BAMBOO: FUTURISTIC RESOURCE FOR BIOENERGY-ITS COMMERCIAL APPLICATION AND BENEFITS

Abstract

The sustainability of the resources for the massive production of energy as well as materialsis one of the crucial setbacksfaced globally today. The giant production units are looking for resources which are renewable.The plant which we know as “Bamboo” shows a promising characteristics owing to its renewable and abundant cellulosic content. Bamboo has shown tremendous potential owing to its physical and mechanical strength. There are substantial reports to prove that bamboo plant has enough natural content and its environmental perspective to substituteany fossil fuel for the production of energy and materials. The plant in discussion holds desirable properties of the fuel compared to any biomass. Bamboo can be used as bioenergy as its entire solid, liquid and gaseous content can be transformed into desired output. The present discussion is an state of art presentation representing bamboo as natural, renewable and abundant resource of bioenergy. However, the massive production, harvest and management of the plant might be another point of discussion. The review has been compiled with an objective to emphasize the prospective of using bamboo and practically resolving the challenges as future resource for bioenergy.

Keywords: Bamboo, Bioenergy, Biofuel, Bioethanol, Bio-CNG.

Author

Rachna Kumari
M.Sc., B.Ed
Pataliputra University
Patna, India.
rachna.family@gmail.com

Copyright © 2024 Authors

I. BAMBOO – AN INTRODUCTION

Bamboos have gained their importance as the backbone of the village business for ages and will continue to be so even with the rise in the population. A well-known slogan of Rig Veda, "Bestow upon us with hundred culms of bamboos" reflects its utility dawn the civilization. Bamboo is long lived, evergreen timber plant of Poaceae (Ashish, 2021). This plant has low gestation period than any other woody tree (NBM, 2020). Bamboo can be planted for degraded land and drought proofing as it can tolerate different soil conditions (low to high mineral containing) and also drought to submerge content of moisture. It can conserve soil and moisture. This plant can clean atmosphere by fixing maximum carbon, lowers intensity of light as well as safeguards us against UV-rays (Nath et al., 2015). The fastest growing canopy of this plant develops climatic habitat for various lives, leading to release of more oxygen compared to similar strands of tree. Bamboo is recorded as fastest growing renewable woody plant verticallywith multipurpose (the maximum increase in height recorded is approx 1m/ day which makes a millimetre of increment in height every 1.5 minutes (Ashish, 2021). The multi-utility of bamboos are owing to their natural as well as material features as strong, smooth, flexible, cylindrical with hollow stalks. The mechanical processing owing to which the culms can be split, variable length of internodes, flexibility and the intrageneric diversities make them most useful flora. Studies on the history of the civilisation have shown that manufacture of arrows, building materials, ladders etc. are mentioned by mankind (Akinlabi et al., 2017). Moreover, their additional usage are included as ornaments, furnitures, household materials, food, paper, pulp, decorative items etc. (Constro Facilitator, 2020). Owing to their versatility, these plants have been sustaining economical and natural basis of living to the village residents hence, designated as "Poor man's timber" (Prasath et al., 2017). Maintaining their renewable nature as resource of energy, they minimise greenhouse gases establishing as to why bamboo should be considered as contribution in saving our environment and the earth (Liang et al., 2023).

Bamboos have great adaptability towards any kind of climatic conditions. This makes their distribution and growth successful. They can grow in temperature ranging from -20^0C to 45^0C (Lobovikov et al., 2012). They can grow in almost all kind of soils if provided with proper drainage system. Natural occurrence of bamboo species are, however, dependent upon various other factors such as annual rainfall, altitude level, tropical/ temperate climate etc. Maximum occurrence of bamboo has been shown in China (Ahmad et al., 2021). Asia outstands with the maximum variety of genera and species including some of the rare existing bamboo species. North America, South America and Central America are enriched with diversity of bamboo species with approximately 450 species, where 300 species are of woody habit. Africa show comparatively lower diversity with approx 40 species distributed (Ahmad et al., 2021).

II. BAMBOO – THE MOST SUITABLE RESOURCE

Bamboo has an impact in every walk of human life. Bamboo and cane basketry are now-a-days a part of our daily life and activities as they are used in household items like baskets, or bamboo tubes for water, vessels, plates, furnitures, spoons, and fishing rods as well as hunting equipment, bridges, scaffolding, ladders, house frames, flooring, agriculture implements, handicrafts and musical instruments (Liang et al., 2023). Bamboos, in recent years, have gained vast popularity among industrialists as substitute of various agro-based

Copyright © 2024 Authors

industries. Large scale industries such as Bio-CNG, Bio-ethanol, Paper-pulp etc. have strategically started using bamboo as their base raw material (Sukumaran et al., 2013). Bamboo has proven to be most economical bio resource with abundant availability. Some of the recent reports show that keyboards and computer chips are being made of bamboo (Lu, 2020). Employment generation from bamboo harvesting has reached a benchmark and thereby, bamboo helps in poverty alleviation. Today, around the world more than 2.5 billion people generate their livelihood depending on this grass (Rana et al., 2010). The industrial prospective of bamboos as important substitute of timber as well as other uses are gaining attention. Bamboo furniture, materials of construction, high-value flooring, side walls and particle board, computer chips, biofuel and biodiesel) have great potential for the future (Pande and Pandey, 2008). Intensifying green market promotes innovative opportunities to bamboo as substitute of plastics. Bamboos have become the reason for development of cottage/ medium scale industries to large scale industries (paper, pulp, fabrics, CNG, biodiesel) and on the other hand it can become a potential tool combating rural poverty and livelihood (Van and King, 2019).

Being a natural resource with extreme capability of biomass regeneration, bamboo has incredible effect on environment. Particularly, the plant is best timber-substitute and hence, it results in minimal deforestation of scarce vegetations. Further, they restrict erosion of soil, lead to conversion of CO_2 to O_2 as well as minimising the consequences of overall warming of earth (Kumar et al., 2019).

III. BAMBOO – AS POTENT RAW MATERIAL FOR SMALL SCALE INDUSTRIES

Small scale industries form the economical backbone of any state or nation. Government run various awareness programmes and provide lots of opportunities to generate entrepreneur (NBM, 2019). Small scale/ cottage industries supports nation by

1. Generating employment for local unemployed people
2. Household customized products
3. Adding revenue to nation’s economy
4. Enhancing the living standard of people.

Small scale industries based on Bamboo and its part are easy to start with low investment.

Depending upon the properties bamboos are utilized. The outstanding characteristics in various ways of bamboo include strength, smooth as well as straight culm, hollow and round, the ease by which it splits, availability in variable sizes, different internodal sizes, easiness while cutting and drilling holes as well as its tough structure externally, no foul taste or smell and their high biomass regeneration (Nagarnaik et al., 2019). Construction equipment, agricultural implements/ tools, as edible and weaponry products etc. are some of the daily uses (Hossain et al., 2015). Bamboo based industrial sectors are one of the oldest of conventionalsmall scaleventures in our country. The origin of craft from bamboo is known since dawn the civilization when production of crops started. Manufacturers eventually started fabricating bamboo mats, baskets, and products of household use. Gradually, for rural people, bamboo became the means of livelihood (Bal et al., 2012). Nowadays, bamboo based industries are spread in various tribal and rural areas of the country and is a consistent source of income generation.

Copyright © 2024 Authors

Bamboo and related products are used to manufacture varied types of in-house and commercial applications owing to their availability and diversity (Panda, 2011). Bamboo market products are in demand owing to its durability and eco-friendly properties. Such expertise occupies a remarkable position in the handicraft industry. As a material, this grass is renewable with eco- friendly characteristics and sustainable properties (Bhelkar et al., 2019).

Various products made of bamboo in small scale industry are:

- Weaved bamboo blind and screen
- Sitting Stools
- Different types of mats
- Wind chimes

- Candleholder
- Wall hangings
- Fishing equipment

Copyright © 2024 Authors



- Baskets in different sizes and pattern
- Lampshades
- Headgear



- Musical instruments
- Barbecue sticks
- Skewers
- Fruit forks
- Serving trays, cutlery sets along with cups etc
- Plant support sticks
- Party picks



- Rice Spoon
- Kite stick

Copyright © 2024 Authors

- Toothpicks
- Incense sticks




- Handle of knife
- Seat cushions
- Brooms
- Backscratchers and ear scrappers
- Decorative curtains



- Handbags
- Walking sticks etc.
- Flower vases as well as ashtrays
- Fans (foldable)



Copyright © 2024 Authors

Some Important Species of Bamboo used for Small Scale Industries

Sl. No.	Species	Uses
1.	*Bambusa arundinacea* Retz.	Household carpentry, boxes, ornamental, vases etc.
2.	*Bambusa balcooa* Roxb.	Rickshaw hood frames, Fishing rods as well as agricultural implements, baskets and mats.
3.	*Bambusa bambos* (L.)Voss	Making ladders.
4.	*Bambusa nutans* Wall ex Munro	Poles for various purposes
5.	*Bambusa polymorpha* Munro	matting, handicrafts, board-making
6.	*Bambusa tulda* Roxb.	boxes, basketry, mats, household utensils, handicrafts
7.	*Dendrocalamus. giganteus* Munro	Buckets, boat masts, matting, woven wares, bamboo boards, interior applications.
8.	*Dendrocalamushamiltonii* Ne es	household utensils such as water containers, baskets, mats
9.	*Dendrocalamus longispathus* Kurz*brandisii*	Boxes, basketry, mats, containers.
10.	*Dendrocalamusstrictus* Nees	Instruments for music, mat, biofuels, sticks, tools for agriculture, baskets, rafts, domestic items and brooms.
11.	*Melocanna baccifera* (Roxb.) Kurz	Household items, wall hangings, decorative items, tools, floor cover, screens etc. ,
12.	*Thyrsostachysoliveri*	Basketry, handicrafts, broom handles.

(Miah and Rahman, 2001)

IV. THE SOCIO-ECONOMIC IMPACT OF BAMBOO BASED SMALL SCALE INDUSTRIES

Large number of involvement of local poor and unemployed people are directly benefitted by these industries. Beneficiary includes from growers to people engaged in transport, primary processors, secondary processors, wholesalers (Borowski, 2019). Most of the works in such industries are environment and eco-friendly, hence even females actively participate and gain benefit as full time employee. During the course of employment benefit, the living standard of the local people has improved (Rana et al., 2010). This change has a positive impact on the literacy rate of such areas.The country/ state on the other hand are benefitted with revenue generation with the market value and demand of bamboo made products (Tambe et al., 2020). Such products are subjected to list of export material, thereby generating worldwide market (Kaur et al., 2016). Customers get fantastic biodegradable products for their household and daily uses.

V. BAMBOO – FUTURE MATERIAL FOR LARGE SCALE INDUSTRIES

Large scale industries in simple words are categorized as industries with a fixed asset of more than one hundred million rupees (Borowski, 2019). The category mainly includes

Copyright © 2024 Authors

large manufacturing units of natural gas, metal extraction, food processing, fuel generation, automobile, insurance and finance and so on (Kaur et al., 2016).

Large scale industries offer a great advantage:

1. Attain specialization in products by using properly skilled manpower and machinery.
2. High revenue generation for the state and nation. The generated revenue contributes to the GDP.
3. These sectors have commercial advantage of purchasing raw materials and selling products.
4. Such ventures have their own maintenance department and hence can withstand through tough times.

Some of the requirements of large scale are:

- Quality raw materials
- Consistent supply of raw materials

Bamboo has come with the solution to various threats of large scale industries. Collection of raw materials has always been a day to day challenge in the large scale industries. Bamboo has been found as most suitable for bioenergy/ biofuels, pulp and paper industries (Bhelkar et al., 2019). Being a forest produce, it is abundantly available, easy to grow and maintain in farm alongwith crops (agroforestry) (Kittur et al., 2016). Hence, today agro-based industries look at bamboo as their future raw material.

VI. ADVANTAGES OF BIOMASS ENERGY CONTENT OF BAMBOO

1. Bamboo biomass energy dependent power industries convert biomass content to useful electrical energy (Hossain et al., 2015).
2. Bamboo biomass utilizing plants is based on sustainable and renewable fuel.
3. Bamboo based power plant engages domestic resources resulting in our minimal dependence on exotic products.
4. Bamboo pulp based industrial plant employs fuel source of local origin causing enhancement of local market.
5. The energy source generated is securely portable as in production and supply can be made according to customer demand (Ding et al., 2020).
6. Bamboo biomass fuel has been observed to emit extremely low air pollutants.
7. The content of moisture results in combustion of bamboo biomass to occur at comparatively lower thermal requirement than traditional fossil fuels. It lowers N_2O emission inherently. Biomass burning of bamboo has "carbon balance". However, combustion or decomposing wood of other timber plants emit CO_2, CH_4 (a greenhouse gas 22 times worse than CO_2) (Van and King, 2019).
8. Fly ash produced from the power plants based on bamboo biomass can be recycled.
9. It helps in creating India’s energy security with benefits to the farmers.
10. It has high income potential.
11. Bamboo plant leads toneutral carbon cycle that lowers global warming (Nath et al., 2015).

Copyright © 2024 Authors

VII. NEED OF BAMBOO AS RAW MATERIAL

Recently, in order to replace fossil fuels, we have been trending to find alternative energy sources as other natural resources are running out of stock. Various industries like paper, pulp, bio-fuel, fabrics, textiles, furniture etc. currently use plants other than bamboo. This has depleted large areas of natural vegetation.

1. India currently owns only79% of its fuel need. However, using bamboo, we not only attain 100% but will have reserve fuels for future use (Sontakke and jaju, 2021).
2. Bamboo has least detrimental impact on land/ environment. Minimum/ negligible risks are imposed to the environment and human life. As bamboo has high regeneration capacity, can recover the loss within few months.
3. The harvest time for bamboo in years is 3-5 while most timber plant needs 15-30 years. Bamboo plant grows to its maturity and is ready to be used as raw material in a span of 3-5 years, fastest compared to any other plant on the earth (Pandey and Ojha, 2013).
4. Bamboo has the typical property of high biomass productivity, self-regeneration, adaptability to survive even in poor soilscan grow on degraded land and thereby, it is one of the best-known biomass resources.
5. The infrequent flowering behaviour at an interval of about 60 to 120 years further makes bamboo as suitable quality raw material for consistent supply (Zheng et al., 2020).
6. Bamboo plants need either very less or negligible amount of fertilizers.

VIII. BIO-CNG

1. Bamboo and its Inherent Properties as Suitable Bio-Fuel

- Bamboo has comparatively lower ash substance and alkali index, one of the most desirable fuel characteristic (Bhelkar et al., 2019).
- Compared to any other agriculture products and wastes, bamboo has high heat value (HHV), thereby confirming its suitability for complete combustion (i.e. utility in thermal energy plant) (Hossain and Numan, 2015).
- Low content of moisture in bamboo (around 8-23%) in comparison to corn stalk, rice husk, rice straw and bagasse. Low moisture increases efficiency of utilization by the reduction of input energy to dry the biomass (Chin et al., 2017).
- Bio-CNG made from bamboo will have high calorific value and can be used in blast furnaces and can also be converted to electricity (Berndes et al., 2003).

Hence, the extensive usage of biomass of the plant under discussion has high potential to be used as resource to gain variety of bioenergy.

2. **Bio-CNG Production: Steps of Manufacture:** A Digester/ Bioreactor (effluent free) is filled 80% with microbial culture. Raw material (bamboo) is fed into reactor with feed mixing tank.

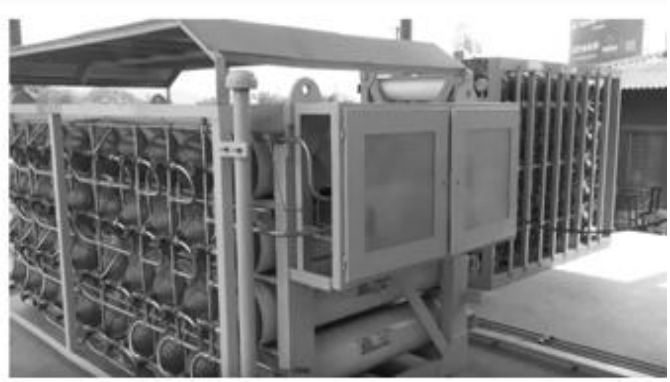
Copyright © 2024 Authors

Bioreactor/ Digester at Bio-CNG Production Centre

Temperature is maintained at 37^{o} C (optimum condition for bacteria to grow and multiply). Condition of tank slurry is monitored regularly. The overflow from digester is carried to a storage tank through pipes. At this point a separator is made to segregate solid and liquid products. Solid waste is carried to another vessel. Dry waste (solid waste) can be transformed/ packaged into bricks for re-use in furnace for cooking or in another fire heated systems. The generated biogas mixture is comprised of: Methane, Carbon dioxide, traces of hydrogen sulphide and moisture. These are stored in specially created rubber balloons followed by purification process. It is essential to purify methane free from any impurities for safety in storage and use at high pressure. This makes CNG almost 96% pure or more, ready to be used as vehicle fuel (Montano and Dam, 2021).

Methane Purity Testing Machine

Copyright © 2024 Authors



Bio-CNG Storage at distribution centre

Vehicle Tank Filled with Bio-CNG

IX. BIO-ETHANOL

1. **Application of Bio-Ethanol:** Bio-ethanol finds it uses in varied fields. Its uses are diversified as it is being used in laboratory chemical to rocket fuel, recreational drug to medicinal solvent. Bio-ethanol is mainly produced by sugar fermentation process and is substitute for petrol fuel (Hamat, 2012). However, Bio-ethanol finds its application:

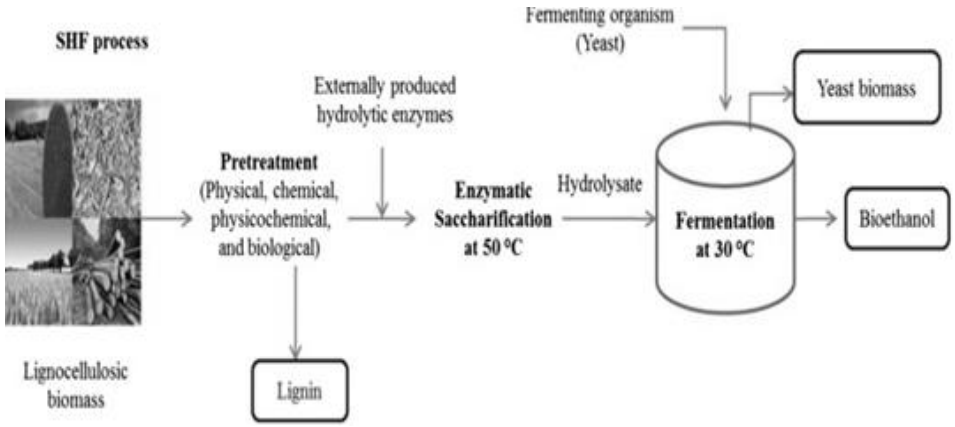
    - As transport and ignition fuel that will substitute gasoline.
    - As energy source to regenerate power by direct combustion
    - As fuel source utilizing thermo-chemical effect for fuel-cells
    - As raw material stock for chemical industries.

2. **Benefit of using Bamboo as Raw Material for Bio-Ethanol Production Compared to Other Forest/ Agriculture Products**

    - Gases bushed out during bio-ethanol production are healthier; it ignites cleanly (comparatively absolute combustion).
    - Utilizing bio-ethanol supplemented ignitions reduces the net emissions of greenhouse gases in considerable amounts (Hamat, 2012).

Copyright © 2024 Authors

- The bamboo fuels are "carbon neutral". The CO2 exhausted in the manufacture of bio-ethanol process is nearly similar in quantity to the amount which bamboo plant has fixed during photosynthesis (Hossain et al., 2015).
- Bamboo has high regeneration capacity.
- Less cost input.
- Naturally bamboos are found in abundance, with fast growth, require less management skills.
- High and quick income return to the farmers and growers.
- It lowers the emission of certain by-products as high-octane additives (Phan et al., 2023).
- The toxic concentrations of fuel spills are biodegraded/ lowered to non-toxic level.



Diagrammatic Representation of Bio-Ethanol Production

3. **Bio-Ethanol: Steps of Manufacture:** Bamboo contains more than 60% cellulose and should be used as economical resource stock for manufacture of bioethanol (Berndes et al., 2003). Bamboo is treated with Sulfuric acid (2%) in $3/4^{th}$ of w/w ethanol at 160^{o}C for half an hour. Delignification is done further by treating with 10 – 20% w/w Sodium hydroxide or Calcium hydroxide. This causes removal of Sodium hydroxide (nearly 96.5%) or Calcium hydroxide (85.75) lignin removal. Post that, hydrolysis is done in presence of enzymes of delignified cellulosic bamboo substrate with cellulose and glucosidase. The treatment resulted into 80.9% - 95.5% saccharification post forty-eight hours of incubation. The incubation is performed at 50°C maintaining pH level of 4.8. Further, ebullition of catalytic hydrolysates with yeast for 24 hours resulted in the formation of 89.1% - 92% bio-ethanol. (Sang, 2013)

X. PAPER AND PULP PRODUCTION FROM BAMBOO

Pulps are fibrous lignocellulosic materials are prepared from cellulose fibre of bamboos (Montano and Dam, 2021). Newspaper, magazines, toilet papers are few examples of paper made without mixing any kind of chemicals. The biomass of bamboo is employed to produce pulp which contains complete certain components as long fibers of cellulose (suitable for manufacture of paper), lignin (polymer of three-dimensional characteristics promoting strong bonding the fibers of cellulose fibres) and hemicellulose (Sang, 2013). Pulp is produced so that the bulk composition of the fibres (as in chips, stems etc) can be

Copyright © 2024 Authors

simplified into the component fibres. The pulp production is applied mainly for the manufacture of paper and bamboo boards. Notable quality parameters as viscosity, dirt count, bamboo furnish besides the strength of fibers, its extractives and brightness makes bamboo fibres as best suitable bio-resource.

XI. ADVANTAGES OF USING BAMBOO AS RAW MATERIAL FOR PAPER AND PULP INDUSTRY

1. Bamboo has virgin fibers (material used to make paper that has not been recycled from previous paper or other materials) thereby avoiding the excessive usage of strict bleaching of colours and dyes different from those of recycled products (Berndes et al., 2003).
2. Bamboo fibre are longest and strong fibre, hence used to make long sheet of papers (Kaur et al., 2017).
3. Convenient source of high cellulose content.
4. Bamboo fibers produce soft raw material of paper making which is comparatively softer than recycled paper from any other timber products (Chen et al., 2021).
5. Such fibers possess high strength resulting in strong products of paper.
6. These fibers shows quick self degradation in environment, hence a safe disposal systems can be expected.
7. The plant in discussion is a fast growing grass on the earth. Some of the species shows growth rate nearly 28-40 cm/ day. After cutting of the culm, the part close to earth is left, it takes 6-7 months for the growth of new culm (Zheng et al., 2020).
8. Nearly 27,000 timber plants are deforested daily for the manufacture of toilet paper around the world. Bamboo can easily substitute other timber plants for production of pulp and thereby helping us to save trees and endangered vegetation (Pandey and Ojha, 2013).
9. Bamboos can be grown in depleted soil or with little water and helps to replenish soils by complementing macro as well as micronutrients, it also improves infertile areas. It plays an important role by protecting soil from erosion and retaining moisture owing to its peculiar rhizome (root) system.

XII. STEPS OF PAPER PRODUCTION

The leaves of bamboo plant and the tender pith present in inner part of stout bamboo culms are extracted, grinded and crushed. Treated cellulose mass is then dipped and drenched in an solution of 15 per cent – 20 per cent of aq. NaOH. The process is undertaken at temperature range of 20^{o}C to 25^{o}C for nearly 1-3 hours. This results in the formation of bamboo alkali cellulose. Cellulosic alkaline stuff is compressed to extract excess basic (NaOH) solution (if any). Alkaline cellulosic material is then dried for a day. In order to make it jelly like, nearly one-third of total carbon disulfide is complemented in alkali cellulose to sulfurize the compound. Leftover carbon disulfide is then separated out. The sodium xanthogenate (cellulose material) is the finally obtained. Further, NaOH is diluted and supplemented with sodium xanthogenate which makes a viscous mixture comprising nearly 5 per cent sodium hydroxide and 7 – 15 per cent cellulose. The viscous cellulosic content thus obtained is passed along a spinneret outlet with high pressure in a large vessel consisting dil. Acidic solution of H_2SO_4. The resulting mixture hardens the content of sodium xanthogenate converting it into complete cellulose matter. The obtained fiber is passed through the manufacturing facility of wet wipes. The system has got spun lace tools/ technique which thereby turns the fiber into slender, biodegradable sheets. The

Copyright © 2024 Authors

aforementioned sheets are produced by water jets of enhanced pressure. Paper manufactured is then dried and loaded into bulky rolls. (Kaur et al., 2017 and Chen et al., 2021)

Products of paper industry

XIII. BAMBOO – PLANT OF FUTURE WORLD

A systemic supply and value chain formulation starting with growers to end users need to be framed. On one hand, we need to focus on the elite quality production of bamboo plants on industrial scale, their periodic harvest, preservation, processing, product manufacture, marketing in coordinated and integrated manner. The team should focus on the research and development sector to produce superior clones to maintain uniformity in the raw materials.The records found that during the past almost forty years, the bulk supply from incompetent commercial ventures (in pulp and paper industry) has depreciated from 50 per cent to 18 per cent, however, the delivery of unprocessed bamboos rose to 63% which was 40% earlier (Tambe et al., 2020). The old and conventional bulk promotion of bamboo in construction,basketry etc., have been decreased, and new assured massive market is yet to beopened. This lag is leadingto reduction in demand of bamboo raw material. The phylogeny has recorded the recent trends which show greater than 80 per cent of the bamboo availability from forest has not been utilized. We advocate that prime huddles in extensive use of bamboo as bioenergy is its extensive utility in small and large scale industries. Moreover, bamboo will help us to generate employment by promoting ventures that enables creation of job and farmer incomes both.

XIV. ACKNOWLEDGEMENT

The author would like to acknowledge and give sincere gratitude to Prof. and Head of Department, Mrs. Bindu Singh for her invaluable guidance, advises and suggestions in the completion of this chapter. Author would also like to convey special thanks to Meena Singh, Mr. Sonu Kumar and Siddhi Singh for their extended help in collecting materials and continuous support throughout this journey.

REFERENCES

[1] Ashish Ranjan. “Bamboo Tissue Culture - Commercial Applications and Environment". Acta Scientific Agriculture 5.10 (2021): 12-14. DOI: https://actascientific.com/ASAG/pdf/ASAG-05-1061.pdf
[2] National Bamboo Mission. A guide 2021

Copyright © 2024 Authors

[3] Arun Jyoti Nath, Rattan Lal, Ashesh Kumar Das. "Managing woody bamboos for carbon farming and carbon trading". Global Ecology and Conservation 3 (2015): 654-663. DOI: https://doi.org/10.1016/j.gecco.2015.03.002
[4] Akinlabi, E.T., Anane-Fenin, K., Akwada, D.R. Applications of Bamboo. In: Bamboo. Springer, Cham. (2017): 179-219. DOI: https://doi.org/10.1007/978-3-319-56808-9_5
[5] Constro Facilitator. "Advantages and application of bamboo in modern design". 2020. DOI: https://constrofacilitator.com/advantages-and-application-of-bamboo-in-modern-design/
[6] C. N. HariPrasath and A. Balasubramaniam."Bamboo – The Poor man's timber".Journal of Agriculture and Rural Development. 44.11 (2017): 8-11. DOI: https://www.researchgate.net/publication/342040456_Bamboo_-_The_poor_man's_timber
[7] Zhiwei Liang, AndrásNeményi, GergőPéterKovács and CsabaGyuricza. "Potential use of bamboo resources in energy value-added conversion technology and energy systems". *GCB Bioenergy*. 15.8 (2023): 936-953. DOI: 10.1111/gcbb.13072
[8] M. Lobovikov, D. Schoene, L. Yping. "Bamboo in climate change and rural livelihood".Mitig. Adapt. Strateg.Glob. Change, 17 (2012): 261-276. DOI: https://doi.org/10.1007/s11027-011-9324-8
[9] V. Kleinhenz, D.J. Midmore. "Aspects of bamboo agronomy". Adv. Agron., 74 (2001): 99-153. https://doi.org/10.1016/S0065-2113(01)74032-1
[10] Zishan Ahmad, AnamicaUpadhyay, Yulong Ding, AbolghassemEmamverdian, and Anwar Shahzad. "Bamboo: Origin, Habitat, Distributions and Global Prospective".Biotechnological Advances in Bamboo. (2021): 1-31. DOI: 10.1007/978-981-16-1310-4_1
[11] Bioethanol production from bamboo (Dendrocalamus sp.) process waste. Mathiyazhakan Kuttiraja, Raveendran Sindhu, Preeti Varghese, Soolankandath Sandhya, Parameswara Bin od, Sankar Vani, Ashok Pandey, Rajeev Kumar Sukumaran. Biomass and Bioenergy, 59 (2013): 142-150. DOI: https://doi.org/10.1016/j.biombioe.2013.10.015
[12] Libo Lu. Research on the Innovative Application of Bamboo in Modern Product Design with the Aid of Computer Simulation Software. Journal of Physics: Conference Series. 1648 (2020). DOI: 10.1088/1742-6596/1648/2/022143
[13] M. ParvezRana, Sharif Ahmed Mukul, M. Shawkat Islam Sohel, Mohammad ShaheedHossainChowdhury, SaymaAkhter, M. QumruzzamanChowdhury, Masao Koike. Economics and Employment Generation of Bamboo-Based Enterprises: A Case Study from Eastern Bangladesh. Small-scale Forestry, 9 (2010): 41–51. DOI: 10.1007/s11842-009-9100-8
[14] S.K. PANDE and S. PANDEY.Bamboo for the 21st century.The International Forestry Review.10 (2), Special Issue: The Indian Forest Sector - Current Trends and Future Challenges (2008), 134-146. DOI: https://www.jstor.org/stable/43740330
[15] Van derLugt, P., & King, C. (2019). Bamboo in the Circular Economy: The potential of bamboo in a zerowaste, low-carbon future. (Policy Synthesis Report; Vol. 6).International Bamboo and Rattan Organisation (INBAR). DOI: https://pure.tudelft.nl/ws/portalfiles/portal/84146701/1578039902.pdf
[16] Anil Kumar,Arun Dwivedi, Prashant Baredar, Om Prakash. Bamboo as a complementary crop to address climate change and livelihoods – Insights from India.Forest policy and economics. 102 (2019): 66-74. DOI: https://doi.org/10.1016/j.forpol.2019.02.007
[17] National Bamboo Mission, operational guidelines. 2019.
[18] DOI: https://nbm.nic.in/Documents/pdf/NBM_Guidelines_New.pdf
[19] Dr. P. B. Nagarnaik, DineshBhonde, Dr. D. K. Parbat, Dr. U. P. Waghe. Physical and Mechanical Properties of Bamboo (DendrocalmusStrictus). International Journal of Scientific & Engineering Research, 5-1 (2014): 455-459. DOI: https://www.researchgate.net/publication/271829605
[20] Hossain M.F., Islam M.A. and Numan S.M. Multipurpose Uses of Bamboo Plants: A Review. International Research Journal of Biological Sciences. 4-12 (2015): 57-60. DOI: https://www.researchgate.net/publication/287199703
[21] Bal M.L., Singhal P., Satya S., Naik S.N. and Kar A. Bamboo Shoot Preservation for Enhancing its Business Potential and Local Economy: A Review. Critical Reviews in Food Science and Nutrition. 52 – 9 (2012), 804-814. DOI: 10.1080/10408398.2010.511321
[22] Panda H., Bamboo Plantation and Utilization. Handbook, Publisher: Asia Pacific Business Press Inc. (2011). DOI: https://www.niir.org/books/book_pdf/101182/niir-bamboo-plantation-utilization-handbook.pdf
[23] FALGUN BHELKAR, VISHAL V. SHUKLA, M. M. GUPTA, K. N. AGRAWAL and J. P. MODAK. A REVIEW ON BAMBOO AS THE SOURCE OF GREEN AND SUSTAINABLE ENERGY. International

Copyright © 2024 Authors

Journal of Mechanical and Production Engineering Research and Development (IJMPERD) 9 Special Issue (2019): 226-231. DOI: https://www.researchgate.net/publication/335927633

[24] Md. DaneshMiah and LutforRahman. Bamboo based small scale cottage industries in urban and rural areas of Bangladesh. International Journal of Forestry and Environmental Sciences. 2 – 1&2 (2001): 108-111. DOI: https://www.researchgate.net/publication/304462397

[25] PiotrBorowski. Bamboo as an innovative material for many branches of world industry.Annals of WULS Forestry and Wood Technology. 107 (2019): 13-18. DOI: 10.5604/01.3001.0013.7632

[26] PerminderJitKaura*, K.K.Pantb ,SantoshSatyaa , S.N.Naik. Bamboo: The Material of Future. International journal series in multidisciplinary research. 2 – 2 (2016): 17-24. DOI: https://www.researchgate.net/publication/298029730

[27] B. H. Kittur, K. Sudhakara, B. Mohan Kumar, T. K. Kunhamu& P. Sureshkumar. Bamboo based agroforestry systems in Kerala, India: performance of turmeric (Curcuma longa L.) in the subcanopy of differentially spaced seven year-old bamboo stand. Agroforestry system. 90 – 2 (2016): 237-250. DOI: 10.1007/s10457-015-9849-z

[28] Yulong Ding, AbolghassemEmamverdian, FatemehRanaei and Zishan Ahmad.Application of Bamboo Plants in Nine Aspects.The Scientific World Journal. 2020. DOI: 10.1155/2020/7284203

[29] UjwalSontakke, SantoshJaju. Green hydrogen economy and opportunities for India. IOP Conf. Series: Materials Science and Engineering. 2021: 01-13. DOI: 10.1088/1757-899X/1206/1/012005

[30] Ashok K. Pandey, VijayalakshmiOjha. Standardization of harvesting age of bamboo shoots with respect to nutritional and anti-nutritional components.Journal of Forestry Research. 24 – 1 (2013): 83−90. DOI 10.1007/s11676-012-0317-6

[31] Xiao Zheng, Shuyan Lin, Huajun Fu, Yawen Wan and Yulong Ding. The Bamboo Flowering Cycle Sheds Light on Flowering Diversity. 11 – 381 (2020). DOI: 10.3389/fpls.2020.00381

[32] Chin, K., Ibrahim, S., Hakeem, K., H'ng, P., Lee, S., and Mohd Lila, M. Bioenergy production from bamboo: Potential source from Malaysia's perspective," *BioRes.* 12 - 3 (2017), 6844-6867. DOI: https://bioresources.cnr.ncsu.edu/wpcontent/uploads/2017/06/BioRes_12_3_6844_REVIEW_Chin_IHHL_Bioenergy_Production_Bamboo_Source_Malaysian_Perspective_11308.pdf

[33] Göran Berndes, Monique Hoogwijk, Richard van den Broek. The contribution of biomass in the future global energy supply: a review of 17 studies. Biomass and Bioenergy. 25 – 1 (2003): 1-28. DOI: https://doi.org/10.1016/S0961-9534(02)00185-X

[34] Claudia DazaMontaño, Jan E.G. van Dam. Potential of Bamboo for Renewable Energy: Main Issues and Technology Options.Forest, Trees and Agroforestry. 2021. DOI:https://www.researchgate.net/publication/356149082

[35] Wan MuhdFarid Bin Wan Hamat. A thesis submitted in fulfillment of the requirements for the award of the degree of Bachelor of Chemical Engineering (Gas Technology). 2012. DOI: https://core.ac.uk/download/pdf/159182055.pdf

[36] Anh N. Phan,Snunkhaem Echaroj, Malee Santikunaporn. Supercritical ethanol liquefaction of bamboo leaves using functionalized reduced graphene oxides for high quality bio-oil production. Renewable Energy. 204 (2023) 848-857. DOI: https://doi.org/10.1016/j.renene.2022.12.110

[37] Supercritical ethanol as an enhanced medium for lignocellulosic biomass liquefaction: Influence of physical process parameters. Byung-In Sang, Steffen Brand a b, RatnaFrida Susanti, SeokKi Kim, Hong-shik Lee, Jaehoon Kim.Energy. 59 – 15 (2013): 173 - 182. DOI: https://doi.org/10.1016/j.energy.2013.06.049

[38] Haitao Li, Chen Chen, AssimaDauletbek, FengShen, David Hui, Milan Gaff, Rodolfo Lorenzo, Ileana Corbi, OttaviaCorbi and Mahmud Ashraf. Properties and Applications of Bamboo Fiber–A Current-State-of-the Art.Journals of Renewable Materials. 2021: 1-19. DOI: 10.32604/jrm.2022.018685

[39] N. Kaur, S. Saxena, H. Gaur, P. Goyal. A Review on Bamboo Fiber Composites and its Applications.International Conference on Infocom Technologies and Unmanned Systems (ICTUS'2017), Dec. 18-20, 2017, ADET, Amity University Dubai, UAE. DOI: https://www.researchgate.net/publication/323067941

[40] Sandeep Tambe, Suprava Patnaik, Anup Upadhyay, Advait Edgaonkar, Rekha Singhal, Jigyasa Bisaria, Pankaj Srivastava, Mohan Hiralal, Kailash Dahake, Abhishek Gawande, Pratik Surkar. Research Trends: Evidence-based policy for bamboo development in India: From "supply push" to "demand pull". Forest Policy and Economics. 116 (2020): DOI: https://doi.org/10.1016/j.forpol.2020.102187

Copyright © 2024 Authors