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Production of cardboard from waste rice husk

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ABSTRACT

Rice husk does not have substantial commercial value and generally present an environmental problem concerning its disposal. This investigation determines the suitability of producing cardboard from rice husk, thus, reducing the amount of pulping material required from virgin wood. Maceration process was used to produce cardboards from their pulps. For comparative evaluation, along with rice husk, bagasse and waste paper were used. The latter were blended in different ratios and their mechanical strength determined. Rice husk contained 15.2% lignin, 20.56% ash with kappa number of 99.48 while bagasse had 13.70% lignin and 2.23% ash with kappa number of 88.39. The maceration period of rice husk and bagasse was between 6 and 15 days and 5–10 days with the corresponding pulp yield of 40.44–46.55% and 46.01–36.76%, respectively. The average lignin content of rice husk pulp and bagasse pulp was 3.09–2.9% and 2.95–2.43%, respectively. The tensile index, edgewise crush resistance, average bursting index of cardboard from rice husk was 11.31 N m/g, 1.11 kN/m and 0.84 kPa m^2/g, respectively. For the rice husk mixed bagasse cardboard, the optimal ratios were (20/80), (40/60), and (60/40) with a tensile index of 17.96, 16.66 and 12.94 N m/g, respectively. The edgewise compressive resistance was 2.91, 2.42 and 1.99 kN/m, respectively. The bursting index was 1.88, 1.55, and 1.26 kPa m^2/g, respectively. The optimal rice husk mixed waste paper ratio was (20/80) with a tensile index of 21.52 N m/g with an edgewise compressive resistance of 2.75 kN/m and a bursting index of 1.35 kPa m^2/g. Thus, these cardboards are suitable for packaging as corrugating medium, wrapping and insulating board.

Introduction

Cardboard can be manufactured from virgin wood pulp. From an environmental point of view, using virgin wood can be avoided by utilization of other substitute. The increased demand for wooden supplies can be met through enlarged utilization of forest waste, increased utilization of waste paper, increased utilization of non-wood fibrous plants, or other environmentally sound pulping process [1]. Rice hulls are a by-product of the rice industry, with a total of 75 million tons worldwide. Despite numerous exploitations and broad researches have been proliferated, such efforts are handicapped by the limitations of its low nutritive properties, degradation resistance, abrasiveness, low apparent density and high ash content, attributed to another form of pollution phenomenon, rice husk ash [2]. Consequently, useful applications for rice husk are required to solve this problem [3].

Some of the advantages of rice husk mills include:

- There is insignificant damage on ecological balance since they are based on annually renewable raw materials often plentiful in supply and with disposal problems.
- No outflow of foreign exchange is needed to import raw materials.
- Sale of agricultural-residue provides further revenue to farmers who have little other opportunities for outside income.
- Employment is provided to rural labour.

Agricultural-residues like rice husk and bagasse are locally available either for free or at a very small cost. The major cost in such cases is incurred on collecting and transporting these raw materials. Due to the bulk of these raw materials, transportation can as well be a major cost factor in processing. Nearly all of these raw materials are collected manually and as such the labour costs constitute a big percentage of the total raw material costs. Thus, in countries with very low labour rates, pulp production with these raw materials can be extremely encouraging relative to wood pulping [4]. Consequently, the possibility of manufacturing cardboard from rice husk residues together with bagasse and

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waste paper was investigated. Their strengths were compared to that of virgin fibres normally used in the production of cardboard for packaging, to see whether the cardboard obtained from rice hulls residues could replace to some extent the pulping material in normal cardboard production. For that purpose, it was important to determine the optimum pulping time in terms of yield, kappa number and lignin content various mixtures of various mixtures of waste papers and rice husk pulp and bagasse pulp and rice husk pulp and to compare the mechanical properties of cardboards manufactured from these mixtures. The optimal amount of virgin fibre to be added also had to be determined so as to maintain strength.

Fibre morphology in non-wood plants used in cardboard making

Morphological characteristics, such as fibre length and width, are essential in estimating pulp quality of fibres [5]. Kiaie et al. [6] stated that the flexibility coefficient of bagasse and rice residues is included in high rigid fibres group and thick wall fibre group. Consequently, they do not have efficient elasticity and they are used more on fibre plate, rigid cardboard and cardboard production [7]. Kiaie et al. [6] also concluded the following as shown in Table 1.

Benefits of using rice husk include:

- Use of local fibre sources would offer import substitution.
- Rice husk are underutilized.
- It will expand the economic viability of the existing paper mills and lead to their revival.
- Saving in foreign exchange will be attained by reducing the amount of imported pulp and exportation of papers and paper products to other countries.
- Environmental problems on agricultural crop residues would be tackled.

Materials and methods

Raw material

Rice husks and depithed bagasse were oven-dried and stored for further use. The oven dried samples of bagasse were cut into pieces of about 2 cm long following research done by Madakadze et al. [30]. Waste papers were cut into small papers, about 2–3 cm on a side and oven dried.

Production of cardboard

Pulping by cold maceration

The maceration fluid is prepared by mixing 1 part of 30% hydrogen peroxide solution, 4 parts of distilled water, and 5 parts of glacial acetic acid. The risk husks chips were then soaked in the maceration mixture for days until digestion. The mixture was thoroughly stirred each day. According to Ibrahim [8], digestion is achieved when the pulp is formed, that is when the rice husk has softened. The average room temperature was 29 °C. At the end, the pulps were washed and screened into accept and reject (the one with knots and uncooked rice husk, due to incomplete reaction of the sample with the macerating chemicals). Finally, the accepted pulp was oven dried so as to determine the yield.

Determination of optimum maceration conditions, in terms of pulp yield, kappa number and lignin content

Samples of 15 g of bagasse and rice husk were soaked in 80 ml of the macerating liquor. They were allowed to macerate for 5, 6, 9, 10, 12, 15, 20 and 25 days. At the end, the pulps were washed with equal bathing ratio and finally screened into accept and reject.

Determination of kappa number and lignin content for raw rice husk

600 ml of distilled water were added to 0.5 g of the rice husk. 75 ml of 4 N sulphuric acid and 75 ml of 0.1 N potassium permanganate were mixed, and added to the above solution. The mixture was stirred and its temperature was maintained at 25 °C for about 10 min using a water bath. After 10 min, 15 ml of the 1 N potassium iodide was added to the mixture and stirred. 25 ml of the mixture was titrated against 0.1 N sodium thiosulphate to pale colour, two drops of starch indicator solution was added and the titration continued to colourless solution.

The Hussain et al. [9] method was used to determine the kappa number and lignin content:

$$\mathrm{P-No} = 75 - v$$

$$\mathrm{K-No} = \frac{\mathrm{P-No} \times f}{w}$$

$$\%L = \mathrm{K-No} \times 0.155$$

where P-No = permanganate number; v = titre value (ml); L = lignin content; K-No = kappa number; f = correction factor (50%); and w = weight of raw sample mixed with distilled water (g).

Pulp kappa number and lignin content of rice husk pulp

This method was used by Ibrahim [8] which was adapted from TAPPI 236 om-06.

1500 ml of distilled water was added to 1.0 g of dry weight of pulp and stirred thoroughly. 40 ml of 4 N sulphuric acid solution was added to the mixture and stirred. After about 5 min, 40 ml of 0.1 N potassium permanganate was added and stirred. After another 5 min, 5 ml of the 1 N potassium iodide was added and stirred. The reaction temperature was noted. 25 ml of the solution was titrated against the 0.1 N sodium thiosulphate to pale colour. Two drops of starch indicator solution was added and the titration continued to colourless solution.

Kappa number and the lignin content were evaluated as follows:

$$\mathrm{P-No} = 40 - v$$

$$\theta = T_r - T_o$$

Table 1
Biometric properties, chemical composition and morphology characteristics of bagasse and rice.
Source: [6].

Biometric properties	Chemical composition	Morphology characteristics
Fibre length: bagasse > rice (lowest)	Lignin: (highest) rice > bagasse	Slenderness ratio: bagasse > rice
Fibre diameter: bagasse (highest) > rice	Cellulose: bagasse > rice	Flexibility ratio: bagasse > rice
Cell wall thickness: bagasse > rice (lowest)	Extractive: bagasse > rice	Runkel ratio: bagasse > rice
Lumen width: bagasse > rice	Ash: (highest) rice > bagasse	–