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Investigation of processing parameters and properties of date palm fiber for the production of quality fiber boards

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Abstract

The anatomic properties of date fiber and its suitability in the production of alternative material for structural engineering application in the construction industry were investigated. Sample preparation was conducted in accordance with TAPPI Standard T12 – OS – 75, which specifies that samples be grinded to a fine particle size to permeate 0.4mm screen and retained on a 0.6mm screen. The moisture, lignin, extractives, alpha cellulose, and ash content, fiber dimensions, and weight percentage of cross and Bevan cellulose were all investigated. Pulping operation was further carried out which resulted in the production of good quality pulps, and subsequent production of various grades of fiber boards. Testing was carried out at 20^0C and 65% relative humidity; the board samples were conditioned in this atmosphere for about 3 ½ hours before testing. Pulp yield was exceptionally high. The impact of sodium silicate and carboxyl methyl cellulose (CMC) yielded fiber boards which displayed good strength properties. The processing parameters obtained affirm that date fiber offer considerable potentials in the production of quality boards that offer alternatives to wood.

Keywords: Cellulose–fiber; date fiber; sulphidity; CMC; ligno–cellulose; TAPPI

1. Introduction

The date palm (phoenix dactylifera) also known as the medjool palm is a tall, beautiful and majestic tree that is known for its edible sweet fruits, the dates. The tree belongs to the Arecaceae or Palmae family and the genus phoenix. The Date palm produces true real dates. It is the second most known and most useful palm tree in the world after the coconut palm tree. The date palm is a sub-tropical palm which reaches an average height of 60 to 100 feet. There are several varieties peculiar to each producing country. Dates are grown in Iraq, Persia, Egypt, Arabia and North Africa. The palm is very hard and will grow under the most arid conditions where few other plants can survive, but it prefers a blackish or salty clay soil. It requires hot and dry climate for most of the year. While it is in flower, and until the fruits begin to ripen, irrigation should be given every week. Commercially, the date palm is grown for its fruits, but for local market it is also the source of the strong alcoholic drink (Barreveld, 2007).

The date palm fruit is one of the most important sources of nutrition for the people in the Middle East. It is considered to be a delicacy. The date is a good source of sugar, potassium, fat and minerals. Only a female tree can form dates. Usually it starts producing fruits after 5-8 years. They may be eaten fresh or dried. The fruits can be stored for several years. The dates are also used as secondary products to make wine, syrup, vinegar, cakes and cream. (Chandra, Anju and Gupta, 2002)

Date wastes palms generated as a byproduct of its fruits and alcoholic drink in considerable amounts are usually considered as waste materials and pose a disposal problem which constitute nuisance to the environment where they are processed. They often have negative value as resources are employed to burn the materials on site or transport for disposal elsewhere. The common method of disposal by burning causes a great deal of pollution and is a menace to the environment. The chemical constituents of date wastes palm are carbon, oxygen, hydrogen, ash (largely silica).They are composed of cellulose; other carbohydrates present are starch, sugar, and lignin, which act as an adhesive for cellulose. (Maheswarappa and Rao, 2004)

In the building and construction industry, fiber board is a basic material. The development of well - developed machineries to produce it has been largely responsible for contributing to the provision of adequate shelter throughout the world (F.A.O., 2003)

About 50% of the total cost of all constructions can be accounted for by building materials alone, and in low-income shelter, the value of building materials could be as high as 80% of total cost because of the relatively low requirements for other inputs, such as equipment, installations and specialized skills. This trend of rising costs and falling supplies of materials can be reversed, if the system of production is based on locally available resources (Elinwa and Buba, 2006). The responsibility for improving these situations rests, to large extent, on the ability of the construction industry to meet the demands for basic physical investment in the built environment. Given this pivotal role of construction in national development, the building materials constitutes the single largest input in construction.

Building materials have been a cause for inadequate construction output, high construction cost, abandonment of construction projects and sometimes inadequate building maintenance in developing countries (Elinwa and Uba, 2003). This situation has come about because majority of our basic building materials are imported at enormous cost to the economy. Because of scarce foreign exchange, costs are prohibitive and supply is limited.

Economic growth of a nation is directly related to the level and efficiency of capital formulation. Typical indicators of underdevelopment are inadequacies in physical infrastructure, shelter and related amenities. Nigeria is faced with many problems in which shelter provision is one of them, and so the next twenty to fifty years, the construction industry will still remain very viable and thus will need a lot of building materials as inputs (Elinwa and Mangvwat, 2004).

2. Materials and methods

2.1. Materials

The raw material investigated in this research work is Date palm. This was sourced during post harvest processing at Oke-Ira in Ebute-Metta (West), Mainland local Government Area of Lagos State and Gidan Kwano, Minna, Niger State, Nigeria.

2.2. Methods

Methods developed by Technical Association of the Australian and New Zealand Pulp and Paper Industry Inc.,(APPITA,2006) and the Technical Association of Pulp and Paper Industry (TAPPI,2004), were adopted.

2.2.1. Moisture content

The moisture content of sample was determined by measuring the weight loss after drying the sample at 105^{o}C, calculated on the basis of moisture –free wood (Newell, 2007).

2.2.2. Extractives

The solubility of wood in various solvent is a measure of the extraneous materials. The solubility of the sample in ethanol/toluene in a 1:2 volume ratio gave a measure of the extractives content. This procedure is TAPPI Standard (T204, 2004) and ASTM Standard (D-1107, 2006). The sample meal was refluxed for 8 hours in a Soxhlet flask, and the weight loss of the extracted dried sample was measured (Casey, 2008).

2.2.3. Lignin

TAPPI Official Method was conducted for the Determination of Acid-insoluble Lignin in the samples (T222 om-88, 2004). The finely ground sample was treated with 72% H_2SO_4 for 2 hours at 20^{o}C. Followed by dilution to 3% H_2SO_4 and refluxing for 4 hours. To ascertain the validity of result obtained, an equivalent but shorter method was also employed. This was done by treating the sample with 72% H_2SO_4 at 30^{o}C for 1 hour, followed by 1 hour at 120^{o}C in 3% H_2SO_4. In both cases the determination was gravimetric (APPITA, 2006).

2.2.4. Ash analysis

Ash analysis was performed in accordance with Tappi Standard T 15 and ASTM Standard D 1102. In these standards ash is defined as the residue remaining after dry ignition of the wood at 575^{o}C. Elemental composition of the ash is determined by dissolving the residue in strong HNO_3 and analyzing the solution by absorption or atomic emission. The inorganic elemental composition of the sample can be determined directly by neutron activation analysis (TAPPI-211-om-93, 2004).

2.2.5. Holocellulose

Holocelullose is the total polysaccharide (cellulose and hemicelluloses) content of the sample, and methods for its determination seek to remove all of the lignin from the sample without disturbing the carbohydrates. The procedure adopted was TAPPI standard method (T-249, 2004) and ASTM Standard method (D-1104, 2006). Extracted sample meal was treated alternatively with chlorine gas and 2-amino ethanol until a white residue (holocellulose) remains. The acid chlorite method was also used (Saikia and Goswami, 2006).

2.2.6. Alpha cellulose

Alpha cellulose was obtained after treatment of the holocellulose with 17.5% NaOH in accordance with ASTM Standard method (D-1103, 2006). This procedure removes most, but not all, of the hemicelluloses (Horn and Setterholm, 2003).

2.2.7. Fiber dimension

Fiber extraction analysis was carried out by macerating in the boiling mixture of ethanol and hydrogen peroxide in ratio 2 to 1. The fibers obtained were carefully mounted on a slide with aid of dissecting needle, and aligned for easier observation and measurement. About twenty fibers were measured per each sample at a magnification of X 101 on a Reichort Visopam projection microscope. All samples were measured in a swollen condition.

2.2.8. Digestion of date palm residues

After a thorough cleaning process, 3kg of air-dry chips of the sample was loaded into the digester. The sample was covered with the cooking liquor of about 17% sulphidity, and the lid of the digester was firmly bolted to prevent leakage. The digester was switched on and the time of rise of temperature and pressure was noted at intervals of five minutes. The pulping temperatures rose gradually up to 138^oC during a period of 141 minutes and remain steady. The temperature however did not exceed 138^oC. the initial P^H of the pulping liquor was recorded at 6.0. The digester's initial temperature, pressure and starting time were all noted, and the various changes in parameters were also recorded. Drop in the value of temperature of the operating digester indicated cessation of pulping operation. The digester was switched off, allowed to cool below 60^oC and the content blown down.

The resultant pulp was subjected to thorough washing with plenty of water. When it was observed that subsequent washing resulted in no further change in colour, the pulp was transferred into the valley beater for processing into a more refined pulp.

Strength properties were determined after nine (9) beating times and the results obtained were plotted against time. Study of the graph derived from the values recorded during the pulping operation indicated that the cooking took about 105minutes to reach the maximum temperature of 138^oC.

3. Results

Table 1
Levels of different parameters investigated on date fiber samples

Parameters	Fiber (sample 1)	Fiber (sample 2)
Moisture content (wt%)	23.20	21.80
Alpha cellulose(wt %)	49.30	48.91
Ash (wt%)	4.30	4.70
Lignin(wt%)	12.90	13.20
Extractives(wt%)	8.60	8.40
Fiber length (mm)	1.55	1.53
Fiber width (µ)	6.034	6.00
Pulp yield (wt %)	61.30	58.12
Liquor to sample ratio	4:1	4 : 1
Maximum cooking temperature (^oC)	136	136
Time at maximum cooking temperature (mins)	29	29
Overall cooking time (mins)	74	74
Sulphidity(%)	20	20

4. Discussion of results

From the water absorption test carried out, it was showed that CMC reinforced Date Fiber furnished building boards offered poor resistance to deterioration during the period of observation of 2 weeks at 3 days intervals. This was due to poor water- tightness, resulting into increased water permeability, and eventual deterioration that occurred gradually over a period of 8 weeks.

Table 1 revealed that the date fiber, at the conditions tested, withstood outstanding loading parameters that are often related to the tensile and flexural strength of products of composites of fiber systems. It could be deduced from the result that these mechanical properties increased with degree of fibrillation with time of pulp-beating, up to a certain point, and then decreased gradually. Additionally the cooking regime showed that temperature above 180^oC was highly undesirable, because the destruction of cellulose was severe. This is evident from the result of a decrease in pulp yielding approximately 23wt% after a period of 90 minutes, contrary to the observed improved yield and good pulp quality at the temperature range of 135-138^oC.

It was observed that the optimum result was achieved at the maximum cooking temperature of 136^oC for 74 minutes, when the resultant pulp had a good feel, a fairly bright color, and very slow tendency to felt. These properties are generally desirable in the production and performance of board panels.

5. Conclusion

From the results obtained, it can be deduced that, date fiber possess the properties desirable for the production of fiber board panels, especially as substitute to wood when the various processing parameters are observed.

6. Recommendations

From the results achieved in the processing of date fiber for the production of boards, which indicate the date fiber can be used as substitute to wood in the production of fiber-boards despite it moisture vulnerability. This can be achieved if the various processing details are adopted as to ensure that the fiber mechanics is not damaged as to affect the quality of boards. It is thus recommended that date fiber be utilized in the production of quality fiber boards.

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