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Chemical and thermal characterization of the construction material of nests of seven species of wasps from Norte de Santander - Colombia

Caracterización química y térmica del material de construcción de nidos de siete especies de avispas del Norte de Santander - Colombia

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ABSTRACT

Social wasps are insects that construct their nests using wood pulp, plant and themselves secretions for the accomplishment of their activities as a colony. Currently in Colombia, there is little knowledge about this interesting material due to its characteristics, which could be used in promising applications. In this work the chemical and thermal characterization of nests of seven species of wasps *(Agelaia pallipes, Agelaia multipicta, Agelaia areata, Polybia aequatorialis, Parachartergus apicalis, Mischucytharus imitator, Brachygastra lecheguana)* living in Norte de Santander, was carried out with the purpose of establishing if there are significant differences between species and provide information that could be used as a model or precursors for the synthesis in biomimetics and / or nanotechnology. Thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) were performed using a Thermal analyser SDT-Q600 from T.A. Instruments. An infrared spectrophotometer FT-IR SHIMADZU Prestige-21 with ATR was used for infrared analysis. The fluorescence analysis (XRF) was performed using a sequential X-ray fluorescence spectrometer of dispersive wavelength of 4kW BRUKER model S8 TIGER. The thermogravimetric analysis shows three mass losses and four degradation processes related to moisture loss, degradation of hemicellulose, cellulose and lignin. The infrared analysis allowed identifying characteristic functional groups of cellulose, hemicellulose and lignin. Through the X-ray fluorescence analysis, some metals such as K, Ca, Al, Mg, Ti, Cr, Mn, Fe, Ni, Cu, Zn, Se and Li were found. The analyses made of the samples allowed to establish differences and similarities in the construction material of the studied species.

Keywords:

Wasps, Nests, Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), Fourier Transform Infrared Spectroscopy (FTIR), X-ray Fluorescence (XRF).

RESUMEN

Las avispas sociales son insectos que construyen sus nidos utilizando pulpa de madera, secreciones de plantas y de diferentes partes de su cuerpo que requieren para la realización y ejecución de sus actividades como colonia. Actualmente en Colombia se tiene poco conocimiento acerca de este material que podría aprovecharse en diferentes aplicaciones. En el presente trabajo se realizó la caracterización química y térmica de nidos de siete especies de avispas *(Agelaia pallipes, Agelaia multipicta, Agelaia areata, Polybia aequatorialis, Parachartergus apicalis, Mischucytharus imitator, Brachygastra lecheguana)* de Norte de Santander con motivos de establecer si existen diferencias significativas entre especies y proporcionar información que sea la base de otras investigaciones encaminadas hacia la utilización de estos materiales como modelos o precursores de síntesis en biomimética y/o nanotecnología. Los análisis termogravimétrico (TGA) y calorimetría diferencial de barrido (DSC) se realizaron empleando un equipo SDT-Q600 de T.A. Instruments. Para el análisis infrarrojo se utilizó un espectrofotómetro infrarrojo FT-IR SHIMADZU Prestige-21 con ATR. El análisis de fluorescencia (XRF) se realizó empleando un espectrómetro secuencial de fluorescencia de rayos X de longitud de onda dispersiva de 4kW marca BRUKER modelo S8 TIGER. En el análisis termogravimétrico se encontraron tres pérdidas de masa y cuatro procesos de degradación

Palabras clave:

Avispas, Nidos, Análisis Termogravimétrico (TGA), Calorimetría Diferencial de barrido (DSC), Espectrofotometría Infrarroja (FTIR), Fluorescencia de Rayos x (XRF).

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relacionados con la pérdida de humedad, la degradación de hemicelulosa, celulosa y lignina. El análisis infrarrojo permitió determinar grupos funcionales característicos de celulosa, hemicelulosa y lignina. A través del análisis de fluorescencia de rayos X, se detectaron los metales K, Ca, Al, Mg, Ti, Cr, Mn, Fe, Ni, Cu, Zn, Se y Li. Los análisis realizados permitieron establecer diferencias y similitudes en el material de construcción de las diferentes especies.

Introduction

Wasps are insects of the order of hymenoptera and suborder apocrite [1], [2]. Hymenoptera are one of the richest metazoan orders on the planet with about 115,000 to 199,000 species described [3] - [6]. Wasps are important within tropical ecosystems because they are insects used in biogeographic and ecological studies, as potential biological control agents, in comprehensive studies involving other zoological and floristic groups, and as bioindicators of regional ecological conditions.

Biologically, they are characterized by building collective nests made of chewed wood pulp. The social wasps are organized in three castes, the reproductive females (queens) in charge of laying eggs, the sterile females (workers) and the males. Once they have built their nests, by chewing wood fibers, they deposit their eggs in compartments or cells, where they develop into larvae and pupae, emerging as adults [7], [8]. In temperate regions, a colony lasts only one season: queens being paired hibernate for about 90 days to emerge in spring and form new colonies; workers live for short periods of time, while males generally die after fertilizing the queen [9].

According to nesting sites, ethno-species build their nests on three types of substrates: constructions, terrestrial and vegetal or arboreal. The first refers to sites and materials of anthropogenic origin [10]. Terrestrial substrate refers to natural cavities or abandoned animal cavities, and plant substrate includes weeds, shrubs, leaves, tree branches and hollow trunks [11], the latter being used by most ethno-species for the establishment of their colonies. In the nests, several central activities of the colony occur, such as the reuse of breeding cells, care of immatures until the emergence in adults, provision of chewed prey for their offspring, trophylaxis and reproductive time division of labor [5], [12], [13].

The way in which the nests are built and the characteristics of the material needed to do so highlight the interest of these social insects as models for different human needs, especially for bioclimatic architectural designs and the design of new materials [14]. Currently, the air circulation system in wasp and termite nests is being applied in the optimization of energy consumption in different human constructions [12].

In recent years, biomimetics has been inspired by biological designs, consisting of the imitation of forms and processes of nature, which can be copied to sustainably and effectively improve the design of different processes and services required by humans [15], [16]. In addition, bioengineering and biotechnology have taken advantage of many biological models to understand and solve problems that may be related to food production, pharmaceuticals, and the health of human beings and animals [17]; in the field of health, in the creation of nanoparticles for biomedical purposes [18].

This study was carried out for the purpose of chemically and thermally characterizing the nests built by seven species of wasps from Norte de Santander, Colombia, and to establish whether there are significant differences between species and to provide information to serve as the basis for other research aimed at the use of these materials in different applications.

Materials and methods

Sampling

Nest samples of wasp species were collected in different municipalities of the department of Norte de Santander; *Agelaia pallipes*, *Parachartergus apicalis* and *Mischucytharus imitator* (Pamplonita), *Agelaia multipicta* (Carmen de Tonchala), *Agelaia areata* and *Polybia aequatorialis* (Cúcuta). Abandoned nests were collected and stored in airtight plastic bags during transport from the collection site to the laboratory.

The identification of the wasp species was carried out by an expert, who examined adult specimens by means of observations under the stereomicroscope at 10X and 30X taking into account the morphological identification keys for them.

Instruments, materials and reagents

For the present study we used a SDT Q-600 thermal analyser from TA Instruments, an FT-IR SHIMADZU Prestige-21 infrared spectrometer with ATR and a 4kW dispersive wavelength X-ray fluorescence sequential spectrometer BRUKER model S8 TIGER.

Thermal analysis DSC - TGA

Thermoanalytic determinations were performed using TA Instruments' SDT Q-600 thermal analyzer which simultaneously performs thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). The analysis was performed using between 10-20 mg of pulverized sample, and it was introduced in an alumina cell. The analysis parameters were: heating ramp of 10 ºC/min, from ambient temperature ~ 20 ºC to 700 ºC in nitrogen atmosphere with a flow of 100 mL/min.

Fourier transform infrared spectroscopy (FTIR)

A SHIMADZU IR Prestige-2.1 infrared spectrophotometer was used using the attenuated total reflection (ATR) technique, the spectra were obtained in the mid-infrared region, at wavelengths of 600 to 4000 cm^{-1}, with a total of 40 scans and a resolution of 4 cm^{-1}.

X-ray fluorescence (XRF)

The XRF analysis was performed using the QUANT-EXPRESS method (fundamental parameters) in the sodium (Na) to uranium (U) range, in a 4kW dispersive wavelength X-ray fluorescence sequential spectrometer BRUKER model S8 TIGER. To detect the heavy elements a Scintillation detector was used and for the light elements a flow detector, the X-ray source was a Rhodium tube (Rh) and the high precision goniometer used for theta and 2 theta angles.

Statistical analysis

Thermal properties were determined using *Universal Analysis* 2000 software (T.A. Instruments, Delaware, USA). The results of the thermal analysis were analyzed with the statistical package of the program Origin pro evaluation version and the statistical software XLSTAT for Microsoft Excel trial version. Variance analysis (ANOVA) was used to find if there were significant differences between the different values obtained.

Results and analysis

Thermogravimetry (TGA)

By means of thermogravimetric analysis (TGA - DTG) four mass loss processes were determined in

Table I. Termogravimeter Analysis Results

SPECIES	T_1 (°C)	T_2 (°C)	T_3 (°C)	Loss of mass (%)
A. pallipes	224,06 ± 1,54	306,02 ± 8,12	350,95 ± 8,15	81,80 ± 2,65
A. multipicta	216,64 ± 2,05	297,24 ± 4,65	323,80 ± 7,45	69,81 ± 3,42
A. areata	238,58 ± 1,80	309,39 ± 1,23	338,63 ± 4,95	59,33 ± 7,34
P. aequatorialis	224,06 ± 3,45	305,49 ± 2,45	341,48 ± 0,98	68,26 ± 3,45
P. apicalis	215,22 ± 2,54	298,79 ± 3,59	322,22 ± 0,34	68,23 ± 1,23
M. imitator	200,39 ± 2,34	287,44 ± 2,87	319,66 ± 2,01	80,02 ± 9,45
B. lecheguana	229,36 ± 7,56	307,10 ± 4,65	345,83 ± 0,54	84,43 ± 1,76

the samples (Figure 1) of the different species. Table I presents the results of the temperatures involved and the percentage of mass loss in each one.

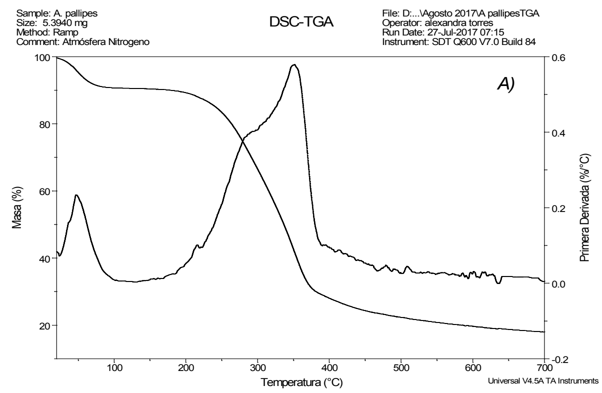
According to Figure 1, initially there was a loss of mass between 50.32 ± 0.84 °C and 87.45 ± 6.74 °C attributed to the loss of water in the form of moisture absorbed at the surface of the nest, in addition to this there were three other processes of loss of mass. The first T1 at 200.39 ± 2.34 °C - 238.58 ± 1.80 °C attributed to the decomposition of hemicelluloses [19]. Statistical analysis reveals that significant differences occur between the nests of the species *A. areata* with the nests of the species *M. imitator*, as well as for the samples of the species *A. areata* with the samples of *P. apicalis*, the samples of *B. lecheguana* with the samples of *M. imitator*, the samples of *P. aequatorialis* with the samples *M. imitator*, *A. multipicta* with the samples of *M. imitator* corroborating in this way, that the differences found in the chemical profile of the nests of the different species is directly related to the chewing process of the vegetable material used and the mixture that the wasps add through oral secretions when building the nests [20] . Studies such as that of M.R. Cole [21], in the nests of three species of social wasps (Vespinae), affirm that the choice of type of plant material, plant fibers and the duration of chewing of the materials affects the physical and chemical characteristics of the construction material of the nest. Kazuyiki Kudo [22], in his study states that oral secretions physically protect the nest from the elements and the processing of the pulp is an aspect that could affect the absorption capacity of the nest paper and its durability. Also, the study by Khalid Khan [23], found that the architectural pattern of the nest and the chemical composition vary among different species depending on aspects such as salivary secretions that these insects add to the material, environmental factors and material selection.

On the other hand, studies such as that of W.J. Etges [24], agree that although the place of nesting can influence the composition and thermal behaviour of the nest material, other aspects such as the environment in which wasp colonies carry out nesting and other factors not only genetic, but also exogenous (climate, rain, heat, cold, humidity, among others) must be considered.

The second process, whose mass loss temperature T2 (°C) occurs from 287.44 ± 2.87 °C to 309.99 ± 1.23 °C corresponds to the shoulder present in the DTG curve and is associated with cellulose decomposition; the lowest values were identified in the M species samples. imitator with 287.44 ± 2.87°C, *A. multipicta* with 297.24 ± 4.65°C and *P. apicalis* with 298.79 ± 3.59°C, the samples of the species recording the highest temperature for this peak were *A. areata* with 309.39 ± 1.23°C, *B. lecheguana* with 307.10 ± 4.65°C and *A. pallipes* with 306.02 ± 8.12°C. The samples of the species recording the highest temperature for this peak were *A. areata* with 309.39 ± 1.23°C, *B. lecheguana* with 307.10 ± 4.65°C and *A. pallipes* with 306.02 ± 8.12°C. For this loss of mass there were no statistically significant differences between the nest samples according to the Bonferroni test.

The third process related to temperature T3 (°C), occurs from 319.66 ± 2.01 °C to 350.95 ± 8.15 °C, corresponds to the decomposition of lignin. The lowest temperature for this peak occurred in the nests of the species *M. imitator* with 319.66 ± 2.01 °C, *P. apicalis* with 322.22 ± 0.34 °C and *A. multipicta* with 323.80 ± 7.45 °C, the samples that registered the highest value were the nests of *A. pallipes* with 350.95 ± 8.15 °C and *B. lecheguana* with 345.83 ± 0.54 °C. Likewise, the analysis of variance reveals that the samples that present significant differences are: the nest samples of the species *A. pallipes* with the nest samples of the species *P. apicalis*, samples that were collected in the municipality of Pamplona. There are also differences between *A. pallipes* with *A. multipicta* and *B. lecheguana* with *P. apicalis.*

According to the degradation temperatures recorded in the nest samples, the samples with the lowest value of T1 (°C) were the species *M. imitator*, *P. apicalis* and *A. multipicta*. This could be associated with increased volatility of the extractive (low molecular weight compounds) and hemicelluloses in the material, which probably results in reduced temperatures corresponding to the degradation of components such as hemicellulose and lignin, because degradation of one component in the material may accelerate the degradation of the others [19]. Likewise, the low degradation temperature in the nests of *M. imitator*, *P. apicalis* and *A. multipicta* can lead to undesirable properties such as browning and decreased mechanical resistance when subjected to temperatures above 200°C. The degradation of one component in the material can accelerate the degradation of the others [19], and the low degradation temperature in the nests of *M. imitator, P. apicalis* and *A. multipicta* can lead to undesirable properties such as browning and decreased mechanical resistance when subjected to temperatures above 200°C.



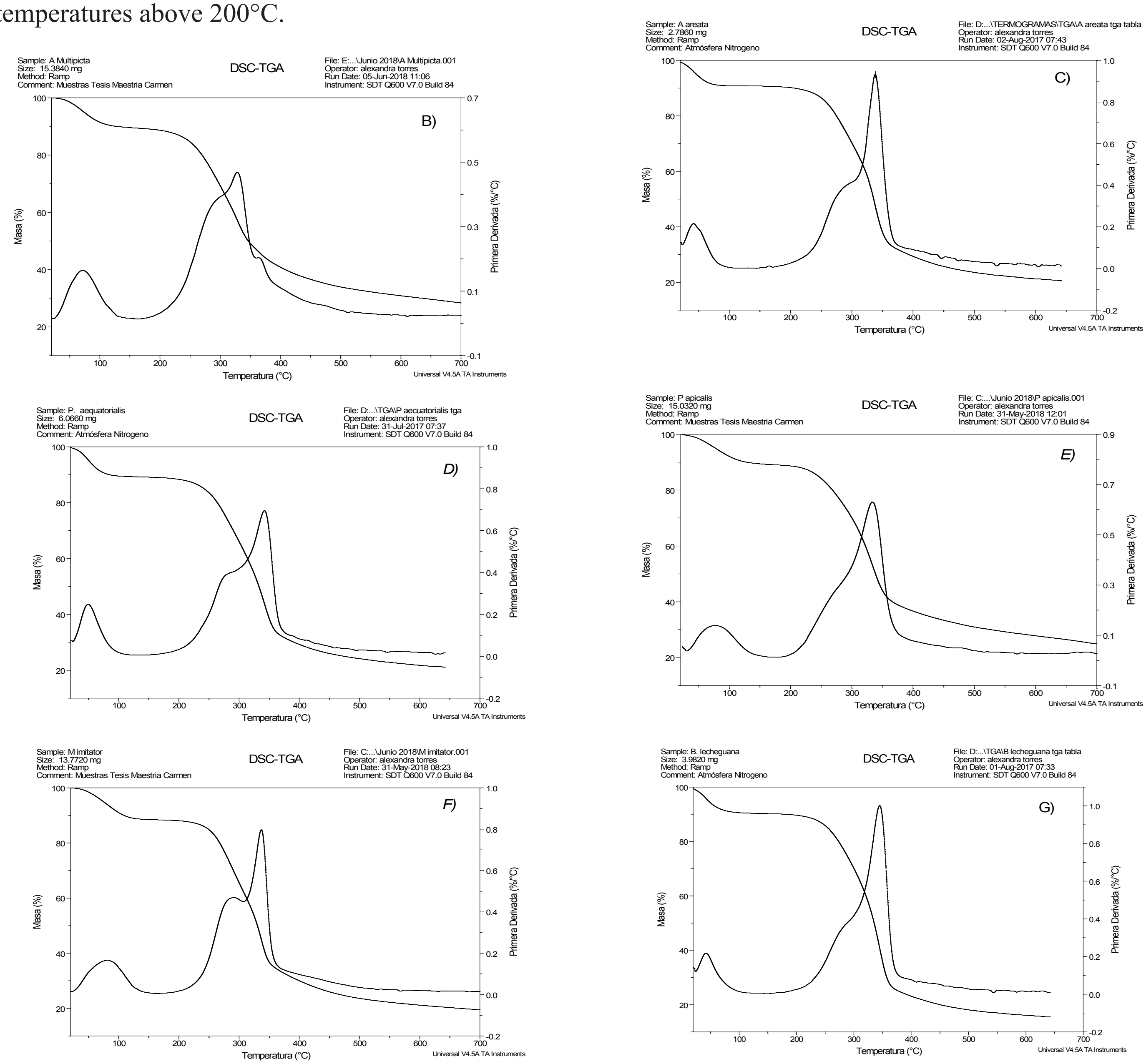


Figure 1. TGA and DTG curves for the nests of the wasp species studied. A) *A. pallipes,* B) *A. multipicta,* C) *A. areata,* D) *P. aequatorialis,* E) *P. apicalis,* F) *M. imitator,* G) *B. lecheguana*

Source: Author

Differential scanning calorimetry (DSC)

Table II shows the results obtained by differential scanning calorimetry. The corresponding thermographs are presented in Figure 2. The thermographs show between 4 and 5 transitions. The first transition corresponds to a large endothermic peak in the temperature range of 54.97 ± 2.34°C - 69.18 ± 3.45°C, attributed to the elimination of moisture when the sample is heated.

content in these nests [25]. Cellulose enthalpy is also higher in *B. lecheguana* and *A. pallipes* compared to the nests of the other species. This is due to the fact that the cellulose chains organized in the nests of these two species can increase the thermal stability of the material even when the degradation temperatures of the extractive content are high (Table 4), since it is necessary to supply more energy to melt the cellulose crystals which increases their enthalpy.

Table II. Maximium Temperatures and Enthalpy of Cellulose Obtained From the DSC Curves

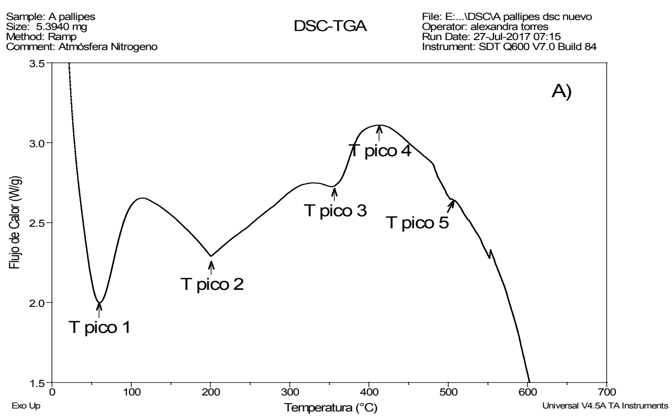
specie	T_{pico1} (°C)	ΔH (J/g)	T_{pico2} (°C)	ΔH (J/g)	T_{pico3} (°C)	ΔH (J/g)	T_{pico4} (°C)	ΔH (J/g)	T_{pico5} (°C)	ΔH (J/g)
A. pallipes	59.73 ± 2,09	84.32 ± 3,45	200.44 ± 2,34	133.24 ± 0,87	353.95 ± 4,32	58.79 ± 0,76	416.36 ± 1,23	41.86 ± 0,98	510.71 ± 0,26	82.00 ± 8,09
A. multipicta	63.81 ± 3,67	74.82 ± 2,34	200.56 ± 3,24	133.80 ± 6,83	316.52 ± 2,34	38.06 ± 6,45	395.22 ±3,45	65.62 ± 3,90	524.08 ± 2,34	123.7 ± 7,65
A. areata	59.97 ± 4,01	75.57 ± 10,23	200.40 ± 9,76	174.62± 0,86	340.42 ± 2,34	48.74 ± 3,08	451.21 ± 0,76	41,86 ± 3,76	--	--
P. aequatorialis	61.29 ± 5,46	82.98 ± 3,54	200.44 ± 6,76	147.80 ± 5,43	343.76 ± 3,09	50.29 ± 0,87	393.63 ± 2,65	57.24 ± 3,76	491.24 ± 3,23	77.79 ± 9,87
P. apicalis	69.18 ± 3,45	90.35 ± 3,45	200.79 ± 3,98	136.23 ± 2,87	317.53 ± 1,24	27.04 ± 31,32	415.93 ± 1,23	38.11 ± 2,34	--	--
M. imitator	64.06 ± 1,09	88.56 ± 34,12	200.43 ± 5,09	138.61 ± 6,87	309.98 ± 1,54	22.88 ± 2,08	433.53 ± 2,34	37.93 ± 4,32	542.93 ± 4,56	87.06 ± 5,87
B. lecheguana	54.97 ± 2,34	86.95 ± 9,81	200.40 ± 0,87	137.23 ± 0,87	358.63 ± 2,34	59.95 ± 9,08	440.99 ± 3,34	42.99 ± 2,12	479.02 ± 1,09	73.14 ± 2,76

corresponds to non-quantifiable transitions and enthalpies in the different samples

The second transition is endothermic and is related to the degradation of hemicelluloses in the range between 200.40 ± 0.87°C - 200.79 ± 3.98°C and similar values were found in the nests of the wasp species studied. The third transition is endothermic in a range between 309.98 ± 1.54°C - 358.63 ± 2.34°C, related to the cellulose fraction, for this transition is included the enthalpy related to the degradation of the crystalline part of the cellulose for the nests of the species studied. Finally, there are two exothermic transitions, one of them between 393.63 ± 2.65°C - 451.21 ± 0.76°C assigned to lignin decomposition, present in all the species studied. The other transition is between 479.02 ± 1.09°C - 542.93 ± 4.56°C; according to other studies, this transition has been related to the formation of gaseous products released during the pyrolysis process experienced by the samples.

The nests of *B. lecheguana* and *A. pallipes* had the highest temperatures associated with cellulose degradation (Table II). Behavior that may be associated with the higher crystalline cellulose

Currently, in the scientific literature, few studies of thermal analysis in materials designed by social insects are reported, especially in wasp construction material. The study reported by Erik Schmolz [26], corroborates the results obtained in this study. On the other hand, considering that wasp nests are built using worn wood fibers, it is possible to make comparisons with other studies related to thermal analysis in wood, finding thermal behavior similar to the results obtained in the nests of the wasp species evaluated in this study [19], [27] - [29].



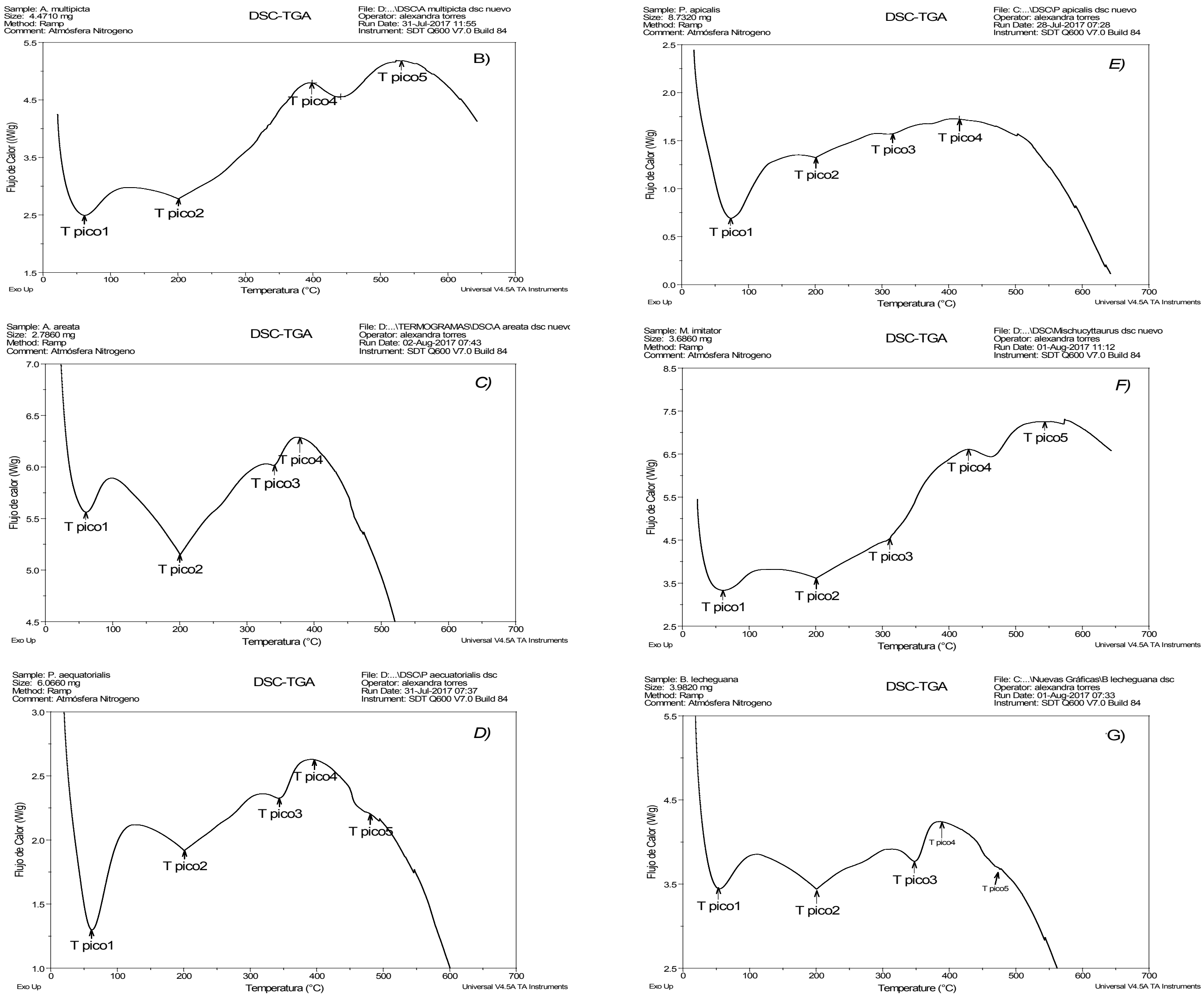


Figure 2. DSC curves for the nests of the wasp species studied. A) *A. pallipes*, B) *A. multipicta*, C) *A. areata*, D) *P. aequatorialis*, E) *P. apicalis*, F) *M. imitator*, G) *B. lecheguana*
Source: Author

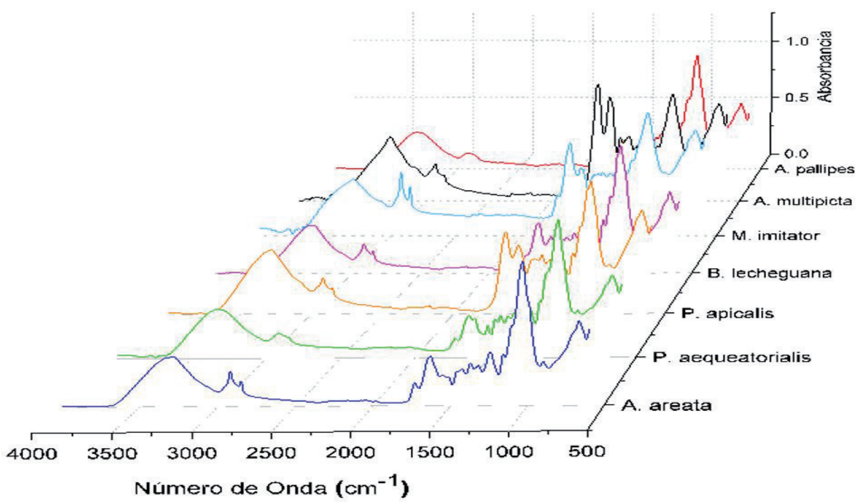


Figure 3. FTIR-ATR spectra of nest samples of different species.
Source: Author

FTIR-ATR Spectroscopy

The IR spectra for the nest samples of the seven wasp species can be seen in Figure 3.

Table III lists the respective identification of the different IR bands in the samples studied; it is possible to observe the presence of bands assigned to vibrational modes characteristic of methyl, methylene, hydroxyl groups characteristic of cellulose, hemicellulose and present in many groups of lignin and carbohydrates [25], [30], [31].

X-ray fluorescence - XRF

Table IV shows the concentration of the metals found in the samples. The species A. areata records the highest values in the metals K, Ca, Al, Mg, Ti, Cr, Mn, Fe, Ni, Zn and Li except for Cu metal in which intermediate values are recorded in comparison with the other species. While in the nests of the species *B. lecheguana* low values are registered in the concentration of the metals Ca, Mg, Ti, Cr, Mn and Cu, with respect to the other species of wasps. The metals Fe, Ca and Mg determined coincide with those found in other studies, affirming that the material can offer very promising applications in adsorption studies, [32] other authors affirm that the composition of the material is quite different from one species to another, and report that the most important components in the nests are: Ca, Si, Al, Mg and K, this coincides with the results obtained in this study, although the metal found in greater quantity was iron [2], [23].

Table III. Identification of Functional Groups in the IR Spectra of the Samples

Type of link	Wave number (cm^{-1})	*A. areata*	*A. multipicta*	*A. pallipes*	*B. lecheguana*	*M. imitator*	*P. aequatorialis*	*P. apicalis*
O-H (Celulosa)	3276-3575	3281	3276	3337	3284	3284	3331	3277
C-H	2917 - 2940	2918	2923	2922	2917	2919	2925	2919
-CH_2	2850 - 2870	2851	2852	2864	2852	2851	2851	2852
C=O (Carbonilo)	1728 - 1735	1730	--	1728	1728	1728	1728	--
C=O	1612 - 1643	1627	1629	1630	1630	1627	1631	1628
C-C (Lignina)	1590 - 1600	--	--	1594	--	--	1594	--
N-H	1530 - 1559	1547	1538	--	1542	1543	1546	1542
C=C (Lignina)	1504 - 1510	1510	--	1505	--	--	1507	--
CH_2	1450 -1460	1454	1452	1456	1453	1442	1456	1444
CH	1418-1425	1424	--	1423	1423	1420	1420	1424
C-CH_3 (Lignina - Carbohidratos)	1365 - 1375	1367	1375	1369	1370	1375	1371	1374
CH_2	1315 - 1324	1317	1315	1323	1314	1320	1323	1315
C-O, C=O, C-C	1233 - 1243	1241	1238	1233	1237	1236	1234	1241
-OH	1200 -1210	--	--	--	1204	--	--	1205
C-O-C (Celulosa)	1145 -1165	1155	1158	1155	1155	1150	1153	1156
O-H (Celulosa)	1104 – 1110	1105	--	1106	1104	--	1104	1104
C-O	1030 – 1060	1031	1035	1030	1030	1030	1035	1035
C-H (Celulosa - hemicelulosa)	890 - 899	897	893	894	896	894	894	896
C-H	660-669	663	665	666	664	664	662	666

corresponds to the absorption bands not found in the different samples.

Table IV. Elemental Composition of Wasp Nest Samples

Esp. / Element	Concentration (mg/kg)						
	A. pallipes	*A. multipicta*	*A. areata*	*P. aequatorialis*	*P. apicalis*	*M. imitator*	*B. lecheguana*
K	189,5 ± 0,5	266,3 ± 0,3	305,3 ± 0,2	186,7 ± 0,3	247,0 ± 0,2	256,5 ± 0,6	253,5 ± 0,5
Ca	125,2 ± 0,3	228,9 ± 0,2	265,3 ± 0,3	243,9 ± 0,3	238,7 ± 0,1	137,2 ± 0,4	97,6 ± 0,2
Al	399,5 ± 0,3	809,3 ± 0,2	965,4 ± 0,3	977,6 ± 0,3	780,8 ± 0,4	566,6 ± 0,2	476,6 ± 0,2
Mg	221,6 ± 0,2	342,7 ± 0,1	406,6 ± 0,2	349,6 ± 0,2	407,8 ± 0,3	231,6 ± 0,3	221,6 ± 0,2
Ti	38,5 ± 0,2	61,6 ± 0,3	78,4 ± 0,1	47,5 ± 0,3	58,2 ± 0,3	38,5 ± 0,2	27,3 ± 0,1
Cr	5,67 ± 0,01	15,8 ± 0,2	17,5 ± 0,3	15,34 ± 0,04	14,7 ± 0,2	5,67 ± 0,01	4,98 ± 0,03
Mn	2,09 ± 0,03	4,23 ± 0,03	6,78 ± 0,05	5,16 ± 0,02	4,32 ± 0,04	2,09 ± 0,03	1,89 ± 0,02
Fe	1009,5 ± 0,7	1735 ± 1	2635 ± 1	1390 ± 1	1420 ± 1	1070,5 ± 0,7	1099,7 ± 0,3
Ni	11,8 ± 0,4	15,8 ± 0,1	16,9 ± 0,2	21,6 ± 0,3	14,7 ± 0,2	12,8 ± 0,4	9,56 ± 0,06
Cu	13,4 ± 0,6	27,5 ± 0,4	13,9 ± 0,2	27,6 ± 0,5	25,0 ± 0,5	15,4 ± 0,6	12,7 ± 0,3
Zn	26,9 ± 0,4	104,3 ± 0,2	145,8 ± 0,1	102,7 ± 0,3	98,6 ± 0,3	56,9 ± 0,4	37,8 ± 0,2
Se	---	---	---	1,4 ± 0,2	5,4 ± 0,2	---	---
Li	---	12,2 ± 0,3	17,9 ± 0,2	5,9 ± 0,7	3,9 ± 0,4	2,3 ± 0,4	---

corresponds to the non-quantifiable elements in the different samples.

Conclusions

The characteristic bands of the compounds, in the FTIR spectra of the nests of the different species, exhibit the presence of hemicellulose, cellulose and lignin, as well as aliphatic and aromatic hydrocarbons, alcohols, phenols, ketones and aliphatic acids.

Through X-ray fluorescence (XRF) were found in all samples mostly iron and aluminum, results that differ from that reported for nests of species not found in Colombia, which contain more calcium and potassium.

Thermogravimetric analysis showed that the nest samples of the analyzed species *A. pallipes, A. multipicta, A. areata, P. aequatorialis, P. apicalis, M. imitator and B. lecheguana*, presented four losses of mass, the first of these (50.32 ± 0.84 - 87.45± 6.74 °C) attributed to the loss of water in the form of moisture absorbed in the surface of the nest; In addition to this there are three other processes, the first (200,39 ± 2,34 °C - 238,58 ± 1,80 °C) attributed to the decomposition of hemicelluloses, the second process (274,10 ± 4,65 °C - 307,39 ± 1,23 °C) associated with cellulose degradation and the third process (323,22 ± 0,34 °C - 350,95 ± 8,15 °C) corresponding to lignin degradation.

By thermal analysis, it is found that the nests of the species *M. imitator*, *P. apicalis* and *A. multipicta* have less thermal stability compared to the samples of the other species, and the building material of these species is characterized by starting the degradation process at relatively lower temperatures, which causes a reduction in thermal stability. Behavior that is probably associated with a greater volatility of the extracts (low molecular weight compounds).

The results of the different analyses indicate that there are variables of structure, composition and thermal behaviour that differ significantly in the nests regardless of the species, genus or place of origin of the samples.

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