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Processing of Elephant Dung and its Utilization as a Raw Material for Making Exotic Paper

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Abstract

Paper is one of the most in demand commodities of the world. Excessive deforestation has led to scarcity of wood resources, and it is needed to conserve them to protect the integrity of the ecosystem. The pulp and paper scientists are continuously struggling for non-wood raw materials that can be pulped in to exotic papers of high value. In the present study, an attempt was made to investigate the potential of elephant dung as a non-conventional raw material to make exotic paper. For this purpose, elephant dung was dried under sun for 4-5 hours and then in oven at 105°C for 30 min. The dung sample was then cooked by chemithermomechnical (CTMP), semi-chemical and chemical soda-anthraquinone pulping processes in different experimental trials by varying the alkali dose. The papers were then tested for different physical and optical properties to estimate the quality of the elephant dung paper. In the current study, the optimum cooking conditions to make elephant dung paper in terms of maximum properties was 14.0% NaOH and 0.5% Anthraquinone (AQ) on o.d.p. Different type of exotic papers can be produced from elephant dung such as writing sheets, diaries, scrap books and greeting cards in a wide variety of styles and colors that could attract the attention of tourists and art lovers; resulting in revenue generation that could be used for the betterment of elephants and their owners.

Keywords: Elephant dung, exotic paper, non- wood paper products, elephant dung recycling, deforestation.

Introduction

Paper and its products are one of the most in demand commodities of the world. The importance of paper is demonstrated by the fact that its consumption per person is associated with the welfare standard and literacy rate of a country[1]. The raw materials for paper production are wood, non wood and recycled fiber. Wood, however, is a 90% contributor to global paper production[2]. Using wood for paper production results in negative environmental impacts because of cutting trees (deforestation) which endangers the biodiversity and hence the whole forest ecosystem is disrupted. Due to excessive industrial consumption of wood, the timber resources of the world are dwindling while the consumption of paper is increasing day by day. Adopting non-wood raw materials for paper production is a solution to ecosystem threats caused by overcutting of trees for manufacture of paper from wood. Even a 5-10% share of non-wood raw materials in the paper market could have economic and environmental benefits[3].

Non wood fibers are traditionally classified as industrial crops, natural plants and the agricultural by products[4]. In comparison to wood fibers, the non wood fibers vary in chemical composition and physical properties[5]. The variations depend on the climatic conditions, the type of soil and the plant species[6].

Elephant dung is a potential raw material for production of exotic paper[7]. Elephants are herbivores and their dung contains undigested plant fibers making the excreta an excellent raw material for paper production[8]. Digestibility of elephants has been studied in both wild and captive and is estimated to be 30-45% in wild[9], and 35-39% in captive[10]. Hence, 50-60% of fibrous food consumed by an elephant is excreted undigested.

An Elephant can produce up to 240 pounds (110 Kg) of dung per day[11]. The dung produced per day can be used to produce 265 sheets of paper (an average size of 30×25 inches). There are currently between 470,000 and 630,000 wild African elephants[12] while in Asia there are approximately 50,000 elephants in the wild. The countries homes to elephants are India, Myanmar and Africa and elephant dung paper can be used to make a wide range of products from simple writing sheets, to diaries and large scrap books. The inquisitive tourist market provides opportunity for artisans to generate revenue through the presence of elephants. Conventionally, Elephant dung paper is made like any other handmade paper. The process involves the formation of a liquid suspension of boiled and washed dung fibers that are sometimes mixed with recycled paper and wood glue. The resultant pulp is then drained through a wire mesh and a mat of inter woven fibers is obtained. The mat is pressed and dried to obtain paper[13]. There are many advantages of making paper from elephant dung. The dung is waste material and absolutely free. It is good business strategy to utilize waste into a useful product. The paper manufactured from dung generates revenue and make people realize that elephants are not just liabilities but assets.

The current study is an attempt to manufacture paper from elephant dung. Keeping in mind the growing demand for paper, it is need of the hour to make innovations in the pulp and paper industry. Even little share of eco-friendly fibers in papermaking will save timber resources to some extent. The demand for exotic papers is increasing both locally and internationally specially among people who have an eye for creativity and nature conservation. Elephant dung paper is not only exotic but also gives a message of animal conservation and protection while reducing the grave problem of dung disposal.

Material and Methods

Materials: Elephant dung, Sodium Hydroxide, Anthraquinone (AQ), surfactant

Sample Preparation: The dung boluses were separated using fork shaped wood branches, spread on large plastic sheets and dried for five hours under sun (average temperature 40 $\pm$ 5°C) to avoid fungal and beetle growth. The air dried dung was then placed in hot air oven at 105°C for 30 minutes to disinfect the dung. The sample was then stored in zip lock polyethylene bags at room temperature until further experimentation.

Evaluation of Chemical Properties of Elephant Dung: The pretreated elephant dung sample was thoroughly mixed and then a representative sample was collected for the chemical analysis of raw material according to standard methods. Table-1 shows the results for chemical analysis of dung sample. The tests performed were:

Moisture Content: TAPPI test method (T 210 cm-03, 2003) was used to calculate the moisture content of the elephant dung sample. 2.0 g of specimen was weighed in a tared, dried weighing bottle and heated in electric oven at 105°C to a constant weight. The bottle was then reweighed and percent moisture was calculated by formula[14]:

$$\text{Percent Moisture Content} = \frac{W2 - W1}{W2 - WT} \times 100$$

Where: W2 = weight of bottle and specimen prior to drying, W1 = weight of bottle and specimen after drying, WT = tare weight of bottle.

Alpha Cellulose (TAPPI test method T 203 cm-99, 2009) 1.5 g of elephant dung sample was taken and 100.0 ml of 17.5% NaOH was added in two installments of 15.0 ml and 25.0 ml respectively. The sample was stirred for 15 minutes after both additions of NaOH reagent. 100.0 ml of distilled water was then added and contents of the beaker were covered and allowed to stand for 30 minutes. The resultant pulp suspension was stirred and filtered. 5.0 ml of the filtrate and 10.0 ml of 0.5N potassium dichromate solution was taken in a 250 ml flask. 30.0 ml of concentrated H_2SO_4 was added cautiously, while swirling the flask. 50.0ml of water was added to the mixture after cooling it for 15 minutes and then left until room temperature was achieved. Titration was carried out with 0.1N ferrous ammonium sulfate solution with an end point of purple by adding two to four 2 drops of Ferroin indicator. A blank titration substituting the pulp filtrate with 2.5 ml of 17.5% NaOH and 2.5 ml of water was carried out. The alpha-cellulose percentage was calculated using formula[15]:

$$\text{Alpha Cellulose}(\%) = 100 - [6.85(V2 - V1) \times \frac{20}{A \times W}]$$

Where: V1 = titration of the pulp filtrate, ml, V2 = blank titration, ml, N = exact normality of the ferrous ammonium sulfate solution, A = volume of the pulp filtrate used in the oxidation, ml, W = oven-dry weight of pulp specimen (g)

Acid Insoluble Lignin (TAPPI test method T 222 om-02, 2002) 2.0 g of pulverized elephant dung sample was taken and 40.0 ml of 72.0% sulphuric acid was added in small increments with constant stirring. The temperature of the mixture was approximately 2°C. After the specimen was dispersed, the beaker was covered and left in water bath at 20°C for 30 minutes. 300-400 ml of water and the sample was added to a 2000.0 ml flask and the final volume was maintained at 1540.0 ml by adding distilled water. The contents of the flask were boiled in reflex condenser for four hours and left overnight. The supernatant was siphoned off and residues were washed with hot water, dried in oven at 105°C, cooled in dessicator and lignin (%) was calculated by using equation[16]:

$$\text{Acid insoluble lignin content } (\%) = \text{Lignin (g)} \times 100/2.0\text{g}$$

Table-1
Chemical analysis of elephant dung sample

Chemical parameters	Composition (%)
Moisture	8.20
Alpha cellulose	71.67
Acid insoluble lignin	30.50

Steps Involved in Production of Paper from Dried Elephant Dung: Sand removal by decantation method: The dried sample of elephant dung was submerged in a bucket filled with water. The sample was stirred for 2-3 minutes and then allowed to settle for 15-20 minutes. The dung sample being less dense will float on the surface of water and sand being denser will be settled down at the bottom of the bucket. The dung was then collected from top by decantation and washed several times with distilled water to remove residual sand and mud particles if any which clung to the dung because of lying on the ground prior to collection from elephant house. The washed sample was then manually pressed to high consistency (>25%) and stored in refrigerator at 4°C prior to further experimentation.

Pulping of Elephant Dung Samples: Three different cooking trials were carried out to pulp elephant dung sample. For each trial 1000.0 g o.d. elephant dung sample was fed in the closed loop revolving digester followed by the addition of cooking liquor. Figure 1 shows a schematic of pulping process. The detail of each experimental trial is given in the table 1.

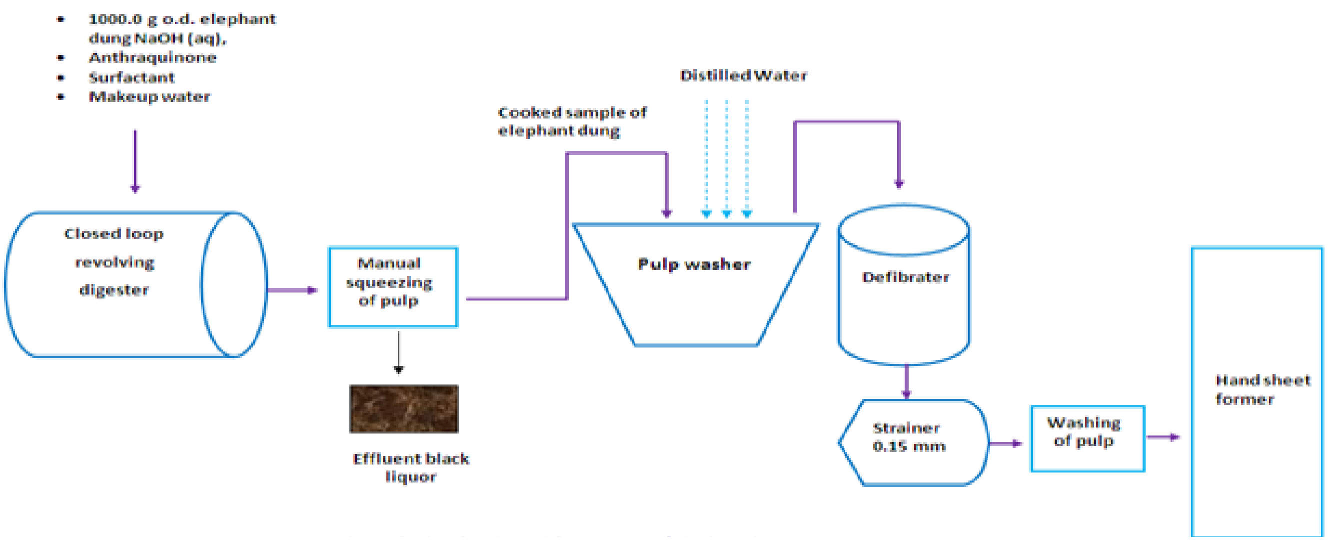

Figure-1
Schematic showing the pulping process of elephant dung

Table-2
Pulping Conditions of Various Experimental Trials

Cooking Trial	Pulping Type	Cooking Chemicals	Cooking Temperature (ºC)	Cooking Time (minutes)	Cooking Pressure (bar)	Consistency (%)
C-1	Chemitherm o-mechanical	4.0% NaOH on o.d.p 0.5% AQ on o.d.p 0.1% surfactant on o.d.p	165	45	6-8	15
C-2	Semi-Chemical	10.0% NaOH on o.d.p 0.5% AQ on o.d.p 0.1% surfactant on o.d.p	165	45	6-8	15
C-3	Chemical	14.0% NaOH on o.d.p 0.5% AQ on o.d.p 0.1% surfactant on o.d.p	165	45	6-8	15

To maintain the consistency, makeup water was added to produce steam in the digester and to facilitate the pulping process. At the end of each pulping trial, the digester was switched off and steam was allowed to release.

Washing of Pulp: The cooked sample of elephant dung was transferred in the pulp washer to wash it thoroughly with water till neutral pH was achieved. Washing was done on #40 mesh wire screen.

Defibration of Pulp: The pulp obtained after all cooking trials was defibrated using laboratory defibrator at 3000 r.p.m for 60 seconds to disintegrate the pulp.

Straining of Pulp: After disintegrating or refining the pulp of different trials, the shives were removed using pulp strainer. This strainer was fitted with a 0.15 mm slot screen. During the process water is intermittently added to separate the cooked fibers from shives and knots (uncooked fibers). The strained slurry is then again washed in pulp washer, dewatered by manual pressing to high consistency (>25%) and stored in polyethylene zip lock bags at 4°C until further processing and testing procedures.

Formation of Handsheets: The standard method of Scandinavian Pulp, Paper and Board Testing Committee was used for sheet making [17]. The pulp sample was disintegrated in distilled water using pulp fiber disintegrator until all fibers were dispersed. The handsheet machine was opened and half filled with water after which the sheet former was closed. The pulp required for 70 grammage sheet was calculated on the basis of area of sheet. The measured pulp was poured in the handsheet former and stirred for a few seconds. The water was then drained from the water outlet. The straining pan was pulled out and blotting sheets were used to pick the handsheet. The handsheet was then dewatered with hydraulic press and dried at 105ºC for twenty minutes. The samples of handsheets made of pulp from each cooking trial are shown in figure-2.

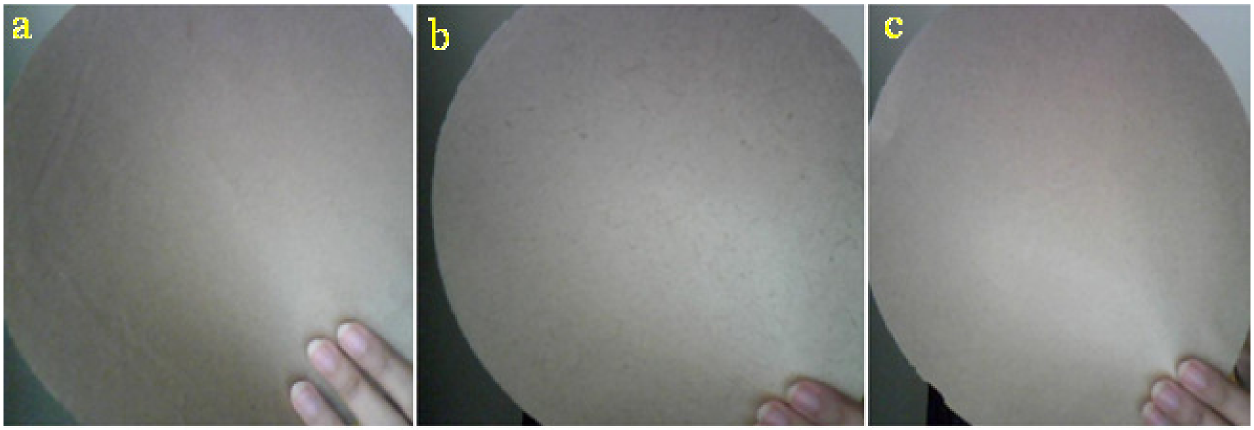

Figure-2
(a) Handsheet from pulping trial C-1 (b) Handsheet from pulping trial C-2 (c) Handsheet from pulping trial C-3

Study of Optical Properties of Handsheets Made From Elephant Dung: Brightness (TAPPI test method T 452 om-08, 2008): Brightness is a commonly used term in paper industry. It is the numerical value of the reflectance factor of a sample with respect to blue light of specific spectral and geometric characteristics. Zeroing of the Photovoltaic color, opacity, Brightness and Reflectance Meter was carried out and brightness was measured using the brightness meter[18].

Opacity: This is defined as 100 times the ratio of light reflected by paper specimen when backed by a black body of 0.5% reflectance. Opacity was determined for handsheets using the Photovoltaic Meter according to ISO method[19].

Whiteness and Yellowness: Yellowness and whiteness for all handsheets were calculated by using Standard Practice for Calculating Yellowness and Whiteness Indices from color coordinates measured by Photovoltaic Meter. Standard plate was placed and reflectance values of sheet were noted for each filter. Yellowness and whiteness Index were then calculated through standard method[20].

Testing of Physical Properties of Handsheets Made From Elephant Dung Pulp: Measurement of Thickness (Caliper): The thickness or caliper of the sheet was determined in microns using by Land W micrometer. The handsheet was inserted in the slit and moved in left to right direction to get 4 readings. The average of all values was then calculated to be recorded as handsheet thickness[21].

Measurement of Grammage: Grammage is measure of the density of the paper. Grammage of all handsheets was calculated by using the formula: (SCAN-P 6:75)[22]

$$\text{Grammage}\left(\frac{\text{g}}{\text{m}^2}\right) = \frac{\text{weight ofhandsheet(g)}}{\text{area of handsheet}(\text{m}^2)} \times 1000$$

Where: Area of handsheet was 360 cm^2

Measurement of bulk: TAPPI test method (T 411 om-97, 1997) was used to calculate the bulk of the paper by using the following formula[23]:

$$Bulk\ \left(\frac{cc}{g}\right) = \frac{grammage\ \frac{g}{m^2}}{thickness\ (micron)}$$

Measurement of Burst Strength: Bursting strength is a measure of the maximum hydrostatic pressure required to rupture the handsheet specimen at controlled and constantly increasing pressure applied through a rubber diaphragm in a circular area of handsheet (30.5 mm diameter). The maximum pressure reading up to the rupture point was recorded in the pound per square inch (psi) on the Bursting/ Muller tester. The burst index was determined by following equations[24]: (TAPPI method T 403 om-02, 2008).

$$\text{Bursting Strength(KPa)} = \text{Bursting strength(psi)} \times 6.895$$

$$\text{Bursting Index}\ \left(\frac{\text{KPam}^2}{\text{g}}\right) = \frac{\text{Bursting strength (KPa)}}{\text{Grammage}\ (\frac{\text{g}}{\text{m}^2})}$$

Measurement of Tear Strength: The handsheets were cut using a tear cutter and each piece was then placed in the tear tester. The pendulum was raised to its initial position and pointer was carefully set against the stops. The initial knife cut was made and pendulum released. After the tear was completed the pendulum was caught on the return swing without disturbing the position of the pointer. The scale reading was then recorded. Tear index was calculated by (TAPPI test method T 414 om-88, 1998) using equations[25]:

$$\text{Tear strength(mN)} = \text{Tear strength(g)} \times 9.807$$

$$\text{Tear Index}\left(\frac{\text{mNm}^2}{\text{g}}\right) = \text{Tear strength (mN)/Grammage}\ (\frac{\text{g}}{\text{m}^2})$$

Measurement of Tensile Index: Tensile strips of 10.0 cm long and 1.5 cm wide were cut and placed between clamps of tensile tester. The values of force were noted from the tensile tester.

The tensile index was calculated by (TAPPI test method T 404 cm-92, 1992) using equation[26]:

$$\text{Tensile Index}\left(\frac{\text{Nm}}{\text{g}}\right) = \text{Tensile strength}\left(\frac{\text{N}}{\text{mm}^2}\right) \times \frac{\text{thickness(micron)}}{\text{grammage}\left(\frac{\text{g}}{\text{m}^2}\right)}$$

Results and Discussion

Current demand and practices around the globe are focused towards exploiting every possible non-wood raw material which can be processed into paper. Cellulosic contents are essential for any material to be made into paper. The Alpha cellulose content of elephant dung sample was high i.e. 71.67% which is a promising percentage for a raw material used for paper making[27].

When acid insoluble lignin was studied in elephant dung sample, it was found to be substantially high (> 30.0%) as compared to hardwoods and soft woods (≤ 30.0%). This means that a high chemical dose is required to lower the chromophoric contents[28].

Results on Table 3 indicate the optical properties of handsheets made from elephant dung pulp from the three pulping trials. Brightness values were not satisfactory for pulping trial 1 (C-1) with a chemical dose of 4.0%NaOH and hence required improvement to create a presentable exotic paper. The brightness was very low (19.8%) which is indicative of the increased amount of chromophoric groups in the cooked pulp. The yellowness decreased and there was a slight increase in whiteness in pulping trial 2 (C-2) and it increased further when the chemical dose was increased to 14% in pulping trial 3 (C-3). The results for optical properties are shown in figure 3, 5 and 7 for pulping trial C-1, c-2 and C-3 respectively.

Opacity of a paper is its quality of hiding the print on the back side of the sheet[29]. The value of opacity decreased slightly with increase in chemical charge but was high for C-2 and C-3 (98.2%) just like C1 (99.6%)

Results on Table 4 indicate the physical properties of handsheets made from elephant dung pulp from the three cooking trials.

Burst index is indicative of the fiber lengths. The higher the fiber lengths, the greater the burst index[30]. This (1.27 $kPam^2/g$) was found to be very low for C-1 while other strength properties also required improvement so that durability of the paper is increased. The physical properties improved with the increase in chemical charge.

There was a noteworthy increase in tensile index which is a parameter that describes the fiber to fiber bonding in the handsheet. This had a value of 52.7 Nm/g for C-3 and 51.104 Nm/g for C-2 as compared to 37.9 Nm/g for C-1. Improvements were observed in the results for bulk as well as tear and burst indices in handsheets made from elephant dung pulp C-3 in comparison to C-2 and C-1. The results for physical properties are shown in figure 4, 6 and 8 for pulping trial C-1, c-2 and C-3 respectively. The comparison of thickness of handsheets from all pulping trials is shown in figure 9.

Among the cooking trials C-1, C-2 and C-3 carried out, the best optimum properties were achieved for cooking trial C-3.

Table-3
Comparison of Mean Optical Properties of Handsheets Made From Elephant Dung Pulp C-1, C-2 and C-3

Pulping Trials	Brightness (%)	Opacity (%)	Yellowness (%)	Whiteness (%)
C-1	19.8	99.6	37.83	-13
C-2	27.4	98.2	30.36	-7.3
C-3	33.4	98.2	25.04	0

Table-4
Comparison of Mean Physical Properties of Handsheets Made From Elephant Dung Pulp C-1, C-2 and C-3

Pulping Trial	Bulk (cc/g)	Tear index (mNm^2/g)	Burst index ($kPam^2/g$)	Tensile index (Nm/g)	Thickness micrometer
C-1	2.51	2.521	1.27	37.9	176
C-2	2.64	3.591	2.038	51.104	188
C-3	2.6	4.2	2.3	52.7	181

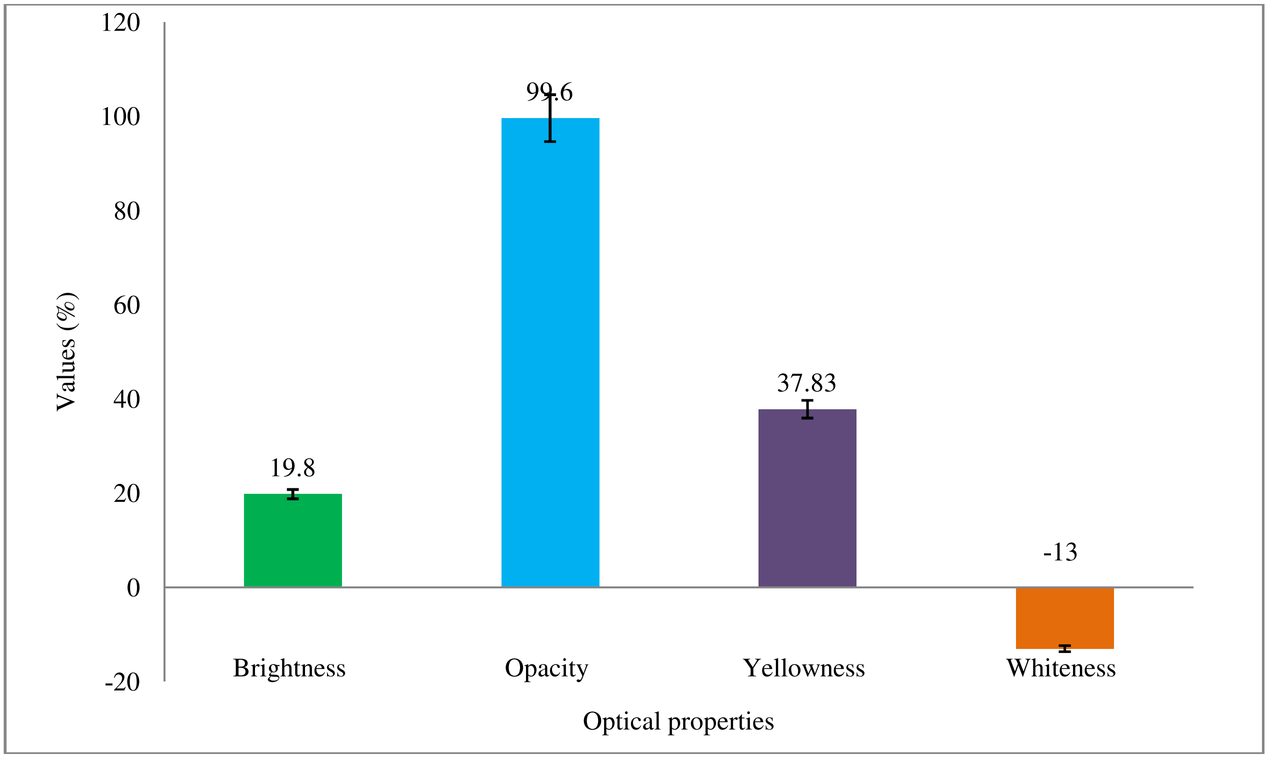

Figure-3
Optical properties of handsheets made from elephant dung pulp – C-1
(C-1 refers to cooking of the pulp sample at conditions mentioned in Table 2)

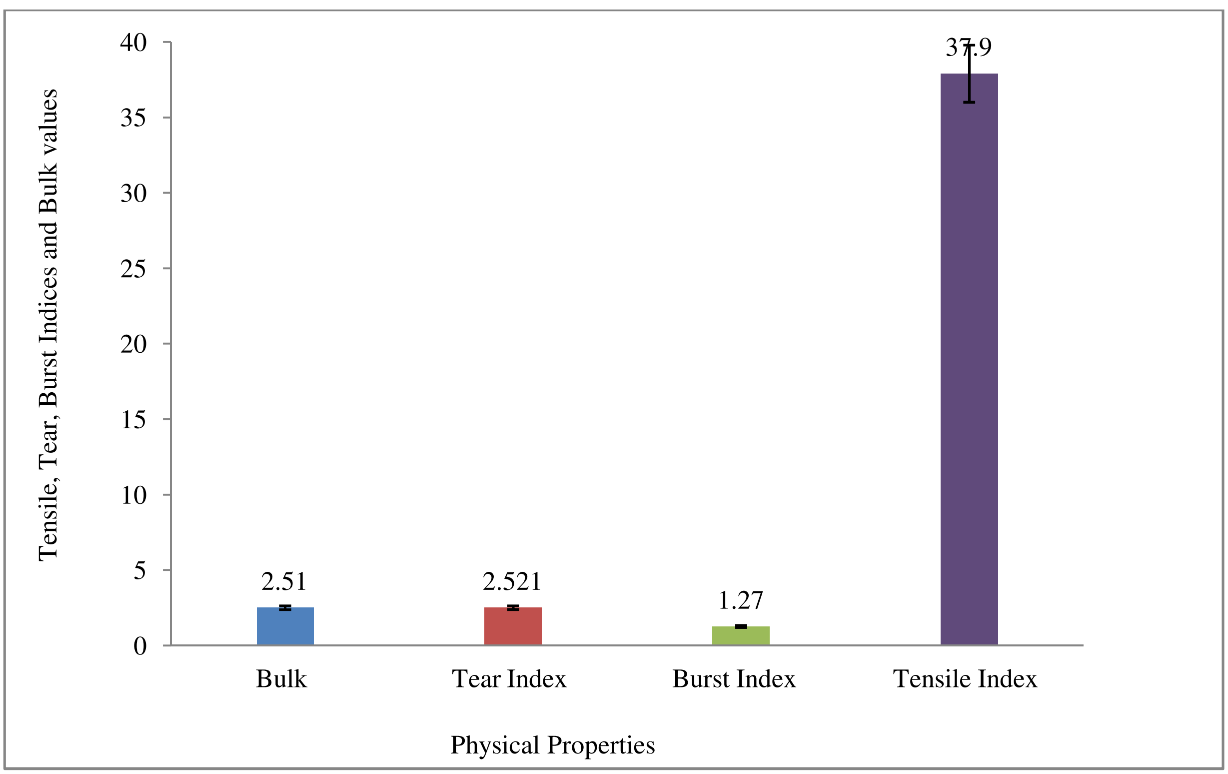

Figure-4
Physical properties of handsheets made from elephant dung pulp – C-1
(C-1 refers to cooking of the pulp sample at conditions mentioned in Table 2)

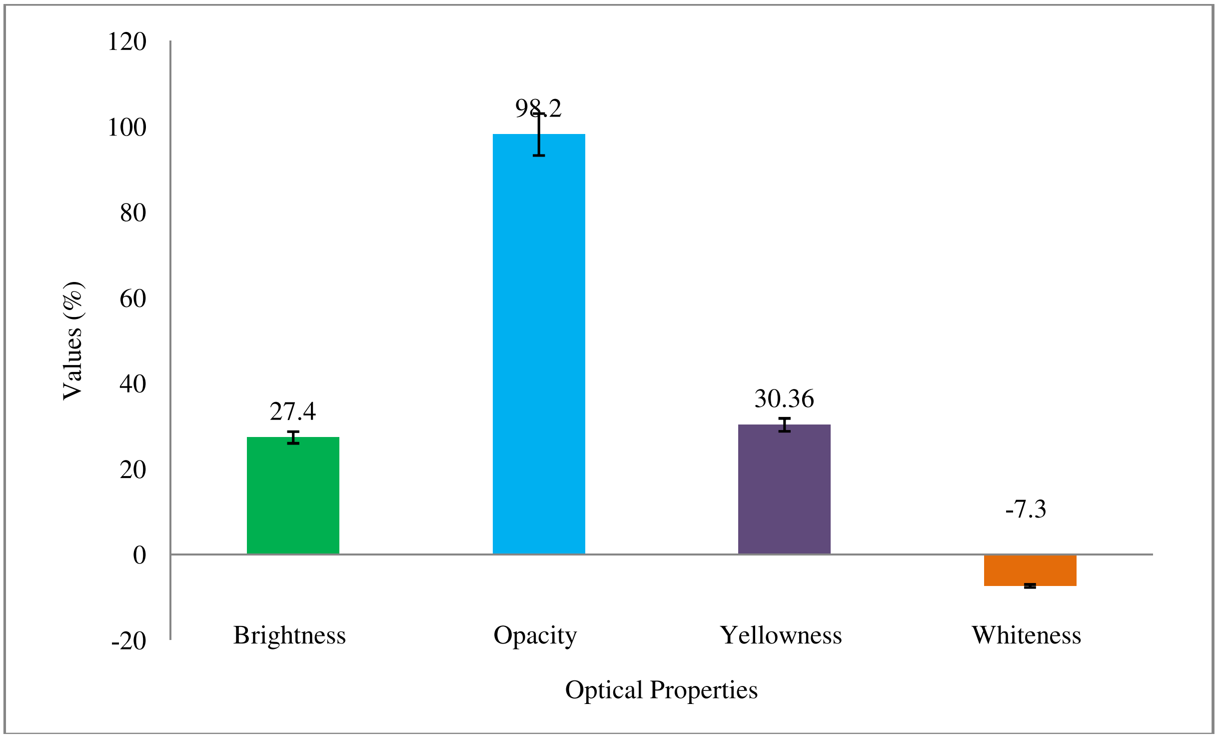

Figure-5
Optical properties of handsheets made from elephant dung pulp – C-2
(C-2 refers to cooking of the pulp sample at conditions mentioned in Table 2)

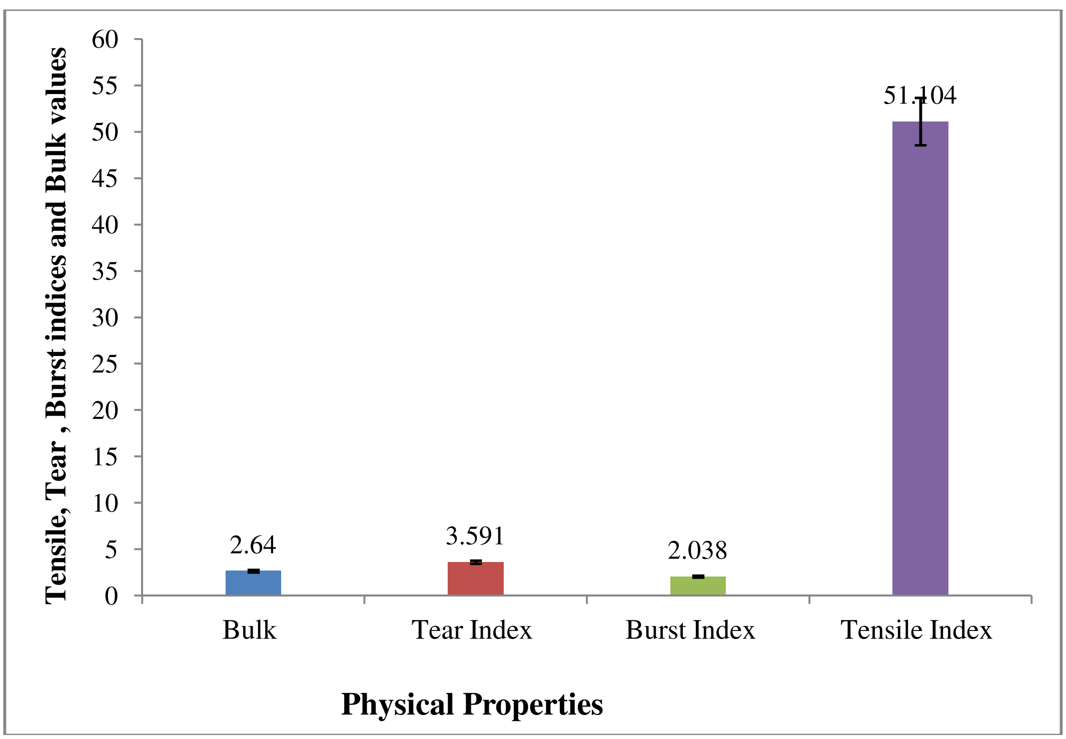

Figure-6
Physical properties of handsheets made from elephant dung pulp – C-2
(C-2refers to cooking of the pulp sample at conditions mentioned in Table 2)

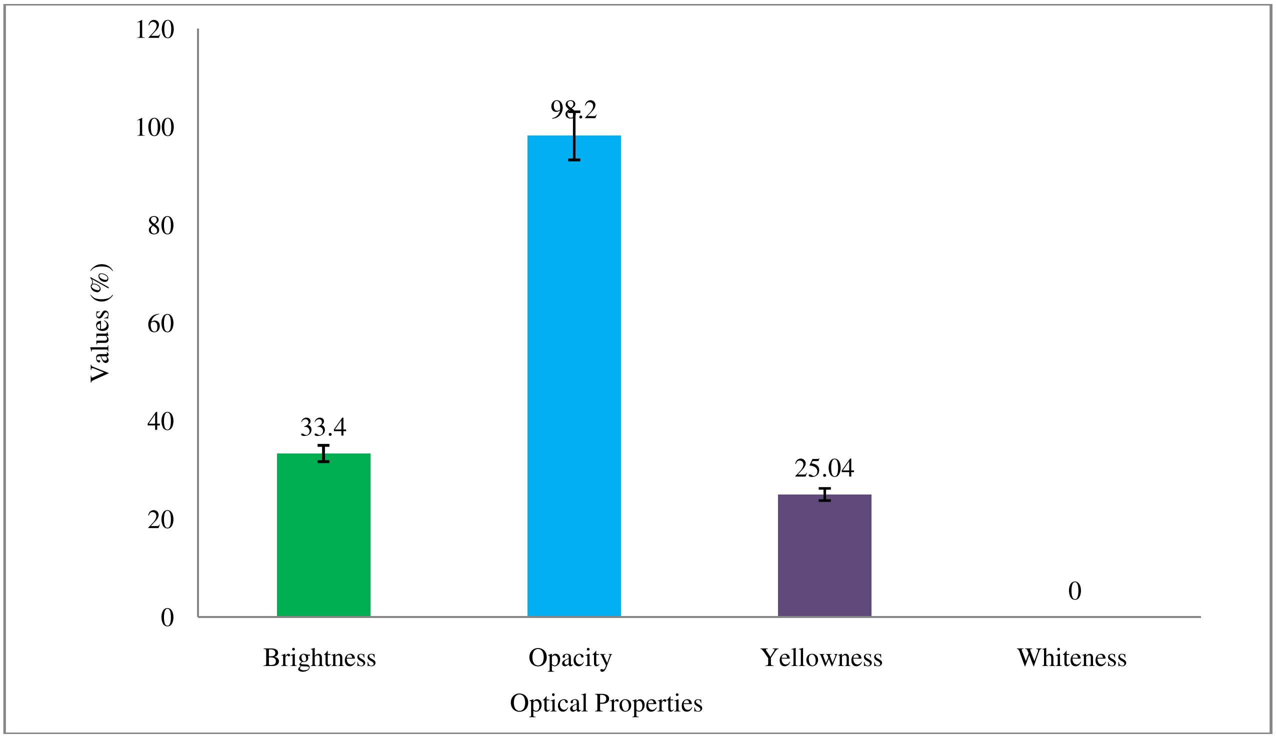

Figure-7
Optical properties of handsheets made from elephant dung pulp – C-3
(C-3 refers to cooking of the pulp sample at conditions mentioned in Table 2)

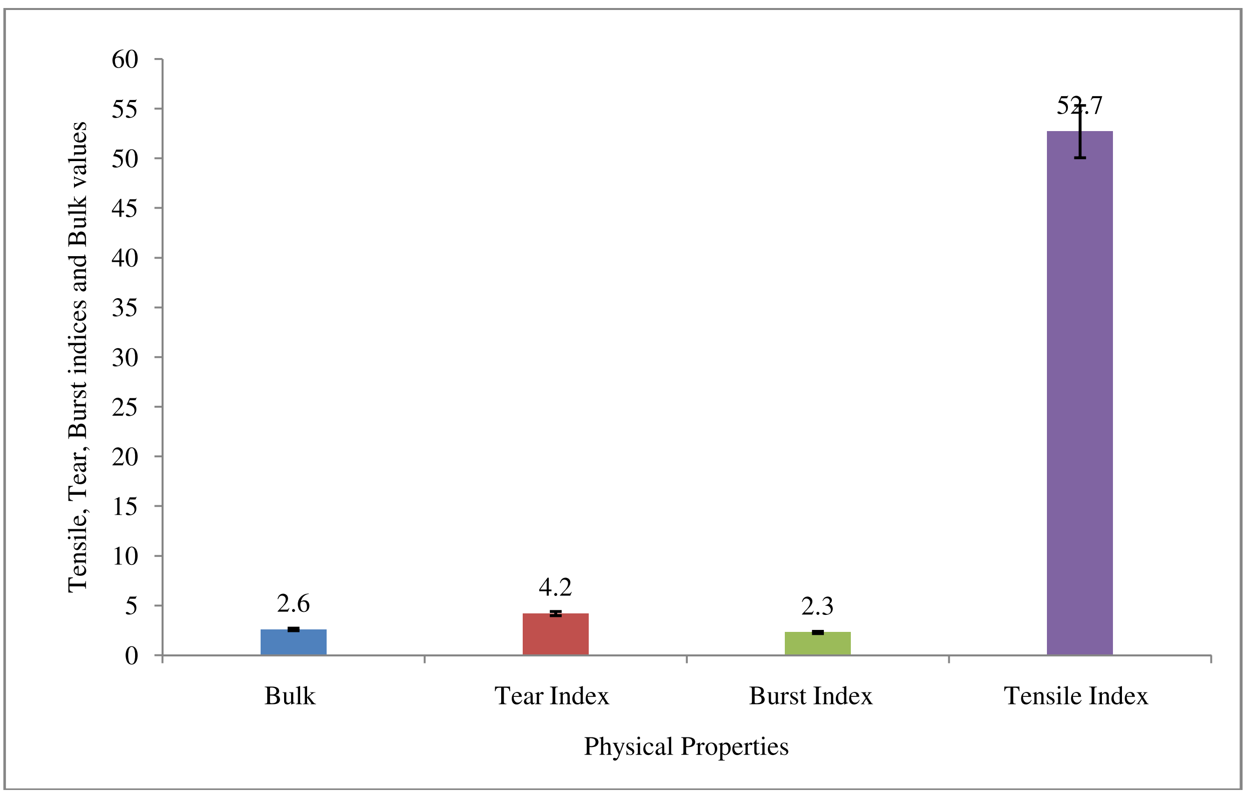

Figure-8
Physical properties of handsheets made from elephant dung pulp – C-3
(C-3 refers to cooking of the pulp sample at conditions mentioned in Table 2)

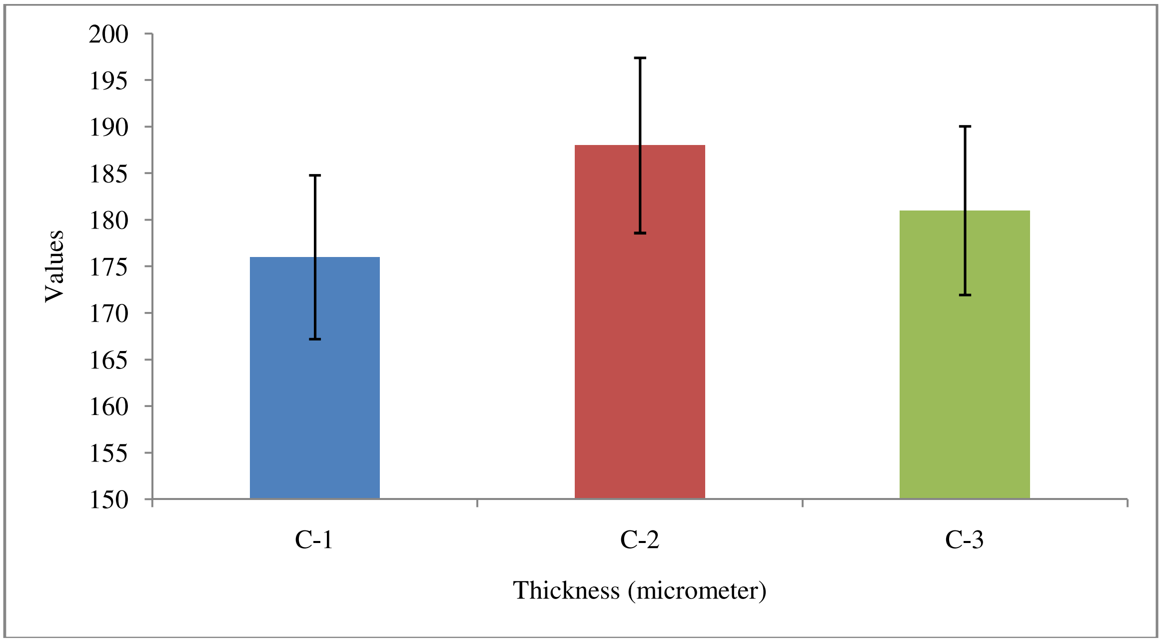

Figure-9
Comparison of thickness of handsheets made from elephant dung pulp C-1, C-2 and C-3
(C-1, C-2 and C-3 refers to cooking of the pulp sample at conditions mentioned in Table 2)

Conclusion

Exotic papers made from non-wood eco-friendly fibers are valued by environmentalists and pulp and paper scientists all over the globe. In view of the present study, it can be concluded that elephant dung can successfully be used as a raw material when pulped by chemithermomechnical (CTMP), semi-chemical and chemical pulping processes. The handsheets produced were tested for physical and optical properties and the results showed that the paper produced is an esthetically presentable exotic paper. The research proved that depending on the purpose of use, papers with different optical and physical properties can be produced by varying the cooking conditions. Elephant dung paper is not only exotic but also gives a message of animal conservation and protection while reducing the grave problem of dung disposal.

Acknowledgements

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