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Bamboo as an innovative material for many branches of world industry

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Abstract: The article presents bamboo as a material that can be used in many branches of industry. The widespread occurrence of bamboo, its rapid growth and very good physico-chemical properties make it a convenient and easily available material in many countries all over the world. Results of some preliminary research carried out in Ethiopia and Guinea show wide range of bamboo applications and the possibilities of its use in Polish conditions. Secondary research based on available sources indicates the promising direction of future development of the economy based on bamboo use.

Keywords: bamboo, industry, energy, climate

INTRODUCTION

Bamboo is the widespread term applied to a wide group of large woody grasses ranging from 10 cm to 40 m in height. They grow in the tropical and subtropical regions of Latin America, Africa and Asia, extending as far north as the southern United States or central China, and as far south as Patagonia. Bamboo also grows in the northern part of Australia (Fig. 1).

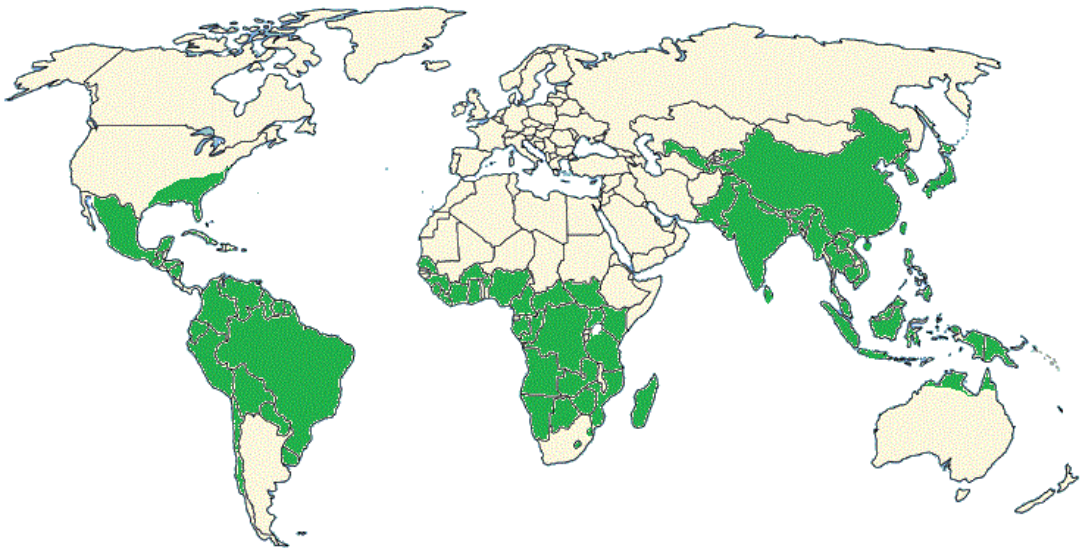

Figure 1. Map of bamboo growth around the world
Note: Dark colour indicates countries with active bamboo growth. Source: based on bambooimport.com

Bamboo is already in everyday use by about 2.5 billion people, mostly for fibber and food mostly in Asia. The subfamily *Bambusoidaea* consists of both woody and herbaceous bamboos with 1575 identified species in 111 different genera. However, bamboo may have a potential as a bioenergy or fibre crop for niche markets, although some reports of its high productivity seem to be exaggerated. Literature on bamboo performance is still scarce (in comparison with that on other materials), with most reports coming from various parts of Asia. There is little evidence overall that bamboo is significantly more productive than many other candidate bioenergy crops, but it shares a number of desirable fuel characteristics with certain other bioenergy feedstocks, such as low ash content and alkali index. Its heating value

is lower than many woody biomass feedstocks but higher than most agricultural wastes and residues, grasses and straws. Although non-fuel applications of bamboo biomass may be actually more gainful than energy recovery, there may also be potential for co-production of bioenergy together with other bamboo processing (Scurlock et. al., 2000).

Qualitative market research methods which include focus group studies, in-depth interviews and observational techniques (Belk 2008) were applied. In this study, the following market research methods were used: (1) observation, (2) primary research and (3) secondary research (Creswell 2009). The author carried out series of research listed above on site in Guinea and Ethiopia. Observations and primary research in Guinea were carried out directly within April–May and August–September 2015, whereas desk research were realized as on-going study. A research project in Ethiopia was realized in September 2014 and May–June 2016. In Guinea-Conakry bamboo and rattan stems are booming in the market of Conakry (capital city) and some of the country's major cities. Mainly bamboo is used to produce poles, stakes and round woods. Bamboo is used for a wide variety of uses: roofing, scaffolding, dry tapades, sheds, rustic bridges, barbed wire stands, etc. Currently there is no precise knowledge about the annual production and consumption of this product (FOSA, 2001).

Ethiopia has over 60% of Africa's natural bamboo, but it has never really been used. Ethiopia has an estimated one million hectares of natural bamboo forest, the largest in the African continent. It is green gold and should be given special attention. There 2 bamboo species considered to be native of Ethiopia: *Oxytenanthera abyssinica* (lowland bamboo) and *Yushania arundinaria alpina* (highland bamboo). In 2015, Ethiopia was the 9th largest exporter of bamboo raw materials in the world (King, 2019).

BAMBOO INLUENCE FOR THE CLIMAT PROTECTION

Bamboo is particularly suitable as a tool for carbon sequestration. Bamboo's carbon sequestration properties have been studied in Mexico and China, where it naturally forms wild forests. The most effective solution to climate change is the abatement of CO_2 (carbon dioxide) emission by reducing our dependence on fossil fuels. As a result of its unbelievable system of roots, bamboo continues to grow irrespectively after being harvested. In contrast to most other plants bamboo are low cost plants, in meaning that they don't require fertilizer, chemicals or pesticides in order to grow. Bamboos can be called self-care plants because they utilise their own fallen leaves to supply them with nutrients when disintegrated into the soil. Due to its incredibly rapid growth cycle and the variety of areas in which it is able to grow, bamboo is also extremely cheap. The first days of bamboo growing is shown in Figure 2.

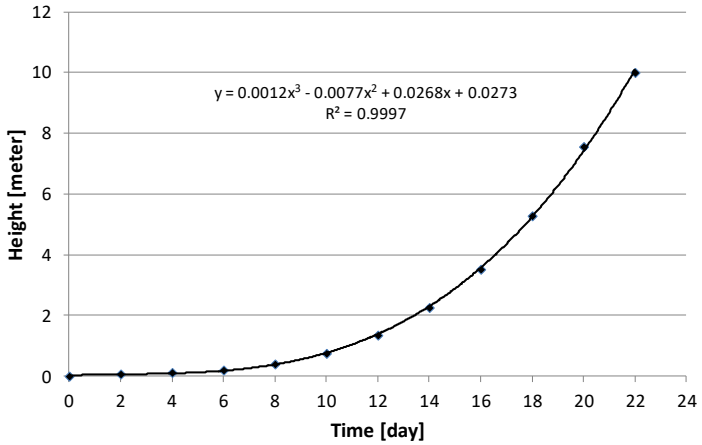

Figure 2. The dynamics of bamboo growth. Source: https://lewisbamboo.com/growth-chart-of-bamboo/

The dynamics of bamboo growth is characterised with rapid increase in the second and third week. It is observed that during the first 12 days a new bamboo can grow about 6 cm per day, 37 cm in another 4 days, while the third week brings a daily growth of about 80 cm. Such rapid growth requires the grass to absorb large quantities of CO_2, meaning that its cultivation as a building material would help reduce the rate of climate change. Over a period of 30 years, bamboo plants and products can store more carbon than certain species of trees. This is mainly because bamboo can be harvested regularly, creating a large number of durable products which store carbon over several years, in addition to the carbon stored in the plant itself. If the world planted an additional 10 million hectares of bamboo on degraded lands, it is estimated that bamboo plants and their products could save over 7 gigatons of CO_2 (carbon dioxide) within 30 years. That is more than 300 million new electric cars could save in the same time period. Importantly, this statistic does not include the emissions saved by substituting aluminium, concrete, plastic, or steel for bamboo. Bamboo has huge strength and flexibility making it an ideal building and construction material in many parts of Africa, Asia and Latin America where it is native. Bamboo has a tensile strength greater than that of mild steel, and withstands compression twice as well as concrete, making it a ready replacement in roads, drainage pipes, housing and even wind turbine blades (King, 2019). In table 1 basic strength properties for bamboo and other materials were presented.

Table 1. Mechanical properties of bamboo, spruce wood and steel

Properties [kN/cm^2]	Bamboo	Spruce wood	Steel
Modulus of elasticity	2000	1100	21000
Compressive strength	6.2–9.5	4.3	14.0
Tension strength	14.8–38.4	8.9	16.0
Bending strength	7.6–27.6	6.8	14.0
Shear strength	2.0	0.7	9.2

Source: GUTU, T. A study on the mechanical strength properties of bamboo to enhance its diversification on its utilization. *International Journal of Innovative Technology and Exploring Engineering*, 2013, 2.5: 314–319.

CHALLENGES AND OPPORTUNITIES FOR BAMBOO PRODUCTION IN POLAND

Bamboo is a diverse plant that easily adopts to different climate and landscape condition. It can grow in a wide variety of soil types, different temperatures and humidity conditions. For Poland's climate, there are dozens of varieties of cold hardy bamboo to consider. Most of them belong to either the *Phyllostachys* or the *Fargesia* group (genus) of bamboo. *Phyllostachys* is one of the most prevalent genera of bamboo, primarily native to China and including about 50 distinct species.

Almost every species of *Phyllostachys* is a fast spreading runner (with an aggressive rhizome root system), and many of them are cold hardy, down to minus 15–20 ^{o}C. Among the varieties which can be grow in Poland are the following: Incense Bamboo *(Phyllostachys atrovaginata),* fine-leaved *Phyllostachys parvifolia, and* Ink-finger (*Phyllostachys nuda).* *Fargesia* is another major genus of bamboo, also indigenous to China and southeast Asia. Unlike *Phyllostachys*, the *Fargesia* bamboos are chiefly dense growing clumpers. This and their cold hardiness have made many varieties of *Fargesia* very popular among gardeners. In Poland, the following varieties will cope well with the climate: Blue fountain bamboo (*Fargesia nitida),* umbrella bamboo (*Fargesia murielae),* and Clumping bamboo, also called "non-running bamboo" (*Fargesia rufa).*

It is worth noting that in Poland with a transient climate (between maritime and continental climate) there are very clear differences in wintering conditions for plants in individual regions. In the Pomeranian zone and in the western part of the country, down to Lower Silesia, the conditions for growing a more sensitive plants are favourable, in the majority of central Poland – moderate, and in the Podlasie province, Lublin, North East part of the Masovia province, Mazury and in the mountains – difficult (see Fig. 3).

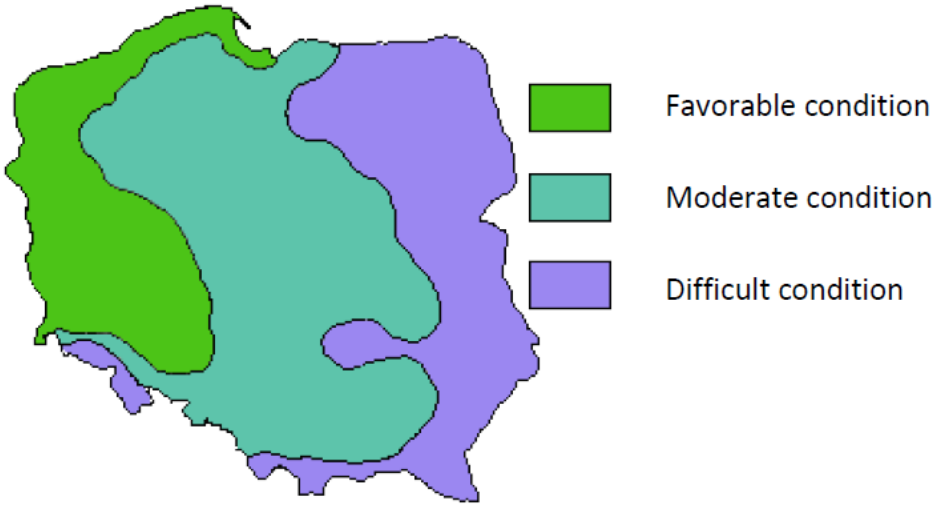

Figure 3. Conditions for wintering sensitive plants in Poland
Source: Hoser Sz. Fargesia www.ragesia.pl

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BAMBOO AS A RENEWABLE SOURCE OF ENERGY PRODUCION

Bamboo may, indeed, have potential as a bioenergy or fibre crop for niche markets. Bamboo has good fibre quality for paper-making, and it shares a number of desirable fuel characteristics with certain other bioenergy feedstocks, such as low ash content and alkali index. The principal ash-forming constituents in bamboo are silica (SiO_2) and potassium (K_2O). It also contains calcium (CaO), chlorine (Cl) and magnesium (MgO) (Kumar, Chandrashekar, 2014). To evaluate the quality of biofuels, it is important to know the content

of sulphur and chlorine. A high content of these elements is causing corrosion and contamination of boilers and increased emissions of Cl_2, SOx and HCl.

Since the plant's health is improved by cutting, bamboo can be re-harvested every three years without any harmful effects to the environment. With the average 500-year life span of a redwood tree, a bamboo plant could be harvested and regrown more than 150 times. Bamboo biomass energy has great potential to be an alternative for fossil fuel. Biomass of bamboo comes from culms, branches and leaves. Bamboo biomass can be processed in various ways (thermal or biochemical conversion) to produce different energy products (charcoal, syngas and biofuels), which can be substitutions for existing fossil fuel products. Bamboo biomass alone cannot fulfil all the demand for energy. It needs to combine with other sources to best exploit their potential and provide sustainable energy supply (Le, Truong, 2014). Bamboo biomass is characterized by a relatively higher heating value than other sorts of biomass, which means it is a good material for direct combustion (e.g. co-combustion in thermal power plant). Many projects on bamboo energy are operating or being implemented all over the world. In African countries, bamboo biomass projects are very popular and mostly used to replace firewood or produce charcoal for domestic use.

BAMBOO AS A ADDITIONAL MATERIAL FOR BIODEGADATION

In Europe, much research of biodegradable materials is conducted. In some materials, pine wood dust is added to change the properties of biodegradable materials (Żelaziński et al., 2019) but also bamboo can improve the results and properties of materials. The biocomposite samples reinforced with raw bamboo fibre and treated showed different degree of biodegradation with weight loss after 30 days of analyses. In general, the biodegradability studies showed that raw bamboo fibre and the biocomposite reinforced with this fibre were more resistant to the action of the microorganisms due to a higher contents of lignin and hemicelluloses. In the plant tissue, lignin acts as a reinforcement, just like cement, between the fibres (Junior et al., 2014).

CONCLUSION

In Europe, specifically in Poland, the cultivation of, but above all, the production of bamboo can achieve a high level of innovation. Europe today has technological advances in some areas of economy and industry such as the micro-propagation, the selection of superior genotypes using molecular markers and biomass gasification for energy production. Any widespread bamboo production implies an industrial use. In a short term perspective, bamboo can be produced and used for soil stabilisation, riparian improvement, wind protection, poles for viticulture or fruit trees, small sticks for horticulture. At medium term bamboo can find utilisation for vannerie and furniture production. Also arts and craft could be considered as an ideal utilisation for everyday equipment. In a long term perspective, bamboo utilisations for industrial purposes require supplementary analyses and tests. Two of them seem of major importance: determination of calorific value for gasification and defibration for the production of boards or biodegradable textiles.

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Streszczenie: *Bambus jako innowacyjny materiał dla wielu gałęzi przemysłu światowego*. W artykule przedstawiono bambus, jako materiał, który można wykorzystać w wielu gałęziach przemysłu. Powszechne występowanie bambusa, jego szybki wzrost i bardzo dobre właściwości fizykochemiczne sprawiają, że jest to materiał wygodny i łatwo dostępny w wielu krajach na całym świecie. Wstępne wyniki badań przeprowadzonych w Etiopii i Gwinei pokazują szerokie możliwości wykorzystania bambusa i możliwości jego implementacji w polskich warunkach. Badania wtórne oparte na dostępnych źródłach wskazują na duży potencjał wykorzystywania bambusa w wielu branżach gospodarki.

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