- Fine screening eliminated 3.80 odt/day of shives from the unbleached pulp stock. These shives were assumed as discarded in this case 3.

- The daily production of unbleached and screened pulp in case 3 would be 2,769.8 odt.

- The virgin chips resulted in 3,599 tons of TDS (total dry solid) per day and the knots in 9.89 tons of TDS/day. Then the sum of both amounts of dry solids for evaporation and recovery boiler would be 3,608.9 tons of TDS/day.

- Then the resulting tons of TDS/odt pulp ratio was 1.303.

Case study # 4: Separate knot and screening shives re-cooking in a captive batch digester



- For the situation of case 4, the mill would feed 5,208 dry tons of eucalyptus wood chips into the continuous digester. This would correspond to 31,565 m^3 of chips, taking a chip density of 0.165 dry tons per cubic meter into account. This amount of wooden chips would correspond to 10,416 solid cubic meters of bark-free wooden logs.

- The virgin wood chip pulp yield was admitted to be 53%, while a yield of 65% was admitted for the knots, due to the fact that in the present case the knots are cooked under conditions suitable for them. The yield assumed for the shives was 55%.

- The daily amount of rejected knots was 20.84 odt, which means something like 0.75% of knots with regard to the unbleached pulp produced. For a knot bulk density of 0.185 odt/m^3 there will be an equivalence of about 113 m^3 of knots volume per day.

- The rejected and re-cooked amount of shives was 3.8 dry tons per day.

- The active alkali charge consumed by the virgin chips corresponds to 18% as NaOH. The white liquor activity was assumed as 80%.

- The active alkali charge consumed by the knots and shives was assumed to be 10%; also assumed a white liquor activity of 80%.

- The virgin chips resulted in 2,760 odt of unbleached pulp, the knots in 13.55 odt/day of unbleached pulp and the shives in 2.1 odt/day. Then, the sum of the three productions carried out in the two digesters was 2,775.7 odt of unscreened pulp, plus the separated knots (20.84 odt/day).

- Fine screening eliminated 3.80 odt/day of shives from the unbleached pulp stock. These shives were re-cooked with the knots in a dedicated captive batch digester in this case 4.

- The daily production of unbleached and screened pulp in case 4 would be 2,771.9 odt.

- The virgin chips resulted in 3,599 tons of TDS (total dry solid) per day; the knots in 9.89 tons TDS/day and the shives in 1.21 tons of TDS/day. Then the sum of the three amounts of dry solids for evaporation and recovery boiler would be 3,610.1 tons TDS/day.

- Then the resulting tons of TDS/odt pulp ratio was 1.302.

==

SAWDUST FROM CHIP CLASSIFICATION

The sawdust from the chip classification area is a residue that in most cases goes unnoticed in the pulp mill. It is what may be called hidden residue: people know it is being generated, but do not notice how much and are not even interested in monitoring or quantifying it. This occurs because in many eucalyptus pulp mills the sawdust separated from the chips is used as fuel in a biomass boiler. Therefore, it is fuel wood or energetic biomass. In case the mill is not self-sufficient in biomass and has to purchase some of this biofuel from third parties, then the sawdust coming from the chip screeners is welcome. The company's technical management may be even stricter about chip classification, choosing to work with screens discarding more sawdust. Thus, chip quality is enhanced and a larger amount of sawdust biomass is gained to the power boiler. It is an interesting and valid option. However, this is not the situation that does occur in many cases. There are many mills consuming also the log bark as source of energetic biomass. All or most logs arriving at the mill have still bark. They pass through the debarkers, which remove the bark and this one is sent to an energetic biomass hogged fuel pile. At the debarking process there is a reasonable loss of wood in the form of loglets from breaking logs, splinters, slivers, etc. Then, the bark is always "contaminated" with some wood. It may also contain the "overs" i.e. oversized chips that are not rechipped, as they will be useful as energy source.

I have written much about all this in the first chapter of this Eucalyptus Online Book, a full chapter dedicated to the bark of the eucalyptus. Go to visit www.eucalyptus.com.br for more information.

Therefore, it is very common that the bark is contaminated with a relative amount of wood, which may reach 2 to 4% of the wood arriving at the mill (an enormous amount). Consequently, when sending the sawdust to this biomass mixture, it will have its particles diluted in that biomass of larger dimensions and proportions. The little sawdust wood fragments are not even very well noticed. It is easy to see the wood splinters, slivers and the "overs" mixed with the bark, but it is difficult to note the presence of sawdust, in spite of the fact that the proportion of sawdust that maybe sent to be mixed with the whole biomass is not low. The most usual figures for sawdust removed in the chip classification area indicate that between 1 and 3% of the weight of the chipped wood ends up being removed as sawdust. Another part of the sawdust follows with the chips to the digester, because the chips are still wet and sawdust and wood dust adhere thereto, so that their complete removal is difficult. In addition, even for modern chip screening processes, when we have large flows of material to screen, they are not quite efficient in segregating the fractions. It may be also admitted that approximately 0.5 to 1.5% of sawdust still remains with the chips and goes to the digesters. As it can be seen, sawdust generation in the process of transforming logs into chips is not at all low. Sawdust and wood powder do play an important role in kraft pulping.

The great problem occurs when the mill has an excess of own biomass to meet its power requirements. When this occurs, there is a superabundance of bark or thin firewood. Sawdust is an undesirable remainder of good wood, which gets lost. Then it becomes too valuable to be wasted, because as a matter of fact sawdust is wood, is a raw material of the pulp manufacturing process that was transformed into a solid fibrous residue. If it has at least an energetic use, it is O.K., but if it is simply scrapped, many costs will be added up and valuable material thrown away. It is a very common pulp mill practice to send bark with wood and sawdust rests to landfills or composting plants. These are final disposal or recycling solutions that do not take into account what sawdust is really worth. Therefore, it should be avoided to use good wood for this purposes, do you agree? The waste is enormous and the cost increase as well. Then, the ecoefficiency suffers therefrom. Fibrous raw material is lost, fuel biomass is lost as well; high environmental costs and environmental liabilities are generated. These costs are enormous, as they imply remunerating all this material thrown away, that might be used as raw material in the mill. There is still the cost added up in the process of converting wood into chips and then for classifying them. In addition, there are the handling and disposal costs for the wastes. It becomes too expensive to throw sawdust and wood rests away. I do not know whether this still occurs at some mills by ingenuousness, management candor or by technical blindness. A good material ends up occupying expensive volumes in industrial landfill. Although it is not a dangerous or harmful residue, there is also a legal bureaucracy to go through, as all industrial wastes require licenses, controls etc. to be disposed away.

When sawdust is sent to burn in the biomass boiler, though there is enough bark to generate the required energy, an expensive biomass is sent to replace an inexpensive energy source (bark). And something will be still left over. It is an incomprehensible loss occurring at the mills. And however incredible it may seem, it is a frequent situation in many pulp mills.

Sawdust formation is inevitable, it is fatally generated and must be separated. However, an amount of sawdust between 2 and 4 or 5% is an enormity, do you agree?. Here, I am considering the amounts of sawdust that are separated and those fed into the digester along with the chips. The processes of converting wood logs into chips are rather rough, involve huge mechanical forces applied to the logs. The latter are non-uniform material in density and diameters. Thus, the thin logs and the less dense woods generate still more sawdust. Let's have a look at the amount of sawdust that can be generated and disposed of (1 to 3% in weight) at a mill producing approximately 2,850 tons of unbleached pulp per day. Such a mill requires about 5,350 odt of wood per day. If a percentage between 1 and 3% turns into sawdust to be sent as biomass to another area of the mill, this corresponds from 60 to 150 odt/day. In wet weight, at 50% average moisture, the total wet sawdust weight is twice as high. Considering the bulk or apparent sawdust density to be 0.120 odt/m³, there will be sawdust volumes from 400 to 1250 m³ to handle. Admitting 1 solid cubic meter of bark-free eucalyptus logs to weigh 500 kg o.d., 4 m³ of sawdust in the form of bulk volume will correspond to 1 m³ of eucalyptus wood in the form of solid log. It is a considerable wood volume which is transformed into sawdust. A volume of 400 m³ of sawdust is equivalent to 100 m³ of logs, which would be enough to produce almost 30 daily tons of pulp under the most optimistic sawdust generating conditions.

Then, what can be done? Wasting is the worst alternative, as thereby costs are added to the process and the environment is mistreated. To remain blind to this reality denotes accommodation, ingenuousness and no vision for opportunities. Even if the mill needs biomass, if firewood is purchased in the market at a lower value than the price of the wood for the pulp manufacturing process, we will be losing money. For each ton of pulp wood that turns into sawdust we might be using a ton of cheaper firewood. In this way we would gain the price difference between these two woods. It is very easy to understand, but using figures it becomes still easier. Let's suppose that our mill has on the market a source of firewood available for 40 US$/odt. Let's also suppose the value of this process wood to be US$ 50/odt. At each ton of sawdust - which is process wood -, which is burned instead of firewood, a value of 10 US$ will be destroyed, do you agree?

The pulp mill often searches and purchases its process wood far away, pays much for the wood, for its transportation, for tolls, for bureaucracy. Some companies purchase wood for the pulp manufacturing process even in other countries, transporting it by ships and the like. It should be still reminded that wood represents the highest proportion in pulp manufacturing cost. In Brazil the wood costs represent approx. 35 to 40% of the direct pulp manufacturing cost. When these expensive and scarce woods arrive at the mills, the technicians accumulate them in log or chip piles and forget to take care of them as something very valuable. In this way some wood is always lost, be it at the storage, at handling, at chip preparation or as sawdust. Decay is also another source of wood losses.

Then, what should be changed in the management of the mills where these losses occur? How could the management face this waste of fibrous resources, energy and money? Awareness comes at the top of the list. Everyone should be aware that the lost wood or sawdust has a cost and that this cost is a high one. Sawdust sent to the biomass does not go there for nothing. Then, after becoming aware of the problem, secondly these losses and wastes should be quantified. How much sawdust is generated per day? What would be the most acceptable values in connection with the technology we have available? Are our chippers operating well? Is the amount of sawdust produced by them high? Why? Is there any difference in sawdust generation among the various chippers? What is the reason for this difference?

This quantification can be achieved by constant monitoring and by means of quality goals established for this residue. It should not be forgotten at any time. As sawdust is always generated, its quantity and its quality must be continuously measured as well.

In the following step, the economical value of its generation must be discovered. To obtain this value, the value of the purchased wood and the addition of value occurred inside the mill until it turned into lost sawdust should be computed. Finally, how much we pay to handle it and to dispose of it. If we sell the sawdust to someone, even to another area of the mill, at which price is this sawdust being transferred?

A simple example is presented below:

- Value of 1 oven dry ton of process wood: US$ 50
- Value added per odt for chip preparation and screening: US$ 2
- Economic value of 1 odt of sawdust: US$ 52
- Economic value of 1 odt of equivalent fuel bark based on calorific value: US$ 30
- Cost of disposal of 1 odt of biomass in a waste dump: US$ 30

In case the bark is thrown away and sawdust is consumed instead of it, the difference of US$ 22 will be lost, plus the value paid to dispose of the bark thrown away in the landfill. As the bark thrown away in the landfill has sawdust mixed therewith, the correct value must be also attributed to this sawdust accompanying the bark to the waste dump area. In other words, all this has an extremely high value, both in the form of money and of waste. To be ecoefficient means to be attentive to these losses and to solve the problem where this problem is being generated. It may be related to the quality of the wood, to the chipper maintenance, to some hole in the chip classifying screens etc. etc. If the sawdust generation cannot be avoided, it is at least possible to try in some way to reduce its generation. It is also possible to learn to use better the generated sawdust. In short: we should always monitor its generation, work to reduce its generation and use more intelligently the sawdust that is being inevitably generated. This is valid both for use as process wood and as energetic wood or biomass fuel. The environmental and economic values resulting from good use of this biomass or these wasted fibers are enormous. Let's imagine that if at each wasted dry ton of sawdust an amount of US$ 20 to US$ 50 is being thrown away or neglected, what would we say of wasting from 60 to 150 odt per day at our hypothetical mill producing one million tons of pulp per year? I wonder whether the top management of the company is paying attention to these figures.

Another alternative is to look for uses for the sawdust other than just burning it in a biomass boiler. When considering carefully the sawdust separated in the chipping area, it can be noted that sawdust is an irregular residue. It consists of wood fractions of several sizes. There are in general three main fractions:

- Mini-chips or pin chips;
- Coarse sawdust;
- Wood dust or fine sawdust.

Eucalyptus wood sawdust separated at chip screening area


Normal and desirable eucalyptus wood chips


Mini-chips or pin chips

Coarse sawdust containing pin chips

"Overs" or oversizedchips

The proportions of the different sawdust fractions depend on a series of factors, but mainly on the wood type, its moisture and decay stage, on the presence or absence of a re-chipper, on the chipper design and adjustments and on the shape and condition of the chip classifying screens.

- **Wood:** The lighter and less dense woods tend to generate more sawdust, more fines, more pin chips. Also it was already said that the wood moisture affects this, as drier woods generate more sawdust. Decayed woods, especially if they are very dry, also generate much sawdust.

- **Re-chipper**: A good part of the splinters, slivers and oversized chips go to re-chipping. Re-chippers are as a matter of fact wood grinders, like those hammer mill type ones. They do a rough work and succeed in transforming about 20 to 40% of the weight of the material fed into them into sawdust. Instead of recovering good chips from the "overs", more sawdust is generated as residue. Therefore, much attention should be paid hereto. The re-chippers must be always monitored and have their addition of value to the mill calculated, as they may be destroying instead of adding value.

- **Chippers**: Although there are nowadays new concepts to convert wood logs into chips, sawdust continues to be generated. This generation depends very much on the stage of conservation and maintenance of the chippers, as well as on their technological age. Ancient or ill-conserved chippers, with clearances, cracks and welds, unbalanced and with already tired shafts and wear plates, generate a lot of sawdust. In situations like that, more than 6% sawdust at the chips may be reached right after wood logs chipping. They also generate many splinters, slivers and oversized chips. The latter, when fed into the re-chipper, generate still more sawdust. A horror movie for the woods, as well as for the mill costs.

- **Chip classifying screens**: According to the mesh opening, a larger or smaller amount of sawdust can be rejected. Open meshes let more pin chips, more mini-chips to go throw. When there are maintenance problems, such as holes in the screens or larger openings in the disk screens, these screens let also good chips to pass throw, which follow to the sawdust waste. Sometimes the mills get along with these problems, which cost much money to them.

For all these reasons, the manager of the wood chip preparation area must keep quantifying and monitoring the quality of the sawdust generated in his area. In general, he is always monitoring the accepted chips, those destined to be fed into the digester. After all, it is the material produced by him, which he transfers to his main customer i.e. the pulp manufacturing process. He is seldom occupied with an attentive analysis of the environmental and economic losses resulting from the generated sawdust which leaves his area. Often, he does not even know the destination of this material.

He must also know how to make his economical calculations, in order to be able to show them to those people who release resources for the maintenance and engineering works for the area. This chip preparation area, so important for the pulp mills, is deserving massive investments at some companies. In other companies, this area is placed in a second order of importance. Nevertheless, in all of them, the managers' attention is rather turned to the digester, to the bleaching line, or to the recovery boiler.

Some companies have another type of fuel available instead of biomass. If they do not find a fast and sustained solution for the separated sawdust, the latter keeps accumulating quickly and exponentially, because the separated volume is fantastically high. This situation contributes to make the company still more inefficient, as they even accept to donate this expensive wood in the form of sawdust to someone coming just with the aim to pick this material up. Or else, they sell it at a derisory price. Even thus, they do not use to monitor its generation, to see whether it is high or low. This is unbelievable, is it not? In short, a wood costing them US$ 50/odt is conceded without charge to someone coming to pick it up, or sold at a price that pays only the handling of it. Even if they sell it as biomass at US$ 30/odt, there are other values the mill has got to bear, such as handling, storage etc. This means losses, without a shadow of a doubt.

Selling sawdust as biomass

My friends, this whole situation is definitively very important. We cannot afford any longer to accept this problem in connection with this kind of residue. We must attribute the just value to this wood preparation area. We need qualified people in it, as well as equipment in perfect operating conditions. Wood is something very expensive and also scarce nowadays. Everything done in order to rationalize its use and to avoid losses is very good. Not to justify is that many managers continue to be inattentive to these opportunities and these wastes.

Now, coming back to the different components of the industrial sawdust of eucalyptus pulp mills, they may be segregated into the following categories:

- **Normal chips**: they may be present in sawdust in exceptional situations, when there are serious maintenance problems in the chip classification area. Whenever good chips appear in the sawdust, immediate action should be taken, as the problem is serious.

- **Pin chips**: they are small long and thin wood fragments, which may remind a little chip or a wooden match. They are in general nearly 1 to 5 mm wide, 1 to 3 mm thick and 10 to 25 mm long.

- **Coarse sawdust**: it consists of homogeneous, ball- or cube-shaped fragments, measuring about 3 to 7 mm of side. It uses to show high contamination with pin chips, as these pin chips also manage to pass through the screens.

- **Fine sawdust or wood dust**: it consists of thin wood fragments, dimensions of which are smaller than 2 mm of side, ranging from fragments to an extremely fine wood flour type dust.

The different sawdust fractions mix well with each other, but they are also easily separated by size classification in screens. This separation is not 100% effective, there will always remain some mixture between the segregated fractions, but it can be done relatively well, if the idea is to use sawdust fractions. The wetter the material, the more difficult is the separation.

When an analysis of the different fragments of the chip preparation area is performed, aiming their possible utilization, more or less the following panorama results for eucalyptus wood:

Chip type *Eucalyptus saligna*	**Wood basic density** **(g/cm³)**	**Number of fragments** **(Millions per m³)** 100% of these materials	**Bulk density (odt/m³)**		
			Loose material	**Slightly pounded material**	**Pressed material with 0.35 kgf/cm² of pressure**
Normal chips	0.48	0.6 to 1	0.16	0.17	0.18
Pin chips	0.46	5 to 12	0.12	0.13	0.16
Coarse sawdust	0.40	25 to 40	0.10	0.12	0.15
"Overs"	0.50	0.1 to 0.2	0.17	0.18	0.19

The fine fraction is that existing in the lowest proportion in the sawdust, relatively to the pin chips and coarse sawdust. It corresponds to about 15 to 30% of the weight of the total sawdust. On the other hand, this fine fraction is the sand and soil richest one. These contaminants arrive at the mill with the wood logs. They manage to pass through the log washing process, as they adhere well to the logs and wet bark rests. At chip screening, due to their minute dimensions, most of them pass along with the sawdust. In addition, in case the sawdust is re-screened, they remain in approx. 70 to 90% of their weight in the fine sawdust fraction. Most of these inorganic matters are silica and silicates. Therefore, when removing the wood sawdust flour or the finest fraction, the sawdust is purified from most soil and sand contained in it. With the screening and the fine fraction separation, the coarse sawdust and the pin chip ash content becomes similar to that of the normal chips, approx. 0.5% highest dry weight basis at the most.

The wood-flour-free sawdust (mixed coarse sawdust and pin chips) consists of a rather interesting material, even for pulping and pulp production. Wood flour is the great active alkali consumer at the kraft pulping, but this is not the case of the coarse sawdust and the pin chips and mini-chips. These fractions may be perfectly directed to cooking, in case the company is willing to separate them for consumption as process wood. Then, it remains to be decided how and where? To return them to the normal chips may be uninteresting, especially in case of modern digesters based on intense liquor recirculation. As this finer materials swell more and turns into fibers prior to the chips, this may affect the liquor re-circulation. The solution may be a separate line of a small batch digester, which may cook the pin chips and the coarse sawdust, specially separated for this purpose. Contrary to what many people think, when cooking these materials under conditions which are suitable for them, a pulp with good yield and compatible qualities to be added to the process can be produced.

Surely that each mill has its specific situation. If it needs biomass, this sawdust may be perfectly viable to complement the biomass requirements. However, if it has an excess of biomass, the re-screened sawdust may become a new and inexpensive wood source for its process, with perfectly acceptable pulp qualities. Even if it presents a slight inferiority with regard to the normal chips, its proportion is not high and it can be diluted in the higher production, as it will be seen hereinafter.

Sawdust being discarded as residue by a pulp manufacturer (great contamination with normal chips due to the overloaded classification screening)

Pulp mill sawdust (great contamination with normal chips)

Results of individualized coarse sawdust and pin chip kraft pulping are common in literature. They are always interesting and a source of enthusiasm. Provided the fine dust is separated, these materials are viable enough for kraft pulp production. The pulp yields are slightly lower than those obtained with normal chips (for coarse sawdust approx. 2 to 4% lower on dry wood basis; for pin chips, approx. 1 to 2% lower). Partly this is due to the inability of carrying out a complete segregation of the various fractions. There is always some fine sawdust to contaminate both the coarse sawdust and the pin chips. For instance, a coarse sawdust analysis we have performed indicated approx. 5% of fine sawdust and pin chips from 10 to 20%; whereas a segregated and "pure" fine sawdust presented 50% of wood dust, about 40% of fine sawdust and 10% of a sawdust that might be called a coarse one.

The pin chips practically consume the same alkaline charge as the normal chips. However, their cooking time may be shorter and their cooking temperature lower than those required for normal chips at the same kappa number level in the pulp. They impregnate more easily and their delignification is favored thereby.

The coarse sawdust, due to its own characteristic, requires some more active alkali – something like 2 to 2.5% as NaOH - than the normal chips. But this is nothing exceptional, do you agree?

For these reasons, I would like to refer again to our hypothetical mill of approx. one million tons of bleached kraft pulp per year. Let's assume it is facing some wood supply difficulties, that this wood is expensive and comes from far way. Let's also assume that it is an energetically very efficient mill and that the eucalyptus log bark is sufficient as auxiliary fuel. The whole amount of sawdust at this mill remains to be used. This mill, now in our case study number 5, chooses to recycle the knots back to the continuous digester, deciding at the same time to set apart a small batch digester for cooking coarse sawdust and pin chips separately, after segregating them from the mill whole sawdust. That cooking of these two materials would be carried out after mixing them with each other. Only the fine sawdust and the wood dust would be separated. This wood dust would be sent to burn in the biomass boiler, so that it would not be a residue to be discarded or to accumulate at the mill. In case bark would continue to be in excess, the mill might begin to debark a part of its logs in the forest, leaving some bark for nutrient cycling in the forest area.

Another option that our mill might take into consideration would be using the batch digester for two purposes:

- Coarse sawdust and pin chip pulping (as in case study number 5);

- Knot and shives pulping (as in case study 4, previously presented).

It would be sufficient for them to adapt themselves, so as to have a closed silo for the knots and pulp screening shives, which would be stored in that silo, while the batch digester would be operating with coarse sawdust and pin chips. The sawdust and pin chip storage might be already made in the open air, while the digester would be used for knot and shive cooking. Everything perfectly viable, nothing exceptional in technical terms.

We know mills cooking the coarse sawdust, the pin chips and the digester knots simultaneously in the same batch digester. This is possible, but it is not the ideal procedure, since sawdust and pin chips require cooking conditions which are very distinct from those required by knots and unbleached stock screening shives. It should be reminded that knots and screening shives just require 8 to 12% of active alkali as NaOH, whereas the coarse sawdust requires approx. 20 to 22% and the pin chips about 18 to 19%.

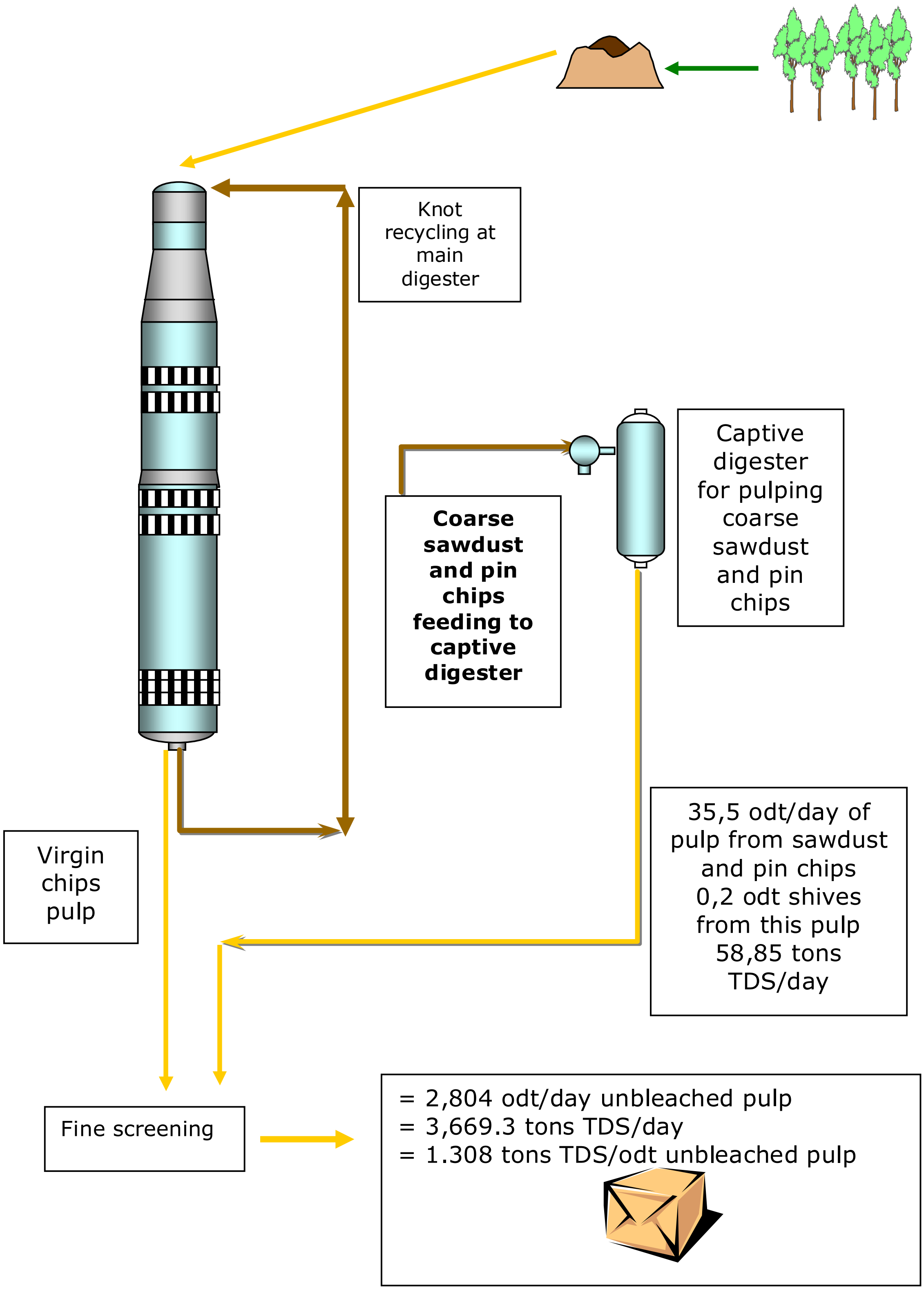
Let's approach now a further case study, that of number 5, in which our hypothetical mill decides to re-pulp the knots in the digester along with the normal chips, and the coarse sawdust and the pin chips in a separate captive batch digester. To the effect of our calculations, the amounts of wood arriving at the mill will be considered to be the same. No new wood entry will occur, just the batch digester will be cooking and producing more pulp from residues that have been disposed of in the other case studies i.e the coarse sawdust and the pin chips. More ecoefficiency for our hypothetical mill. Let's hope that this kind of situation will not be hypothetical any longer in a near future.

Case study # 5: Virgin chip pulping with knot recycling to the main digester, without any loss in chip feeding (corresponds to the previously presented case 1). Coarse sawdust and pin chip segregation for separate cooking in a batch captive digester oriented to this purpose.

- The mill feeds into the digester: 5,208 odt of virgin chips per day
- The mill generates and recycles: 20.84 odt of digester knots per day
- The mill produces in the continuous digester: 2,768.7 odt of unbleached and screened pulp per day
- The mill generates 2% of the weight of the wood entering the process as sawdust and pin chips: 106 odt/day of this combined sawdust

- Coarse sawdust and pin chip fraction: 70% (separated for recovery)
- Dust and fine sawdust fraction: 30% (separated and sent for energy generation as biomass fuel)
- Daily quantity of coarse sawdust and pin chips for pulping: 74 odt/day
- Bulk density or apparent density of this sawdust and pin chip material: 0.12 odt/m^3
- Total sawdust and pin chip volume generated per day: 620 m^3
- Chip cooking yield: 53%
- Net yield in coarse sawdust and pin chip cooking in the batch digester: 48%
- Active alkali as NaOH for the normal chips in the continuous digester: 18%
- Active alkali as NaOH for coarse sawdust and pin chips: 22%
- White liquor activity: 80%
- Total production of unbleached and screened pulps coming from the normal chips, knots and sawdust plus pin chips: 2,804 odt/day
- Total Dry Solids of all sources: 3,669.3 tons TDS/day
- Tons of TDS/odt of total unbleached and screened pulp ratio: 1.308

Case study # 5: Coarse sawdust and pin chip pulping in a separate captive digester. Knot recycling to the main digester along with normal chips.



The result of case 5 shows that the company adds 35.3 odt/day of unbleached and screened pulp with regard to case 1, without affecting its process and without overloading its recovery boiler. The daily production gain was 1.27%, considering the same wood basis.

The pulp obtained from coarse sawdust and pin chips can be perfectly mixed with the normal pulp coming from the continuous digester without impairing its quality. The qualitative differences between the various pulps exist, as it will be seen later on. However, they are small, as small are the proportions of these extra pulps being manufactured. Definitively, as there are no potential problems of more dirt or additional bleaching difficulties, this kind of operation is perfectly safe and viable. The more care taken in segregating the sawdust and in cleaning it, as well as with regard to its quality and specification, the better will be the qualitative results and the lower the impacts on the process.

Pulp production is gained on the same mill site, also a better use of the fibrous raw material is achieved, production is obtained in a cleaner and more ecoefficient manner and the impact on nature is reduced. With the same amount of wood, production is increased, the fibrous residues are almost zeroed, and the environment is better preserved.

Annualizing all this, an additional value of 12,500 adt of bleached pulp will be obtained for the same wood consumption, which is not at all bad for a low investment. Investments will be with a small batch digester and accessories for feeding it with sawdust and pin chips, as well as a sawdust screening device, and some air pollution and spills prevention. Investments are minor in relation to the expected gains.

It should be taken into account that when increasing the production on a same wood basis we have the benefits of fewer trees being demanded for our mill at its production capacity and a smaller planted area will be required.

All this is viable, provided our mill does not need the sawdust as biomass fuel, and also, there will be available white liquor and black liquor recovery capacity. It is worth reflecting on these considerations, is it not?

Nevertheless, there is still an additional case to analyze, the most ecoefficient of all. Let's call it case study number 6. It would be the situation where cooking knots and unbleached stock screening shives would be separately cooked in a batch digester. That same batch digester would be alternatively used to produce pulp from knots and screening shives, as well as for coarse sawdust and pin chips. Something technically perfectly viable. As already seen, a silo would be additionally required for storing the knots and screening shives when the digester were being used to process sawdust and pin chips. This case 6 is a hybrid of cases 4 and 5. It is the one adding most value to the residues and to our fibrous resources.

Let's see now how the main lines for case 6 can be defined:

Case study # 6: Only normal chips are cooked in the main digester. Coarse sawdust and pin chips segregation for separate pulping in a batch digester. Digester knots and screening shives separation for pulping in that batch digester alternately to the coarse sawdust and pin chips.

- The mill feeds into the digester: 5,208 odt of chips per day
- The mill generates: 20.84 odt of knots to be sent to the batch digester
- The mill produces in the continuous digester: 2,760 odt of unbleached and unscreened pulp per day
- The mill produces in the batch digester: 13.55 odt of unbleached pulp equivalent to the re-cooked knots
- The mill produces in the batch digester: 2.2 odt of unbleached pulp equivalent to the pulp screening shives
- The mill produces in the batch digester: 35.5 odt of unbleached pulp from coarse sawdust and pin chips
- Total stock fine pulp screening removes 4 odt/day of screening shives that are re-cooked in the batch digester together with the knots
- Total production of unbleached and screened stock obtained from all fibrous material sources: 2,807.25 odt/day
- Total generation of TDS per day for both digesters: 3,669 tons TDS/day
- Tons of TDS/odt of unbleached and screened pulp ratio: 1.307
- The mill generates 2% of the weight of the wood entering the process as sawdust and pin chips: 106 odt/day of this sawdust
- Coarse sawdust and pin chip fraction: 70% (separated for recovery)
- Dust and fine sawdust fraction: 30% (separated and sent for energy generation as biomass fuel)
- Quantity of fine sawdust and wood dust forwarded for energy generation: 32 odt/day
- Daily quantity of coarse sawdust and pin chips for cooking: 74 odt/day
- Bulk density or apparent density of this sawdust and pin chip material: 0.12 odt/m^3
- Total sawdust and pin chip volume generated per day: 620 m^3

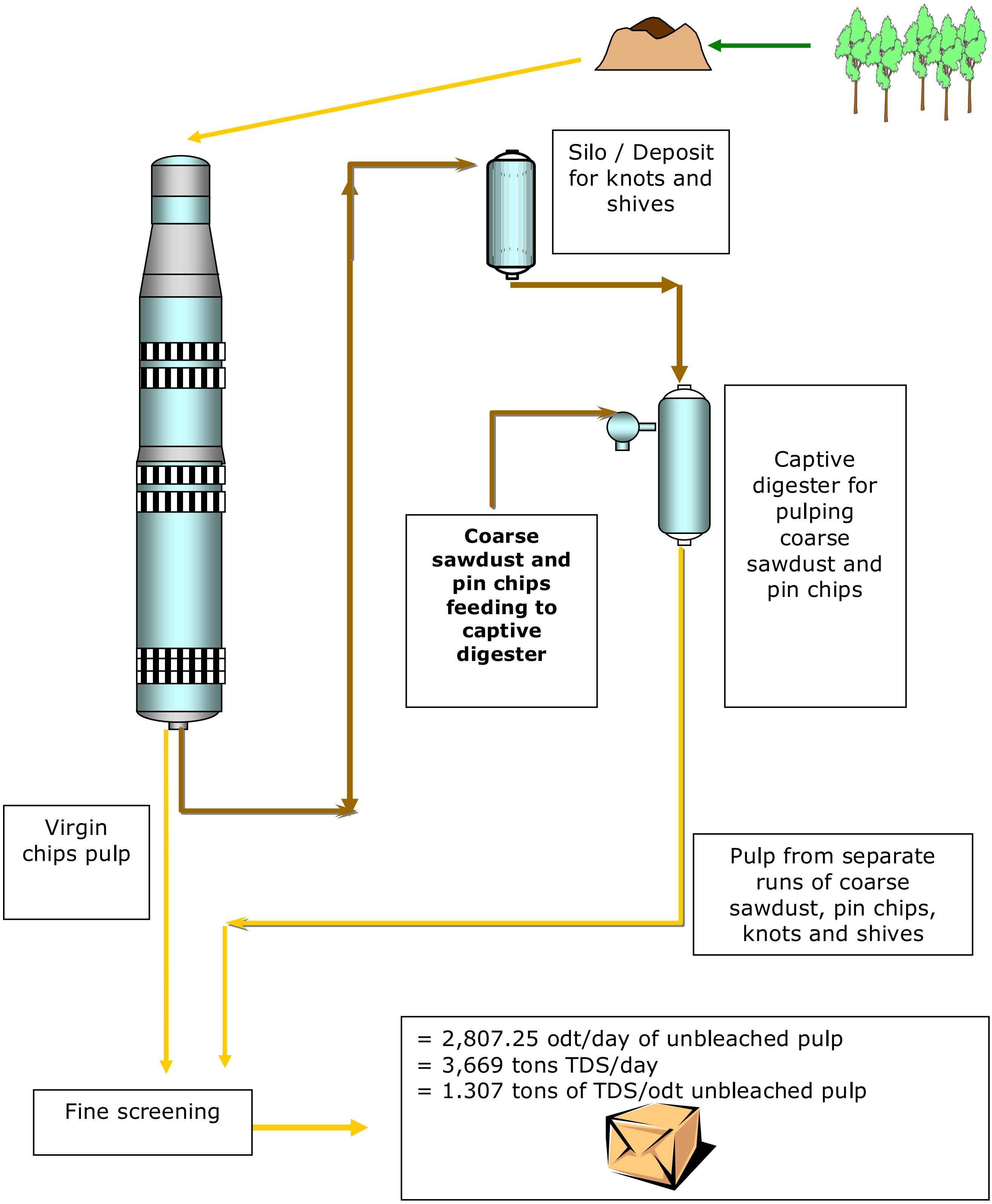
- Virgin chip cooking yield: 53%
- Knot cooking yield in the batch digester: 65%
- Screening shive cooking yield in the batch digester: 55%
- Coarse sawdust and pin chip cooking net yield in the batch digester: 48%
- Active alkali as NaOH for the normal chips in the continuous digester: 18%
- Active alkali as NaOH for coarse sawdust and pin chips: 22%
- Active alkali as NaOH for knot and screening shive cooking: 10%
- White liquor activity: 80%

Now, summarizing cases 1, 4 , 5 and 6 in a single table:

Case	1	4	5	6
Cooking	Chips plus knots in the main digester	Chips in the main digester and knots and shives in a separate digester	Chips plus knots in the main digester and sawdust and pin chip cooking in captive batch digester	Chips in the main digester and knots and shives in a separate digester, alternately with sawdust and pin chip cooking in that same batch digester
Situation	Normal virgin chip feeding was kept the same	Normal virgin chip feeding was kept the same	Normal virgin chip feeding was kept the same	Normal virgin chip feeding was kept the same
Wood consumption in m³/day	10,416	10,416	10,416	10,416
Net solid wood specific consumption in m³/odt of pulp	3.7620	3.7578	3.715	3.710
Unbleached pulp production in odt/day	2,768.7	2,771.9	2,804	2,807.25
Total Dry Solids from digesters tons TDS/day	3,610.5	3,610.1	3,669.3	3,669
tons TDS /odt of unbleached pulp	1.304	1.302	1.308	1.307

Definitively, these are very interesting gains on a constant basis of wood arriving at the mill. I hope that we are planting a new little seedling of technological alternative, in order that our mills may be able to act in this way in the future. Time will tell, I am hopeful…

Case study # 6: Separate pulping of coarse sawdust, pin chips, knots and shives in a captive batch digester



Still for our hypothetical mill of one million tons per year, the fine sawdust separated would correspond to 32 odt. Considering that it may contain 25% of inorganic contents in that fraction (8 odt), there will be still 24 odt of biomass to be sent to the power boiler. The result of all this is a much better use of our resources and a much lower solid residue generation.

In case our hypothetical mill is not willing to consume the sawdust as a fiber source, but as a power source, it would have the 106 odt/day of material for burning. At 50% moisture, this is equivalent to 212 tons as such. At this moisture and this content of inorganic matter, a calorific power of 1,600 kcal/wet kg may be considered. We will have a value of approximately 340,000 Mcal per day, which is equivalent to 32 tons of fuel oil. In specific terms, this sawdust corresponds to about 11 kg of fuel oil supplied as biomass per air dried ton of white pulp produced.

Other options for sawdust would be:

- Selling it as fuel wood to some biomass consumer on the region. It should be near, as sawdust is too bulky for long-distance transportation.
- Using it as raw material for biorefineries and alcohol production.
- Selling it as processed wood, with aggregation of chipping and granulometric classification (wood panel board manufacturers).

In all these situation the selling price should be determined so as to remunerate the wood and the value aggregation to it along the mill process. In another alternative its selling value should be based on the price of the fuel it will replace in its use by the purchaser.

In none of these cases should the sawdust be treated as garbage, as a useless residue to be disposed away. The sawdust and its fractions deserve a much better destination. Thus, we will be qualifying better our environmental, social and economic actions, in search of the sustained development.

==

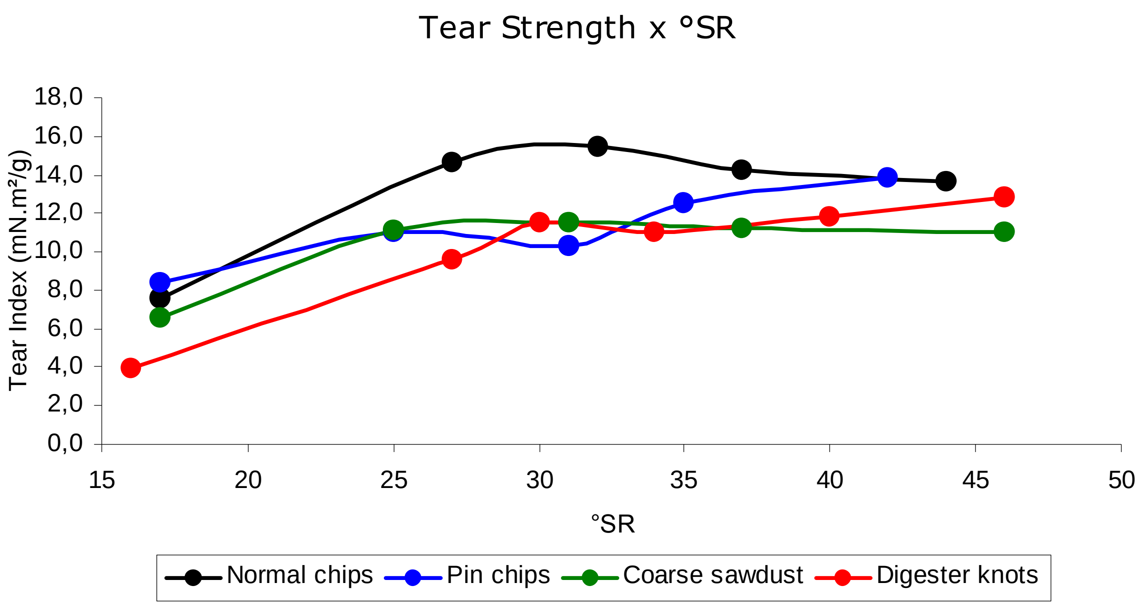
COMPARATIVE QUALITY STUDIES OF KRAFT PULPS FROM DIGESTER REJECTS OR KNOTS, COARSE SAWDUST, PIN CHIPS AND NORMAL EUCALYPTUS CHIPS

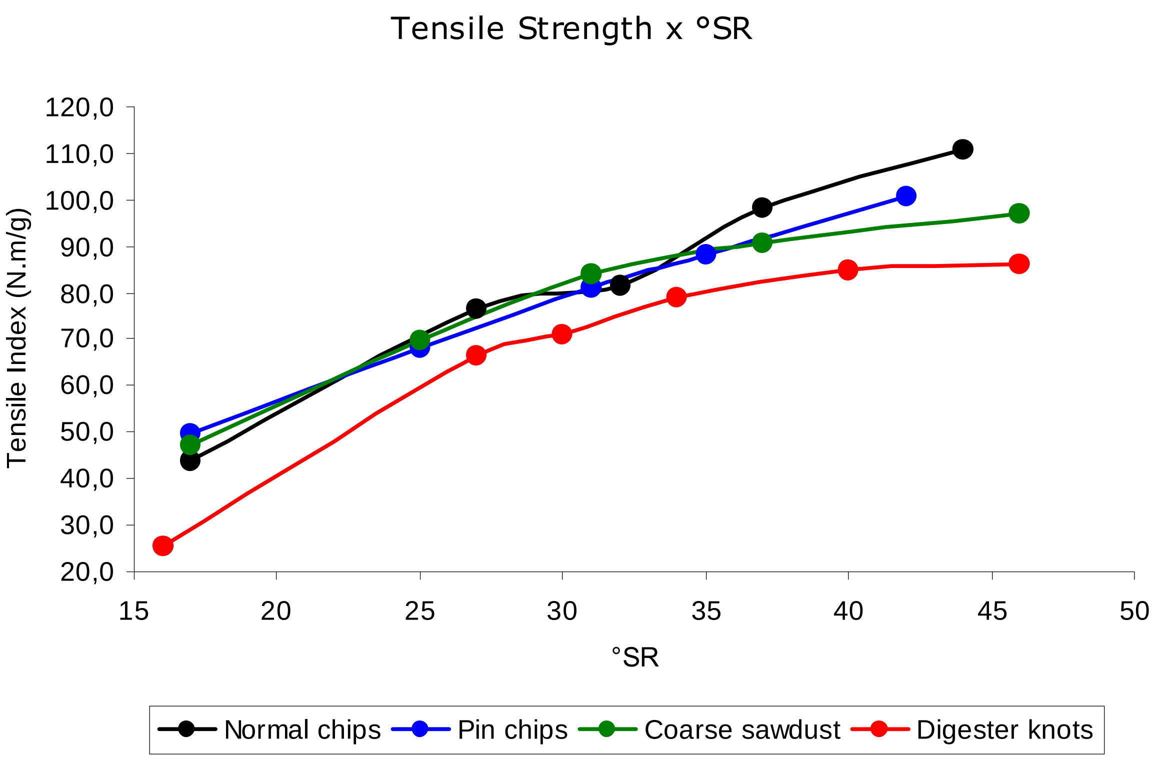
The results reported below come from a study carried out by Pedrazzi, along with myself and other co-authors in 2002, with eucalyptus wood in the State of Rio Grande do Sul, Brazil. This work is available to be accessed both in English and in Portuguese (expanded abstract in both languages) under the literature references in an item following hereinafter. In the studies performed by the authors, viscosities and strengths of unbleached pulps obtained from those fibrous residues were reasonably acceptable for the coarse sawdust and pin chip pulps and perfectly comparable to those obtained from normal chips. The pulp presenting the most unfavorable characteristics as to viscosity was that obtained from digester rejects or knots, with lower viscosities and tensile and tear strengths. On the other hand, these rejects or knots are usually industrially re-cooked now-a-days, consuming a low alkali charge, and no problems of damage to the final product quality due to their recycling are reported.

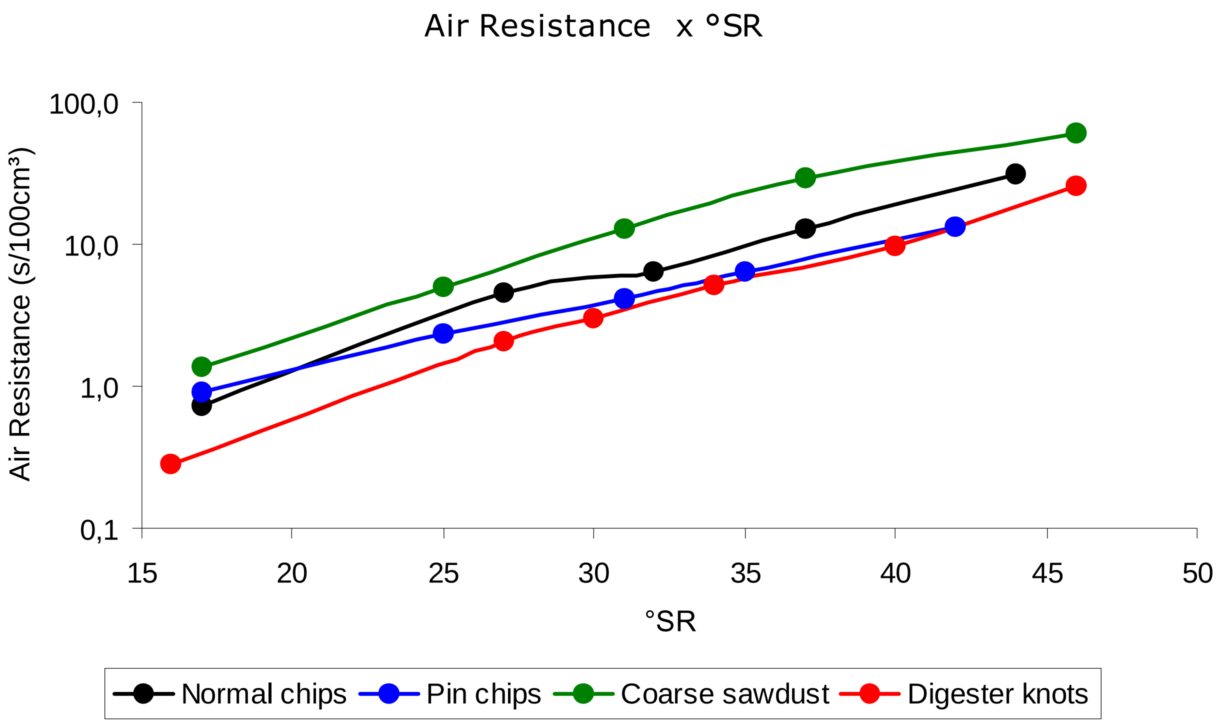
In the air resistance and sheet bulk tests the most porous and bulky pulp was that obtained from digester rejects or knots, showing its interesting characteristic, which should be due to the lower hemicellulose content.

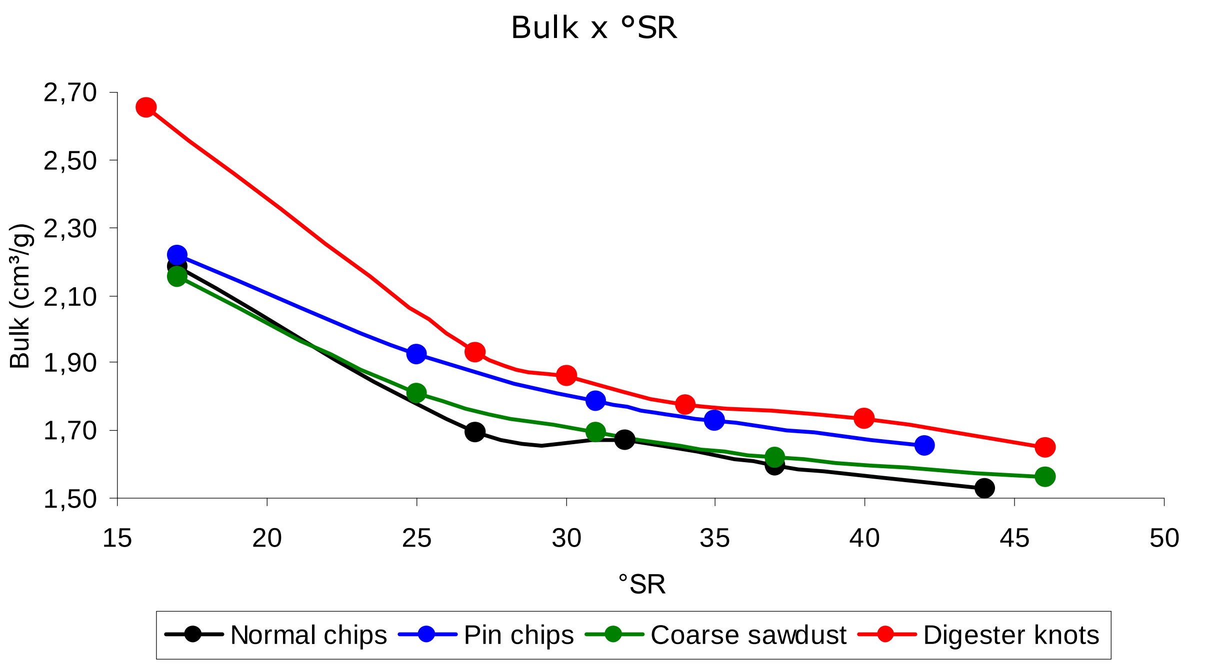
By means of the performed experiment, the authors stated that these fibrous residues were proved to be technically feasible for kraft pulp production, with good yields and physico-mechanical strengths. They concluded by saying that reusing these residues by pulp and paper mills corresponds to an important vision for their future, since all these fibrous materials, which at present sometimes are wasted, may be used as raw materials, increasing mills efficiency in terms of using these more and more scarce fibrous resources.

The following figures show these pulp result evaluations in an easier way for understanding:


Tear Strength x °SR
Tear Index (mN.m²/g)
18,0
16,0
14,0
12,0
10,0
8,0
6,0
4,0
2,0
0,0
15
20
25
30
35
40
45
50
°SR
Normal chips
Pin chips
Coarse sawdust
Digester knots


Tensile Strength x °SR
Tensile Index (N.m/g)
120,0
110,0
100,0
90,0
80,0
70,0
60,0
50,0
40,0
30,0
20,0
15
20
25
30
35
40
45
50
°SR
Normal chips
Pin chips
Coarse sawdust
Digester knots


Air Resistance x °SR
Air Resistance (s/100cm³)
100,0
10,0
1,0
0,1
15
20
25
30
35
40
45
50
°SR
Normal chips
Pin chips
Coarse sawdust
Digester knots


Bulk x °SR
Bulk (cm³/g)
2,70
2,50
2,30
2,10
1,90
1,70
1,50
15
20
25
30
35
40
45
50
°SR
Normal chips
Pin chips
Coarse sawdust
Digester knots

DIRTY BARK FROM THE WOOD PREPARATION AREA

In a previous chapter of our Eucalyptus Online Book we made an extensive evaluation of the eucalyptus tree bark, beginning with its anatomy and proceeding with log debarking and the use of the bark for several purposes, among which the compost preparation. Up to this moment, we did not approach the discussion about bark as fuel biomass, but this will occur in a future exclusive chapter about this subject.

The wet and dirty bark, with contaminants as sand, soil, eucalyptus branches and leaves, is a very common residue at pulp mills. Even if the mill uses bark as biomass or debarks the logs in the forest field, there is always a certain amount of this kind of residue being generated. The residue is usually known as "dirty bark" due to the contaminants, especially inorganic, it contains. Even if the mill burns bark in a biomass boiler, technicians do not like this dirty bark due to the presence of stones ,soil and high moisture content.

Dirty bark consists of contaminated vegetal rests falling from the logs in the log yard or at log washing. It is very common that trucks bring dirt containing logs, because the vehicles are loaded by cranes taking the logs from the ground, and when doing this, they may also grab debris from the ground. In addition, the required care to be taken in the forest field sometimes leave a lot to be the desired one. People in general do not care too much about log contamination with log bark, branches and leaves. As a result of this, an undesirable material enters the mill and will accumulate there later as solid residue. Even if the logs come with bark to be debarked at the mill, the bark gets loose from the logs in the storage woodyard and makes the ground dirty in that area. As the wood yards in their vast majority are not paved, bark falling onto the ground gets still dirtier with soil and stones.

Cleaning logs and wood yards always results in appreciable amounts of this material. Although managers often do not even notice its existence, this residue does not add any value to the process; on the contrary, it destroys value. Even if the company develops compost preparation programs for residual bark, the ideal situation would be to solve the dirty bark problem where bark wastes are generated: in the forest, in the wood yards, in the debarking line and at log washing. The following may help minimize generation of this residue: greater cares in the forest, log yard paving, recovery of every bark falling from the debarking line into the debarkers themselves, improvement in debarking operations, recovery of the bark rests from log washing for feeding the debarkers. It should be remembered that debarkers remove bark from the logs and direct it to the biomass storage area. Bark rests falling onto the ground, if fed into the debarkers, in the end will be directed by the system to the biomass pile, its desired destination.

Bark as residue can occur either in small or in huge quantities. It depends much on the destination the mill gives to bark, as well as on the procedures and care in handling the logs, and on the available debarking system.

There are in general the following more common situations for eucalyptus pulp mills:

1. The logs arrive with bark at the mill, they are mechanically debarked in debarking drums designed for this purpose. Bark and wood residues are used as biomass fuel in an auxiliary boiler.
   When the bark content is high and wood losses are high in the yard and debarking operations, as well as in the chip classification, the generated amount of bark may be above the burning capacity and the requirements of the auxiliary power boiler. In these situations, large amounts of bark accumulate as solid wastes. These quantities may reach absolutely amazing figures, about 100 to 400 kg of wet bark per ton of produced pulp. The values are high because in addition to the losses the bark absorbs much water due to the rains and log washing. This increases its weight. When the logs arrive at the mill, the bark moisture content is lower, between 25 and 45%. When it is washed, it may easily reach moisture content values of 60 to 70%. Therefore, one ton of dry bark arrives at the mill as 1.3 - 1.8 wet tons and may leave as residue weighing 2.8 – 3.3 tons due to its rewetting and soaking.
   Therefore, when designing the mill and its bark demand, it is very important to have a correct bark supply and consumption balance forecast. In case the expectation is a surplus of biomass, it is better to have a mixed operation for debarking, part of it in the forest field and another part at the mill. Thus, some bark fraction will remain in the forest field, enriching the soils, and will not come to the mill, in order to turn into residues. Thus, it will be a cleaner operation, involving less costs with residues, and the forests will be grateful for the nutrients received via the bark that will remain on the ground.

2. The logs are debarked in the forest and small amounts of bark and branches follow with the logs. Field debarking can be more or be less efficient, depending on its kind. Using processing and debarking harvesters still generates much bark that may come with the logs to the mill site. This loose bark releases in the wood yards and at log washing. It gets easily loose from the logs and for this reason it may also make dirty other areas of the mill, as well as the streets on

which the wood log vehicles run. These quantities are very variable, ranging as usual from 25 to 80 kg of wet bark per ton of air dried pulp produced by the mill.


Logs contaminated with bark and forest rests

Bark fuel containing an appreciable amount of wood rests as contaminants


Bark wasted in the yards and on stored logs

Bark separated from the logs in the paved area of the wood yard

Dirty bark, contaminated with soil, sand, stones and wood loglets

The solution for the problem of dirty bark as a residue at the eucalyptus pulp mills basically consists of several operations, procedures and planning:

- Suitable planning for balancing bark fuel generation and consumption: to bring to the mill and to generate just the quantities that the mill will be actually able to use as fuel;
- Effective monitoring and control to guarantee cleaning of the logs arriving at the mill: ample dialog with the forest operators and wood supplying areas;
- Effective quantification of bark biomass fuel contaminants: broken loglets, sawdust, oversized chips etc.;
- Definition of indicators and specifications for moisture and the organic and inorganic bark contaminants;
- Utilization of paved and preferably covered areas to shelter the fuel bark, thus preventing it from getting wet by rain water or else from being subject to other contamination;
- Wood yard paving, especially the log storage areas. It should be striven to have less log storage areas at the mill and more of them in the forest area. When bark makes the forest soil "dirty" this is

excellent: it is a source of carbon and nutrients. On the contrary, when it makes the mill dirty it becomes a residue and pollution.

- Pressing wet bark to remove some water fraction, in order to enhance its quality as fuel;
- Definition of quantities and quality of bark surplus amounts;
- To avoid bark contamination with other types of solid wastes generated at the mill (dregs, grits, lime, sludges etc.). Bark is a natural and no-harmful residue, easy to be understood by the environmental control agencies. For instance, when it contaminates with dregs, it becomes an industrial residue, subject to a stricter control.
- To look for alternatives for using or selling the surplus bark.

Among the alternatives for disposing of the dirty bark, the worst one is to send it to a landfill, a costly, environmentally incorrect and unnecessary procedure. There are the following alternatives to consider:

- Selling it as a clean and pressed biomass, which requires a system to be developed and implemented;
- Returning it to the forest as organic matter and source of nutrients. Forest areas near the mill can be defined, capable of receiving this fertilizing bark. As it is a troublesome and expensive operation, the handling and disposal costs should be born by the mill area, not by the forest area, for this simple reason: the forest people would consider the operation as an increase in their costs, with a return in productivity only in the long run, whereas the mill would anyhow spend some tens of dollars per ton to dispose the bark in a landfill. Instead of this, it would be better that the mill bears these costs for returning bark to the forests.
- Compost preparation from bark, selling or using the compost thus manufactured.

Composted bark prior for being screened

==

WOOD RESTS (LOGLETS, PALLETS, PACKAGINGS ETC)

By wood rests other forms of wood present at the mill can be understood, which are not being suitable or consumed by the process. They may be decayed, burnt, oil contaminated woods, or too large logs in diameter to be chipped, broken loglets, packaging, pallets, constructional timber etc. These kinds of wood always exist at the pulp mills, it is natural to occur. In case the company does not find a destination for them, or else a way of getting rid of them, they will start accumulating somewhere. There will soon appear residue wood deposits in a series of points of the mill.

The best solution for all these woody residues is to burn them as biomass. This can be done by the mill itself, if it has a biomass boiler available. If not, they can be transformed into chips and sold as energetic biomass to third parties in the market. Nowadays, the biomass demand and price are interesting.

In general, these situations are fluctuating, there are moments of higher generation and higher accumulation. On other occasions, the company operates practically without their generation. For this reason, most mills do not have available a structure to deal with these situations. When one of these residues appears in larger amounts, this causes disturbances, problems and material accumulation all over the mill. This makes ugly the landscape of the mill and increases its costs

Wood rests

Broken loglets

Large diameter logs

There will always exist some options to minimize this problem. In this case as well, the worst solution is to throw this material on landfills as residues. The best option is to look for the origin, to discover how this residue is appearing and to try to solve the problem caused by its generation at the very root. For instance, if logs larger than 40 cm in diameter cannot be chipped, their arrival at the mill should be prohibited, they should be sold for another more valuable purpose by the foresters. If there are broken loglets, it should be tried to reduce their generation by handling thin and thicker logs separately, and so on.

Within the internal recycling and selective collection programs, a part of this material may be collected, separated and donated to employees or philanthropy entities. It may be also split, fragmented and transformed into billets or chips for burning or sale. There will be always a solution. The most important thing is to know the costs involved and the value of these residues. It should be remembered that the value of any residue is calculated on the following basis:

1. Value as raw material **(-)**
2. Value added by the process **(-)**
3. Handling, transportation, and storage values **(-)**
4. Value of final disposal on a landfill, if this is the case **(-)**
5. Selling price of this residue **(+)**

Let's suppose we are succeeding in selling the broken wood loglets for US$ 10.00 a wet ton. Some people of the company may even be very happy with the found solution. But apart from having solved the problem, it must be verified how much one is really gaining or losing thereby. The selling value of US$ 10.00 corresponds just to above item No. 5, used for our calculations.

It should be also valued:

- how much is this wood worth as process or energy wood? (let's say it is worth US$ 20.00/ wet ton);

- how much is spent with its handling, removal, loading, internal storage, personnel involved etc.? (let's suppose US$ 3.00 per wet ton)
- how much is spent to dispose of it on a landfill? (If it is not disposed of on a landfill because it is being sold, the value is equal to zero. Even in case it is sold, if sometimes a part of it must be disposed of, there will be for instance an average disposal cost of US$ 3.00/ton for our example, which is the final disposal unit value)
- what is the net amount received for the sale? (let's say it amounts to US$ 10.00 per wet ton).

Then the cost of this residue is as follows:

(-20) + (-3) + (-3) + (+10) = (-16)

i.e. for each wet ton sold for US$ 10.00 we will be losing US$ 16.00. Instead of selling, it is better to solve the problem at its origin, preventing the thin logs from breaking into loglets, do you agree?

==

ORGANIC RESIDUES FROM GARDENING OPERATIONS (PRUNING OF TREES AND MOWING OF LAWNS)

This is a kind of residue of small volume at the pulp and paper mills. It consists of organic matter with fuel power. I am speaking about it because I have seen many companies having a biomass boiler available and throwing these residues on dumping grounds, transforming them into industrial garbage and occupying therewith a valuable volume of a landfill. Then, why not direct them for burning in the biomass boiler along with other biomass rests? If required, it would be interesting for better ecoefficiency to have available a small fragmentizing machine for the branches resulting from pruning the trees, or else they might be chipped in the thin firewood chipper. After all, options do exist, you have just to be wise and to know how to use them best.

Tree pruning and grass mowing rests of gardening operations being taken to a dumping ground or "throw-out" material place, while they might be used as energy source.

==

FINAL REMARKS

Based on all these considerations presented up to this moment, it becomes very clear that it is easy, besides economically and technically feasible, to eliminate a significant quantity of fibrous residues generated by eucalyptus kraft pulp manufacturing. In the present chapter of the Eucalyptus Online Book several ecoefficient solutions have been presented for the digester knots, the unbleached stock screening shives, the chip screening sawdust, the loglets and wood remainders, the dirty bark left over in the woodyard and the rests of organic matter of the gardening operations. In the next book chapter, we will study the losses of pulp fibers and broke generated by paper manufacturing. There are many wastes occurring and their solution is much easier and economical than many people imagine. In a third chapter of this series we will speak about the residues of inorganic nature (ashes, dregs, grits, lime sludges, lime etc.). To complete this series, we will present ecoefficiency and cleaner production concepts, suggest residue handling plans and reinforce the ways of valuing them.

I believe that my purpose with this series of chapters is quite clear: to stimulate those operating or designing mills to avoid solid waste generation, by taking actions at the points where they are generated, in order to try to minimize or even eliminate wasting. We cannot passively accept any longer these huge wastes accumulating as pollution on sanitary landfills, not so sanitary as the name given to them. This is a very poor solution to the solid waste issue, believe me!

===

LITERATURE REFERENCES AND SUGGESTIONS FOR READING

Almeida, R.S.; Amaral, E.J.; Souza, W.M. **Reducao do consumo especifico de madeira no processo kraft.** Seminar "Preparo da Madeira e sua Influencia na Producao da Pasta Celulosica". ABTCP. 8 pp. (2002)

Arroja, L.; Louro, M.; Capela, I. **Gestao integrada de residuos em fabricas de pasta para papel em Portugal.** 9 pp. (Without reference of date or publication source)

Carre, G.; Bergkvist, L.; Nasman, L.; Sjokvist, A. **Medium consistency oxygen bleaching for upgrading of kraft rejects.** Sunds Defibrator. 6 pp. (Without reference of date or publication source)

Couto, L.C. **Influencia da morfologia dos cavacos de madeira de *Eucalyptus urophylla* de origem hibrida na qualidade da celulose kraft.** Federal University of Vicosa. Dissertation of MSc. 118 pp. (1979)
Available at:
http://www.celso-foelkel.com.br/artigos/ufv/Luiz%20Carlos%20Couto.pdf

Foelkel, C. **Poluicao e sinonimo de desperdicio (e de dinheiro jogado fora tambem).** O Papel (August): 30 – 31. (2003)
Available at:
http://www.celso-foelkel.com.br/artigos/52%20final.doc

Foelkel, C. **Administrando o consumo de energia, agua e outros insumos.** Forum ANAVE. PowerPoint presentation: 39 slides. 2004
Available at:
http://www.celso-foelkel.com.br/artigos/Palestras/Adm_Energia.pdf

Foelkel, C. **Casca da arvore do eucalipto: Aspectos morfologicos, fisiologicos, florestais, ecologicos e industriais, visando a producao de celulose e papel.** Eucalyptus Online Book & Newsletter. Chapter 01. 109 pp. (2005)
Available at:
http://www.eucalyptus.com.br/capitulos/capitulo_casca.pdf
http://www.eucalyptus.com.br

Foelkel, C.E.B.; Couto, L.C.; Kato, J. **A utilizacao da serragem de madeira de eucalipto na producao de polpa celulosica.** O Papel (September): 57 – 64. (1979)

Kilback, A. **Re-cooking of shives and knots**. Pulp & Paper Canada 81(1): 23. (1980)

Korpinen, R.; Hultholm, T.; Lonnberg, B.; Achren, S. **Development of sawdust cooking.** Appita Journal 59(5): 406 – 411 (2006)

Oliveira Filho, A.C.; Fernandes, F.M.; Lima, N.R.; Dutra, N.; Ramos, W. **Residuos solidos gerados diretamente dos processos industriais.** 30th ABTCP Annual Congress: 447 – 463. (1997)

Pedrazzi, C.; Foelkel, C.E.B.; Oliveira, P.; Frizzo, S.M.B. **Estudo da qualidade de polpas obtidas de serragem e mini-cavacos de madeira e de rejeitos da fabricacao de celulose kraft de eucalipto.** 35th ABTCP Annual Congress. 6 pp. (2002)
Available at:
http://www.celso-foelkel.com.br/artigos/ABTCP/abtcp.%20para%20site%202002b.pdf

Polowski, S.; Jauhiainen, E. **Gerenciando residuos de fabricas de celulose e papel usando a tecnologia de queima em leito fluidizado**. IV Seminario de Recuperacao e Utilidades. ABTCP. 12 pp. (1995)

RIOCELL. **Polpa filler: especificacoes**. Spec sheet filler market pulp. 1 pp. (1982)

Ross, R.; Johnston, R. **Pressing knots and shives.** Tappi Journal 82(2): 60 – 62. (1999)

Souza, M.C.H.; Reis, E.R.; Serafin, K.; Pedrazzi, C.; Oliveira, P.; Foelkel, C.E.B.; Frizzo, S.M.B. **Variacao da densidade a granel de cavacos de *Eucalyptus saligna* em funcao de suas dimensoes e da umidade.** 35th ABTCP Annual Congress. 6 pp. (2002)
Available at:
http://www.celso-foelkel.com.br/artigos/ABTCP/abtcp.%20para%20site%202002c.pdf

Steiner, C.; Herrera, J.; Foelkel, C.E.B. **Residuos industriais ou bens de producao? O conceito da Riocell**. 21st ABTCP Annual Congress. 14 pp. (1988)
Available at:
http://www.celso-foelkel.com.br/artigos/ABTCP/1988.%20Res%EDduos%20ou%20bens%20de%20produ%E7%E3o.pdf

Zvinakevicius, C.; Foelkel, C.E.B.; Kato, J.; Medeiros Sobrinho, J. **Programa para uso conjunto de residuos fibrosos na producao de celulose kraft.** 14th ABTCP Annual Congress. 22 pp. (1981)
Available at:
http://www.celso-foelkel.com.br/artigos/ABTCP/1981.%20uso%20res%EDduos%20fibrosos.pdf

Zvinakevicius, C.; Foelkel, C.E.B.; Kato, J.; Medeiros Sobrinho, J.; Milanez, A.F. **Utilizacao dos rejeitos do cozimento kraft.** O Papel (September): 59 – 64. (1981)