ANALYSIS OF THE WOOD HUMIDITY IN THE LOGISTICS OF A CELLULOSE PULP INDUSTRY

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ABSTRACT

This article brings an analysis of the wood supply in a cellulose pulp industry and highlights the influence of wood humidity in its transportation costs. In its natural state, wood contains a high level of humidity that is undesirable in various industrial processing. Regarding the cellulose production, humidity increases the wood weight and, consequently, the transportation costs. The evaporation of the humidity excess, before moving the wood to the industrial plant, is an alternative to overcome this problem. The focus undertaken here is to find the number of stock days that the wood takes in the natural evaporation to reach around 35% humidity, which gives the minimum logistic cost of transportation. The computation of the safety stock required in the production of bleached hardwood eucalyptus pulp was also considered.

In order to obtain the optimum drying time of the wood in the field, a data collection was carried out, concerning various degrees of humidity evaporation. Data used were obtained at Aracruz Celulose S.A., a Brazilian cellulose pulp industry, and comprised wood density as a function of evaporation time, freight costs, transport distances, daily stock, among others. As expected, the analysis carried out showed a decrease in wood density due to evaporation during the first three weeks and then remains constant, while the stock of the wood in the field keeps increasing with the time. A safety stock 39% smaller than the actual observed was found.

Keywords: Pulp industry, Wood industry, Logistics

1. INTRODUCTION

In its natural state, wood contains a high level of humidity which is undesirable in various industrial processing. Humidity increases the wood weight, so a significant amount of unnecessary weight is carried during its transportation.

Wood’s density is directly related to humidity, and determines the mix of chemical products in the cellulose pulp process. The right proportion of humidity is around 35%. A significant increase of energy is required to dry out any excess. For example, the use of wood with 47% of humidity requires an additional 149 tons of coal a day (Andrade [1]). This additional energy consumption given in coal is about 1,12 Euros per m^3 of evaporated water.

An interesting aspect of the natural evaporation, without using coal, is the environmental benefit related to low level of carbon dioxide emissions. On the other hand, the stock of drying wood in the field represents costs as well as risk of fire and robbery. Despite its importance, this aspect of the problem is not going to be tackled.

This paper aims the analysis of the wood supply in a cellulose pulp industry. The effect of wood humidity in its transportation costs, the stock time to let the evaporation dry out the 35% humidity excess and the safety stock demanded in the industrial process are approached.

The article is organized as follow. First, the methodology is presented in section 2. In section 3, the wood density is investigated. It is then showed two approaches of stock control in section 4, and a practical application of data obtained in a cellulose pulp production plant. Finally, conclusion and future research are provided in section 5.

2. METHODOLOGY

The methodology comprised the analysis of the effect of the wood humidity on transportation costs, followed by the stock control of a cellulose plant. The study regarded the stock days that the wood takes in the natural evaporation according to Ratniecks [5]. For the analysis of the safety stock two methods were used and the results were compared. The first was based on the stock control according to the level of service, given by Ballou [2]. The second approach considered the lowest volume of wood in a day of stock as given by Ribeiro [6]. A case study was also carried out considering data of a cellulose pulp industry named Aracruz Celulose.

3. WOOD DENSITY

The kind of wood generally used in the cellulose pulp industry is a tall evergreen tree called eucalyptus. Ideally, trees aged among five and eight years are suitable for cut. At the age of seven, trees usually reach their largest height and then begin to enlarge. During the first two weeks after the trees’ cut, a large quantity of humidity remains in the wood, so they are not suitable for use in the cellulose process. On the other hand, if older than sixteen weeks of cut, they will be too dry and need to be hydrated.

Figure 1 shows the variation of wood density during summer and winter.

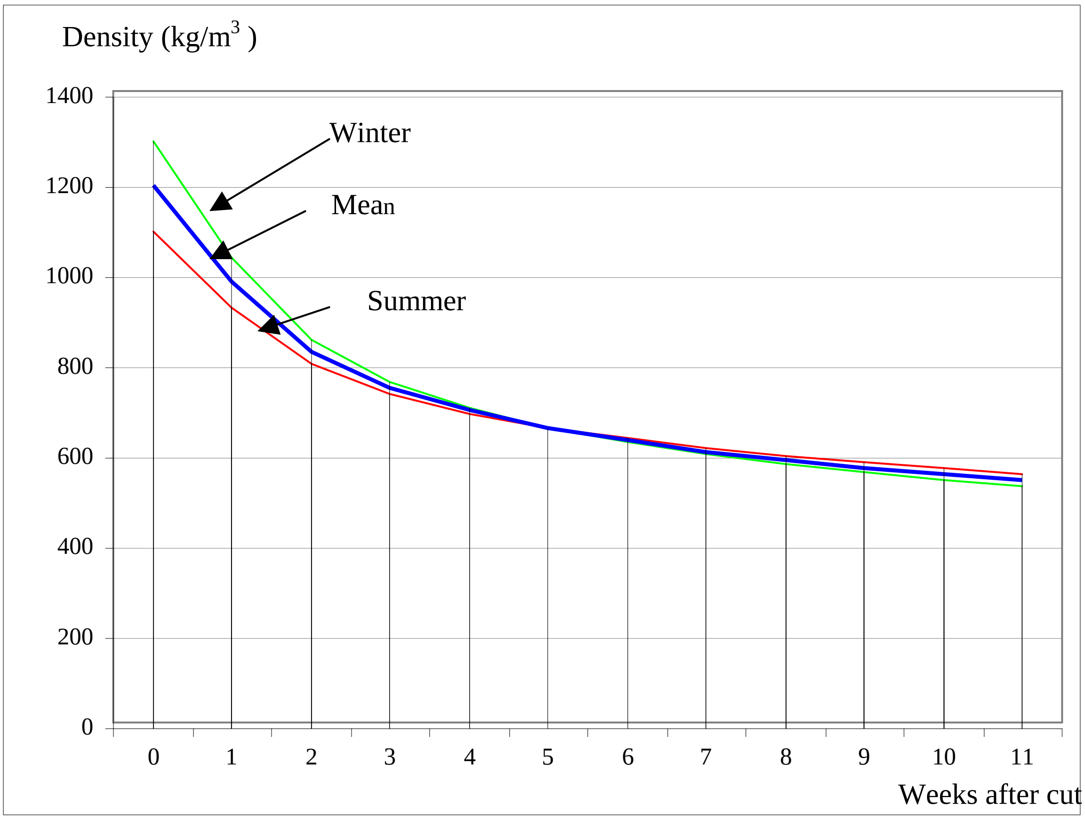

Fig 01: Curve of wood density

Source: Ratniecks [5]

A great density reduction is observed during the first three weeks after the tree cut, when the wood reaches the density of approximately 800 kg/m^3. After the forth week, the decreases are not so steep and it may be unsuitable to keep the wood in the field, since there is the risk of robbery and fire. According to fig. 1, reduction of about 400 kg in one m^3 of transported wood can be obtained. Consequently, freight costs can be reduced.

The results for both period winter and summer were approximately equal. In winter, the tree retains water while in summer it is drier than in any other season. So, the humidity loss is more intense and time consuming during winter, while the other way round in summer.

4. SAFETY STOCK IN A CELULLOSE PULP COMPANY

Aracruz Celulose S.A. is a Brazilian company whose production of bleached hardwood eucalyptus pulp is about 3 million tons per year. It has a plantation of approximately 689 thousand acres in tropical areas where the gains are 20 times the ones in higher latitudes. There are 3 plants in Brazil, but this paper focuses the largest unit, in Barra do Riacho, Espírito Santo.

The forests are located in a radius of about 200 km of the industrial plant. The manufacturing process demands a monthly consumption of wood of approximately 690,000 m3. Per month, 65% of the wood processed (450 thousands m^3/month) is transported by special lorries, 5% (35,000 m^3/month) by railway and 30% (205,000 m^3/month) by barge. The analysis carried out in this paper approaches only the road transportation.

The daily demand is approximately 23,500 m^3 of wood, volume that corresponds the cargo of 500 lorries. About 1,000 m^3 of this amount is daily used in the energy generation. For the energy purpose, trees with the age unsuitable for the cellulose pulp process are used. The industry's yard is able to stock 350,000 m^3 of wood, volume enough to maintain the industry working for 15 days.

The following item approaches the reduction in transportation costs, given in petrol consumption, considering the study of wood density in terms of days of natural evaporation of the excess humidity in the field. In 4.2, the application of the stock analysis is carried out for the Aracruz Celulose company data.

4.1 Effect of the Humidity Reduction in the Wood Transportation

According to data given by Aracruz Celulose S.A. (Ribeiro [6]) the mean specific weight of the wood transported in 2006 was 963 kg/m3, while 960 kg/m3 in the first semester of 2007. Figure 1 shows that such values correspond to a drying time of two weeks in the field.

Wood reaches a specific weight of about 800 Kg/m^3 in three weeks Such a reduction in the weight allows an additional load of the lorries in terms of volume. The corresponding reduction in weight due to the humidity was computed for all road journeys taken in 2006 and 2007. Such an amount was converted into the number of trips that would be saved if the specific wood weight was 800 Kg/m^3. For fuel consumption of about 1.64 km per litre, and considering the trips'distance, an economy of 3.28% in petrol was computed in all travels. For the annual volume of wood transported of approximately 8 milion m^3, such a reduction represents about 160 thousand trips by lorries.

The mean volume of 4,995 m^3 transported in 2006 and 2007 may be increased to 5,200 m^3 with adjustments in the wood density through an additional week of natural evaporation. Since each lorry may carry a larger quantity of wood in each trip, the total number of trips is reduced and, consequently, an economy of fuel may be obtained. In other words, the stock of the wood in the field for three weeks provides a reduction in its humidity and an economy of about 400 kg/m^3 in its transportation to the industry yard. Such an amount demands a reduced number of travels.

4.2 Computation of the safety stock

The safety stock was computed according to two methods: (i) level of service (Ballou [2]) and (ii) the lowest wood volume regarding one day of stock (Ribeiro [6]) The daily data used corresponds to the period 1st January 2006 to 25th November 2007. Wood demand is uncertain and depends on the industry production, as well as the replacement time since it depends on the transport mode used and the distance from forest to industry (Dias [4]). Table 1 shows statistics of the daily stock of Aracruz Celulose company, observed during 365 days between November 2006 and November 2007.

Table 1 – Statistics of the company stock

stock (m^3)		**days**
Maximum	277,851	15.4
Minimum	89,988	5.0
Mean	172,331	9.6
Standard deviation	43,148	2.4

An important aspect to highlight is the change in volume that occurs in the industry yard. The consumed wood depends on the daily performance of the industry, and may be affected by maintenance and production stops (Caputo and Mininno [3]). Table 2 shows the consumed wood for the same period considered in table 1.

Table 2 – Statistics of the consumed wood

wood consumed (m^3/day)	
Maximum	22,581
Minimum	3,472
Mean	16,474
Standard deviation	2,916

Lorry cycles may also interfere in the stock. Statistics of the transported volume gives a maximum value of 25,000 m^3/day, minimum of 5,000 m^3/day, mean of 16,000 m^3/day and standard deviation of 3,000 m^3/day.

The wood replacement is an important variable in the computation of the stock. For intervals of 0.2 days, the data analysis pinpoints a medium volume of reorders of 16.474 m^3. The maximum replacement time is 4.1 days, the minimum 0.8, the average time 1.2 and the standard deviation 0.4.

The computation of the safety stock according to the level of service method (Ballou [2]) is given by equation 1 which considers the variability to attend both the demand and the replacement time.

$$E_{SEG} = z_{NS\%} \sqrt{LT.s_d^2 + d^2.s_{LT}^2} \qquad \text{Eq. 1}$$

Given:

E_{SEG} - safety stock

$z_{NS\%}$ - normal deviation of the standard normal distribution;

LT - lead time

s_d - standard deviation of the demand

d - demand factor

s_{LT} - standard deviation of the lead time

For the data set available and considering the level of service of 99%, the safety stock is 17,000 m^3, and for 99,98% 26,000 m^3.

The computation of the safety stock by the minimum level method (Ribeiro [6]) is based on the lowest level of wood in the stock curve of the previous year such that the minimum volume reaches one day of stock. Such a procedure ensures the attendance of the demand even in presence of great variations. Statistics of daily stock are given in table 3.

Table 3 - Safety stock for the minimum level of wood

stock (m^3)		days
Maximum	205,851	11.4
Minimum	17,988	1.0
Mean	105,657	6.0
Standard deviation	45,433	2.7

For the level of service of 99.98%, the pulp industry needs a stock of 26 thousand m^3 in the plant yard. However, to account for the variations and to prevent the lack of wood in the industrial process, the mean safety stock is of 106 thousand m^3 (table 3). Such a safety stock is 39% smaller than the mean stock observed of 172 thousand m^3, given in table 1. The method of Ribeiro [6] gives a kind of lean safety stock.

5. CONCLUSIONS

Lorries may be better loaded if the excess of wood humidity is evaporated before transportation. For the data analysed, the gains in transportation are about 400 kg/m^3 when the trees are cut and the wood looses humidity in the field for three weeks. This means to get benefits of the lorry capacity and to reduce the number of trips between the forest and the industrial plant. The fuel economy is about 3.3% of oil.

Concerning the safety stock, the application of the method by Ribeiro[6] showed that it is possible to reduce the actual stock observed in the cellulose pulp industry. On average, a volume of 172 thousand m^3 of wood per day was stocked by Aracruz Celulose SA while the safety stock computed was 106 thousand m^3.

For further studies, there is the need of investigation on the trade-off between the stock time on the field and on the plant yard, considering the risks of contamination for fungus, robbery, fire, among others.

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