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CHEMICAL COMPOSITION OF *Schinus molle L.* WOOD AND KRAFT PULPING PROCESS

COMPOSICIÓN QUÍMICA DE LA MADERA DE *Schinus molle L.* Y PROCESO DE PULPEO KRAFT

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Abstract

The determination of the chemical composition of the wood is fundamental in the proposition of its most appropriate uses, as in the case of suggesting the wood for the pulping process kraft. The purpose of this work consisted in determining the basic chemical composition of *Schinus molle L*. wood and to carry out cooking kraft to evaluate the yield and the kappa number. The tree of *S. molle* belongs to the family *Anacardinaceae,* which is broadly established in Mexico. The chemical analysis included the determination of pH, ash content, solubility in organic solvents, quantity of lignin and holocellulose. To evaluate the pulp yield and kappa number, a factorial experimental design 2x2x2 was applied, having as factors and levels the following ones: temperature (160, 165 °C), charge of chemical reagents (16, 18%), cooking time (90, 100 min). Finally, based on the results of this work the possible use of this wood for the kraft pulping process is proposed.

Keywords: Schinus molle, pirul, wood chemistry, pulping kraft.

Resumen

La determinación de la composición química de la madera es fundamental para proponer sus usos más adecuados, por ejemplo, si fuera el caso de sugerir la madera para el proceso de pulpeo kraft. El propósito de este trabajo consistió en determinar la composición química básica de la madera de *Schinus molle* L., y realizar cocimientos kraft para evaluar el rendimiento y el número de kappa. El árbol de *S. molle*, pertenece a la familia *Anacardinaceae* y se encuentra ampliamente establecido en el territorio nacional. El análisis químico comprendió la determinación del pH, cenizas, solubilidad en solventes orgánicos, cantidad de lignina y de holocelulosa. Para evaluar el rendimiento de pulpa y número de kappa, se aplicó un diseño experimental factorial 2x2x2, teniendo como factores y niveles los siguientes: temperatura (160, 165 °C), carga de reactivos (16, 18%), tiempo (90, 100 min). Finalmente, en base a los resultados de este trabajo se argumenta el posible uso de esta madera para el proceso de pulpeo kraft.

Palabras clave: *Schinus molle*, pirul, química de la madera, pulpeo kraft.

1. Introduction

There exists in Mexico a considerable list of species that, for their particular characteristics, they have no commercial use. Among them is *Schinus molle* L. (pirul or false pepper plant) that belongs to the family *Anacardinaceae*. It is native of Peru and naturalized in the Valley of Mexico and in the Central Tableland of the Mexican Republic. It grows up to 10.0 meters high (Niembro, 1990). This species stands out because it is indifferent to the soil type, with the exception of very calcareous or humid ones. It can support a great quantity of climatic conditions, it is resistant to long periods of drought; reproduces with success, and grows rapidly (Torres *et al*., 2000). The tree is primarily used as a shade plant and for ornament. The wood is only used locally as firewood and sometimes in carpentry. The trunk of the tree emanates a resin with extremely dangerous purging properties and it is considered that it could be used in the production of varnishes. Concentrated in the leaves and fruit, it is an essential oil which is employed in homemade medicines against waterfalls and stains in the cornea, as well as in the treatment of venereal diseases and genital-urinary problems. The bark of this tree is used as an infusion, to diminish inflammations and to help to heal ulcers (Niembro, 1990). This tree could offer a valuable timber-

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yielding resource, although it has not been used for the traditional uses such as cabinetmaking, this could be achieved with the production of a chemical pulp. Considering the above-mentioned and based on the scarce literature available on the chemical properties of this wood and reports about the pulping process, the objectives for this work were to carry out a determination of the basic chemical composition of this wood and to obtain a pulp of it, by means of the process kraft, in conditions of low sodium sulfide in white liquor.

2. Materials and methods

The tree of *Schinus molle*, was cut in the region of Uruapan, Michoacán, of which a trunk of 1.20m length, starting from its stump, was obtained. The barked piece was transformed into chips that were later sieved.

2.1 Chemical analyses of the wood.

Chips of the wood were milled in Wiley equipment and the fraction of mesh 40 was used to determine:

- pH (Sandermann and Rothkamm, 1959)
- Inorganic material (TAPPI, 2000)
- Extractives content. An extraction sequence was applied in Soxhlet equipment with cyclohexane (CH), acetone (ACE) and methanol (MET). Finally a watery extraction under reflux (HW) was carried out.
- Runkel lignin content (Runkel and Wilke, 1951)

Holocellulose content (Wise, 1946).

2.2 Kraft pulp process.

To obtain pulp of the pirul wood, a factorial experimental design 2x2x2 was applied (Montgomery, 1991), having the following factors and levels:

A): Temperature (160, 165 °C)
B): Charge of chemical reagents (16, 18%)
C): Cooking time (90, 100 min)

The constants in the pulping process were: 200g of dry base chip, sulphides of the white liquor 5.0%, active alkali 90.5 g/L as Na_2O, total alkali 114.2 g/L as Na_2O, effective alkali 88.2 g/L as Na_2O. The research variables were: yield and kappa number, ascertained according to the TAPPI (2000) norms. The results were evaluated with a level of statistical trust of 95%, using the program Statgraphics Plus Version 4. As an example of the statistical hypotheses that were proven for the mentioned design, it is only illustrated for the case of the pulp yield:

H_0: effect of A = 0
H_1: effect of A ≠ 0

H_0: effect of B = 0
H_1: effect of B ≠ 0

H_0: effect of C = 0
H_1: effect of C ≠ 0.

3. Results and discussion

3.1 Chemical analyses of the wood.

The pH value of the wood was 6.4, a result that falls within the range of pH data reported for hardwoods (Fengel and Wegener, 1983). Table 1 shows the average value results of the basic chemical analysis of *Schinus molle* wood. As mentioned in the Methodology Section, the total solubility of the wood was determined by means of a Soxhlet successive extraction, with the following solvents: cyclohexane (CH), acetone (ACE) methanol (MET), and hot water (HW) under reflux. The results of each extraction appear in Fig. 1.

Table 1. Basic chemical analysis of *S. molle* wood (absolute value)

Analysis	Value (%)
Inorganic material	3.2
Extractives	7.3
Holocellulose	67.3
Runkel lignin	22.2

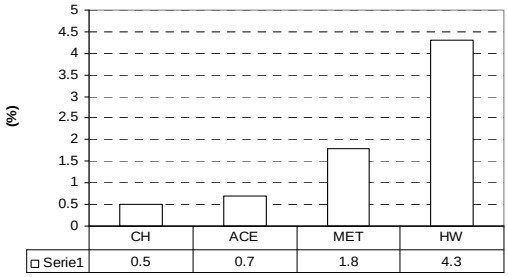

Fig. 1. Results of the successive extraction.

The chemical properties of *S. molle* wood determined in the present investigation are, in general, within the ranges for hardwoods (Fengel and Wegener, 1983), and although we did not have information about the chemical composition of the wood of this species, some bibliographical data can be mentioned on hardwood, in order to establish a comparison. The content of inorganic substances for the studied wood was 3.2% (Table 1), an intermediate value to that reported, for example, for the following species: wood of *Misanteca pekii* is 0.08% and 6.5% for *Poulsania armata* (Torelli and Čufar, 1995). Intermediate values of these are, for example, the following: 0.36% for heartwood of *Swietenia macrophylla*, 0.66% for *Cedrela odorata*

and 0.78% for Manilkara zapota (Rutiaga, 2001), 2.07% for *Pithecelobium dulce* (Huerta, 1996), and 2.4% for *Ceiba pentandra* (Petterson, 1984).

Through the applied extraction, the total solubility of the pirul wood was 7.3% (Table 1). A comparison is not easy to carry out because the extraction sequence is not always the same. It could be considered that the degree of solubility of the wood of *S. molle* is low if it is compared, for example, with the following cases: 12.4% and 13.58% for *Lysiloma acapulcense* and *Pithecellobium dulce*, respectively, in extraction with ethanol (Huerta, 1996), 20.2% for *Dalbergia granadillo* by means of extraction with ethanol - benzene (1:2) (Rutiaga and Rodríguez, 1998), 17.3% and 17.9% for *Swietenia macrophilla* and *Manilkara zapota*, respectively, by means of successive extraction with solvents of growing polarity (Rutiaga, 2001), 17.4% for *Enterolobium cyclocarpum* (Ramos *et al*., 2003), 19.1% for *Andira inermis* (Tellez *et al*., 2002); 16.2% for *Lysiloma acapulcensis* (Mondragón *et al*., 2004). As it can be observed, the content of extractible substances of the wood of *S. molle*, 7.3%, is relatively low in comparison with the others woods mentioned, and comparable with species that have been used in the pulp industry, such as *Pinus pseudostrobus* and *Quercus laurina* that contain in their heartwood extractives of 13.2% and 7.0% (Rutiaga, 2001). Therefore, taking into account their low quantity of extractives, the wood of the studied species could be used for the cellulose obtaining by means of the kraft process, since for this process woods are desirable to contain low amounts of extractives because some of these cause corrosion in equipments (Libby, 1980).

In relation to the applied sequence, the results indicate more solubility of *S. molle* wood in methanol and hot water (Fig. 1). In other words, the proportion of soluble substances is larger in polar solvents. This result coincides with that reported for *Swietenia macrophylla* and *Manilkara zapota* (Rutiaga, 2001), for *Andira inermis* (Téllez *et al*., 2002) and for *Lysiloma acapulcensis* (Mondragón *et al*., 2004). However, this result is not always given, because it depends of the wooden species, for example, in *Cedrela odorata* the highest solubility was in non polar solvents (Rutiaga, 2001), and the same pattern was found for *Pinus pseudostrobus* (Rutiaga, 2001). This reflects, the variability involved in the chemical analysis of wood, as mentioned in the literature (Fengel and Wegener, 1983).

As for the holocellulose content of *S. molle* (67.3%, Table 1), it is considered to be slightly smaller than that reported for other species: Huerta (1996) found 82.16%, 84.05%, 80.0% and 86.26% holocellulose for *Acacia angustissima*, *Leucaena esculenta*, *Lysiloma acapulcense* and *Pithecellobium dulce*, respectively; Zizumbo (1998) indicates that *Pithecellobium ebano* contains 83.49%; Téllez *et al.* (2002) report 84.7% for *Andira inermis*; Mondragón *et al.* (2002) find 81.32% in *Lysiloma acapulcensis*. As a result of this comparison, *S. molle* wood would be feasible as raw material for chemical pulp.

The quantity of lignin in *S. molle* wood (22.2%, Table 1) is also within the ranges in the data reported in the literature, for example: *Leucaena esculenta* 19.34%, *Lysiloma acapulcense* 19.95%, *Acacia angustissima* 20.04% (Huerta, 1996), *Lysiloma acapulcensis* 19.18% (Mondragón *et al*., 2002), *Manilkara zapota* 30.7%, *Swietenia macrophylla* 31.1%, *Cedrela odorata* 34.4% (Rutiaga, 2001), *Andira inermis* 34.2% (Téllez *et al*., 2002). On the other hand, as pointed out previously for some species that have been used in the chemical pulping industry, the lignin contents reported are the following: sapwood (26.6%) and heartwood (27.6%) of *Pinus pseudostrobus*, sapwood (22.4%) and heartwood (23.8%) of *Quercus laurina* (Rutiaga, 2001). Therefore, taking into account the relatively low quantity of lignin, the wood of *S. molle* could be used in chemical pulping, because for this process it is desirable to have matter with a low amount of lignin so that less chemical reagents will be required to eliminate it (Casey, 1990).

3.2 Kraft pulping process.

In Table 2 the Anova is presented that indicates that only the factor of cooking time was statistically significant on the variable of yield (p-value = 0.0422), and the respective hypothesis is rejected. In Fig. 2 it can be appreciated that there is not a significant statistical effect of the factor temperature on the obtained pulp yield. This can be observed in Fig. 3, and is due to the effect of the chemicals charge (reagents charge) used in the kraft cooking on the yield (Fig. 4). This result was shown in the Anova (Table 2). Thus, the process to obtain kraft pulp of this wood, under these experimentation conditions, could be carried out at a temperature of 160ºC and 18% of reagents charge.

As the Anova pointed out (Table 2), the cooking time of wood was the only factor with significant statistical effect, as observed in Fig. 4. According to the factorial design, the largest pulp yield average (46.9%) was obtained when taking the cooking process with the factors proven at the following levels: temperature of 160ºC, 18% of chemicals charge and 100 minutes of cooking time. This obtained yield is relatively high, which suggests that this wood has high holocellulose content and a relatively low quantity of lignin. This is corroborated by the results of the chemical analysis of the wood (Table 1). On the other hand, the cooking conditions decrease the content of sodium sulfide, probably because of the degradation of carbohydrates, as happens when the conditions are severe, and the yield is thus diminished (Casey, 1990).

By way of reference, we cite a study with wood of *Pinus douglasiana*, a species used in the industry of the cellulose. The kraft pulp yield was

from 44% when cooking the wood to 20% of chemicals charge, 120 minutes of cooking time and 168 ºC of temperature (Rutiaga *et al*., 1998). With wood of *Persea americana* (avocado) a yield of 38.4% is reported to pulp at 18% of chemicals charge and 90 minutes of cooking to a temperature of 170 ºC (Anzaldo *et al*., 2004). In wood of *Mangifera indica* (mango) a kraft pulp yield of 39.6% was obtained with 18% of reagents charge and 90 minutes of cooking time to a temperature of 175ºC (Jiménez and Rutiaga, 2005). Even when the pulping conditions are not the same, it can be observed that the yield here obtained is larger than the values reported in the mentioned species. This study therefore suggests that the use of *S. molle* wood to obtain kraft pulp is feasible.

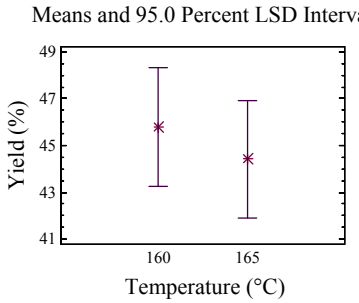

Fig. 2. Graphic of means for the yield vs. temperature.

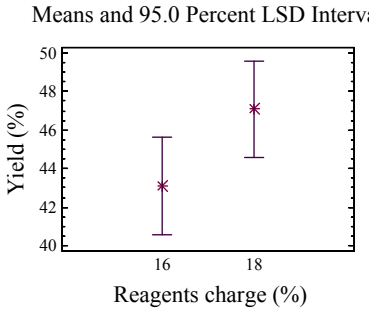

Fig. 3. Graphic of means for the yield vs. charge.

For the case of the kappa number, in accordance with the results of the Anova, two factors only had significant statistical effect, cooking time and chemicals charge with value p (*p*-value) resulted to be smaller by 0.05 (Table 3), and for this their respective outlined hypotheses are rejected. At this point, it is not necessary to give the graphics of the means of the factors on the kappa number, because these results are presented in the analysis of variance (Table 3).

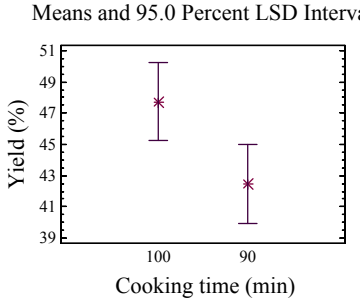

Fig. 4. Graphic of means for the yield vs. time.

The lowest value in the kappa number was 38.5 when the levels of the studied factors were: temperature of 165ºC, cooking time of 100 minutes and 18% of reagents charge. It is observed that for the case of the highest yield, the only variable that changed, with reference to the kappa number, was the temperature (160ºC), and under these conditions the kappa number was 42.1, larger than the lowest value (38.5). With these two results of yield and kappa number, it is suggested that cooking at 160ºC be employed, because this would imply energy saving in the process. The high value of the kappa number, reflects the quantity of residual lignin in the pulp, this would not be a pulp to bleach, but could possibly be used for corrugated paper, where bleached pulp is not necessarily required.

On the other hand, and taking into account that this tree easily adapts to almost any soil type and climate (Torres *et al*., 2000), it would be advisable to carry out studies of availability of the species, taking into consideration that it regenerates soils, and whether it would be a possible raw material for the process of chemical pulping. The results here obtained on the basic chemical composition of the

Table 2. Analysis of variance (Anova) for yield

Analysis of Variance for Yield - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Temperature	7.5625	1	7.5625	0.38	0.5526
B:Charge	62.41	1	62.41	3.14	0.1102
C:Time	111.302	1	111.302	5.60	0.0422
INTERACTIONS					
AB	0.9025	1	0.9025	0.05	0.8360
AC	7.29	1	7.29	0.37	0.5597
BC	11.2225	1	11.2225	0.56	0.4716
RESIDUAL	178.89	9	19.8767		
TOTAL (CORRECTED)	379.58	15			

All F-ratios are based on the residual mean square error.

Table 3. Analysis of variance (Anova) for kappa number

Analysis of Variance for Kappa - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Temperature	29.7025	1	29.7025	0.80	0.3933
B:Charge	223.502	1	223.502	6.05	0.0362
C:Time	299.29	1	299.29	8.10	0.0192
INTERACTIONS					
AB	52.5625	1	52.5625	1.42	0.2635
AC	26.01	1	26.01	0.70	0.4232
BC	46.24	1	46.24	1.25	0.2923
RESIDUAL	332.57	9	36.9522		
TOTAL (CORRECTED)	1009.88	15			

All F-ratios are based on the residual mean square error.

wood (non-acid pH, low content of extractives and lignin) and the results of the pulping process support this proposal.

Conclusions

The chemical composition of *S. molle* wood determined in the present work is in general agreement with the ranges for hardwood. The chemical properties determined were: pH 6.4, inorganic material 3.2%, extractives 7.3%, holocellulose 67.3% and lignin 22.2 %.

The pulping kraft process to obtain maximal pulp yielding and minimal kappa number it would be suggested to carry out at temperature of 160 °C, 18% of reagents charge and 100 min cooking time.

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