III. GUEST ARTICLES

„Ante Portas – Security Studies”
2022, No 1(18)
DOI: 10.33674/120229

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BIOCHAR – AN INNOVATIVE PRODUCT AND A CHANCE FOR SUSTAINABLE DEVELOPMENT

Abstract: *Biochar is becoming the most desirable product to stop global climate change. Climate changes, soil degradation, and increasing water and atmospheric pollution make it necessary to search for new, cheaper, and more effective solutions. Thanks to the use of this raw material in modern agriculture, the environment is regenerated, producers reduce production costs while increasing yields, and consumers can enjoy food free from harmful pollutants. It is a perspective for a better, more sustainable use of the earth's resources, which we finally have a chance to do as it deserves.*

Keywords*: biochar, CO_2 sequestration, sustainable development*

Introduction

According to the idea of sustainable development, society should live in such a way that it takes into account the costs of its decisions. Sustainable means development, equal opportunities, counteracting marginalization and discrimination, and improving the quality of the natural environment, e.g., by limiting the harmful impact of production and consumption on the environment and at the same time protecting natural resources. The word innovation, on the other hand, comes from the Latin *innovatis*, which means renewal, creating

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something new. In Poland, this word is defined as the introduction of something new, a newly introduced thing, novelty, or reform.

This term was introduced to economics by Joseph A. Schumpeter. He was the founder of the Econometric Society and the author of the well-known theory of economic growth and business cycles induced by breakthrough innovations, the theory of the progressive transformation of capitalism into socialism, and a historian of economic thought.

Currently, if a company wants to have continuous and sustainable development, it must constantly expand what it offers. The competitiveness of modern enterprises depends on the introduction of innovation. Enterprises whose goal is constant development must cooperate in the field of innovation with companies from the same industry, other industries in the country and abroad, with universities, R&D institutes, including laboratories, companies intermediating in the transfer, and financing of innovations, with clusters, science and technology parks, representatives of regional, local and self-government authorities and other participants of the innovative environment[2]. For innovation to be successful, it is necessary to closely integrate various departments of the organization. Technical specialists responsible for the design and technology of the new product must cooperate with specialists in economics, management, and finance. The globalization of markets and the accompanying increase in competition, changes in consumer lifestyles and new market challenges that are constantly emerging as a result of socio-economic changes, contribute to the treatment of various forms of innovation as a fundamental and prospective challenge for all participants of this process[3].

The production of biochar is part of the scheme offered and recommended by the UN and the European Union for the full management of biomass residues for the production of biochar, which becomes the main product of the sustainable development of civilization. Considering the high usefulness of biochar, it can be confirmed that the results of research conducted by various natural institutes in the country and Canada, including the Research Institute of Pomology in Skierniewice (prof. Sas), the Institute of Life Sciences in Wrocław (prof. Pietr), the Institute of Agriculture in Krakow, the University of Life Sciences in Poznań, Lublin, Dalhousie University in Halifax, Canada and others on biochar confirm that the use of biochar improves the yield of many vegetables, plants and trees, prevents the development of moulds and fungi, is a great addition to animal foods, etc. as well as for construction as an additive to concrete and plaster mortars, not to mention that it is a great renewable fuel

[2] R. Włodarczyk, *Działalność Innowacyjna Polskich Przedsiębiorstw*, "Zeszyty Naukowe Politechniki Częstochowskiej Zarządzanie", 2017, No. 25, Vol. 2, p. 120.

[3] B. Sojkin, T. Olejniczak, *Innowacyjność produktowa przedsiębiorstw na rynku artykułów żywnościowych*, "Konsumpcja i Rozwój", 2012, No 1, p. 130.

(Regulation on renewable fuels of 2018) for heating, energy, but also use by individual customers as an emission-free fuel for fireplaces, stoves, and also for barbecues.

Ecological safety problems

The problem of forest biomass management. Biomass residues resulting from planned logging and biological forest cleaning are powerful source of renewable energy. The average yield of this biomass can be up to 5 Mg of dry matter per hectare of forest. Until recently, Polish law did not allow for this biomass to be used for energy production. Currently, in the era of an energy crisis, this type of biomass can become an excellent source of biofuel production. Raw biomass from forest residues is also not an ideal substrate for energy processes, due to the high moisture content and significant content of harmful substances, e.g. chlorine for combustion installations.

In this situation, it is advisable to use an innovative solution to process forest biomass into a product that will be friendly as an addition to be used in various branches of the economy, including for agricultural and energy purposes.

The problem of management of residues from poultry and livestock farms. Biomass residues from poultry and animal breeding (chicken and manure) are a reservoir of minerals necessary to supplement the soil with nutrients. Even 50 years ago, it was practically the only fertilizer used in small (up to 10 ha) farms. However, this fertilizer poses biological and veterinary problems. To use manure and dust on a large scale, and at the same time to prevent this unfavourable phenomenon, an innovative technology of auto thermal carbonization of this type of biomass can be used. Comparative tests (at IUNG Puławy) of samples of manure from cow farms and biochar obtained from this manure show comparable nutritional values, much lower content of heavy elements than allowed in artificial fertilizers, and no Salmonella bacilli or eggs of intestinal parasites were found in the biochar sample.

The obtained biochar can therefore be freely used in agriculture without the risk of contamination to animal life or the environment.

After processing hemp into hemp products, about 10 tons of hay shives and straw remain**.** Currently, around 7.000 tonnes a year of hemp residue, from production, remains unmanaged. Modern installations can already produce biochar and renewable heat.

The problem of costly regeneration processes of planting forest resources. A number of studies conducted since 2010 in various agricultural institutes in the country (e.g. Research Institute of Pomology in Skierniewice, IUNG Puławy, University of Agriculture in Wrocław and Kraków), as well as numerous studies around the world, indicate that biochar accelerates the

process of initial growth of tree and shrub seedlings and also increases annual growth and fruiting in later years. Research and experience show that the use of biochar during the production of seedlings shortens the seedling production time from three to two years.

Autothermal processing of biomass left in the forest after felling trees, the result of biological cleaning of forests, biomass residues from agricultural production, manure processing from poultry and cattle breeding, and straw and hemp shives, into an innovative product like biochar, improves the condition of agricultural production and creates a raw material for construction, light industry and in feed. It will reduce the putrefaction process in Poland by about 8.800.000 tons of biomass each year and, consequently, produce about 1.500.000 tons of biocarbon per year. Using it in industry or agriculture (sequestration) we will reduce CO_2 emissions to the atmosphere by about 4.000.000 tons/year.

The problem of low-quality soils. The degradation of arable soils in Poland is a progressive process and covers an increasing area of agricultural land. These phenomena are the result of improper agricultural management in previous years when emphasis was placed on the use of artificial fertilisers. The high degree of degradation and acidification of soils in fruit crops in Poland makes it necessary to use environmentally friendly organic fertilizers that can be used in organic farming. The most important goal in organic farming should be to maintain soils in a high culture by selecting ecological methods of fertilization. The recommended method is natural nodules. In Poland, weak and very weak soils occupy over 50% of the country's territory. These are mainly soils developed on sands of low and medium loam, characterized by a low content of humus (1-2%), low sorption and water capacity. Cultivation on this type of soil is unfavourable in many respects. Firstly, there is a need to increase the consumption of means of production, mainly artificial fertilisers. Secondly, the cultivation of more profitable crops such as canola, wheat and maize can be very unreliable, especially in years with insufficient rainfall. This creates a complicated situation for a country that relies heavily on agricultural production. Possibilities to improve the condition of soils are very limited, in fact, for the last hundred years we have been dealing with their gradual degradation. A manifestation of this is the content of organic carbon in soils, which, according to most scientific studies, has fallen by half. Supplementing the soil with biochar gives a real chance to improve the condition and structure of the soil. The conducted research shows that the addition of 2 Mg of biocarbon per hectare for the next five to ten years (depending on the quality of the soil) will allow the organic carbon to be restored to the state it was in 100 years ago.

Production of High-Quality Bio-Carb Using Innovative Technology in the Industry

One of the basic conditions for the competitiveness of an organization is innovation, understood as a process of continuous change, contributing to a much better functioning of the entire organization or its unit, both internally and concerning its environment[4]. In the management literature at the end of the last century, it was emphasized that innovation is always a response to the needs of the market, so the company must always be close to the market, orientate to the market, and in fact, be inspired by it[5].

Global convergence is even more about technology and means of production. The best solutions spread rapidly. Those who do not use them are simply eliminated by the competition because their products do not meet the new standards of quality, durability, functionality, aesthetics, etc.[6]. The future is to redefine how coal is used, remodelling the management of residual materials and promoting an innovative supply network.

Striving to meet the constantly growing demand for all forms of energy with new or improved technologies is the reason for modifying the applicable legal and economic regulations. The opposition to the requirements to increase energy and economic efficiency by increasing the intensity and scale of production and the requirements of environmental protection, maintaining biodiversity and the use of areas with limited food usefulness (ILUC – Indirect Land Use Change), led to the adoption by the EU of the RED (Renewable Energy Directive) and FQD (Fuel Quality Directive)[7].

One of the products that should become the most important product of our civilization for the sustainable development of our planet is biochar. The vision for the future is upcycling (a form of secondary processing of waste, which results in products of higher value, treated as valuable raw materials) of bio-waste to create a valuable carbon storage option and support the development of a circular bioeconomy.

Biochar is a product of thermal, anaerobic processing of plant biomass, residual waste from sawmilling activity, waste from the vegetable and fruit industries, municipal wastewater treatment residue, etc. The world produces over 150 million tons of this type of biomass residue, annually. Until now, these residues in the main mass are decaying, increasing the production of carbon dioxide and greenhouse gases every year. The use of this residual waste

[4] B. Mikuła, *Zachowania organizacyjne w kontekście zarządzania wiedzą*, Kraków 2012, p. 63.
[5] P. Drucker, *Innowacje i przedsiębiorczość. Praktyka i zasady*, Warszawa 1992, p. 42.
[6] A. K. Kozmiński, *Zarządzanie. Teoria i praktyka*, Warszawa 2002, p. 564.
[7] A. Roszkowski, *Biomasa i bioenergia – bariery technologiczne i energetyczne*, "Problemy Inżynierii Rolniczej", 2012, Vol. 3(77), pp. 79-100.

for the production of biochar will reduce the emission of these harmful gases into the atmosphere and at the same time will contribute to the production of approximately 20 million tons of biochar.

Biochar acts as a soil conditioner, which, once ploughed, has an effect for decades. Biochar increases soil fertility by stimulating biological activity[8].

The concept of developing a society's agricultural economy with climate in mind should take into account the sequestration (retention) of carbon dioxide by:

1. The action of plants as carbon 'pumps' (assimilation),
2. Replenishment of the carbon element in the soil,
3. Use of rapidly renewable biomass for the production of energy and raw materials.

Biochar is an ideal product that meets these criteria. To restore a sufficient amount of carbon elements to the land, approximately five tons of biochar should be dosed annually for five to ten years per hectare. It is a retention (*sequestration*) of about 10 tons of carbon dioxide per hectare of land. If we managed to apply 10 million tons of biochar to the earth annually, we would stop the emission of about 20 million tons of carbon dioxide. Modern technologies will create a solution for storing carbon dioxide in the form of a renewable resource with a negative carbon balance.

Renewable fuels, especially biomass: straw, waste wood, chips, sawdust, hemp shives, specially cultivated energy plants and animal biomass are gaining more and more important for energy purposes. Their combustion significantly reduces NO_2 and SO_2 emissions and, unlike fossil fuels, does not increase the concentration of carbon dioxide in the atmosphere, therefore they do not contribute to an increase in the greenhouse effect[9].

Closing the mineral cycle will result in:

1. Increasing the efficiency of nutrients and water,
2. Recycling of plant nutrients,
3. Minimization of nutrient losses.

Biochar also fulfils its task in this compartment, when added to the ground as a porous material, it absorbs minerals, stores them, and retains water. Each grain of biochar stores about 5 times more water than it weighs. During the growing season, plants absorb only as much biochar from the grains as the plant needs, minerals, and water.

Stabilization of the ecosystem occurs through:

1. Promoting biodiversity,
2. Compost humus, biochar,

[8] J. Siuta, G. Borowski, *Systemy ochrony i odnowy biologicznie czynnej powierzchni ziemi w Polsce*, Lublin 2019, p. 286.
[9] J. Gładki, *Biowęgiel szansą dla zrównoważonego rozwoju*, Sędziszów 2017, p. 46.

3. Creating a microclimate,
4. Forest plants, cultivation, planting systems,
5. Reduction of pesticides.

Biochar has all the features that allow it to meet the above requirements.

In 2021, a Polish Canadian INNOVATIVE COMPANY was founded, which based on its patent designed installations for the production of biochar. This innovative company has designed a containerized Autothermal Carbonization Installation to process plant biomass residues resulting from logging and biological cleaning of forests, as well as biomass residues from agriculture, including hemp, and waste generated from poultry, pig, cattle, and fur farms.

Today, we know, thanks to numerous scientific studies, that the use of biochar as a component that improves the quality of soils gives us significant benefits both for them and for the environment. Biochar has a highly porous structure with good sorption properties. Biochar is an excellent medium for the transfer and gradual release of nutrients, which then accumulate in the plants and ultimately reach the primary consumers, which in this case is us. In addition, biochar promotes the development of beneficial microorganisms, whose metabolic products are also necessary at all trophic levels (from plants to animals). In addition, when compared to many other soil supplements, biochar does not interfere with the activity of enzymes in the soil, thanks to which the nutrient cycle remains intact over time. Research at Dalhousie University, in Canada, indicated that biochar sorted to 1mm and unsorted biochar created a favourable substrate with a better water ratio and better interaction with plant roots. Thus, the improved properties of the growing medium include available nutrients for the plants and improvements in physical properties such as porosity and water-holding capacity, which in turn improves the growth rate of the plants[10]. The alkaline reaction of biochar in the soil, together with the lowered pH, increases the bioavailability of minerals, e.g. zinc, magnesium, potassium, as well as nitrogen and nutrients.

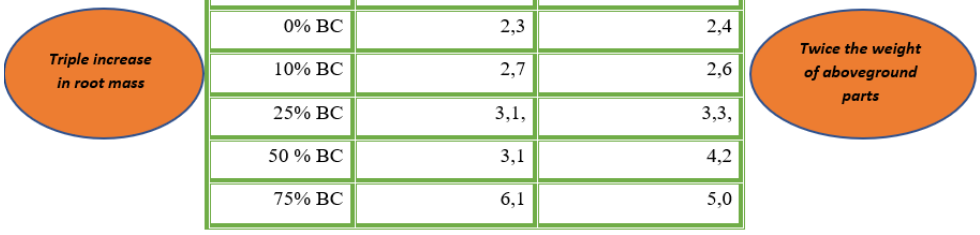
Sample conclusions from the research of biochar as a soil improver:

1. Reduced the number of plant pathogens,
2. Increased the water status of soil and plants,
3. Increased the root, leaf, and fruit system,
4. Accelerated the production process of seedlings of fruit trees, but also of forest trees,
5. Potential fertilizing effect: Possible source of nutrients for plants (Ca, Mg, K, P, Zn, Cu, Mn, Fe, B and others).

[10] L. Abbey, R. Saleh, *RDA Atlantic Biochar Particle Size Effect on Plants*, Truro 2021.

In the use of biochar in greenhouse production, a clear increase in the size of the root structure and the above-ground plant was observed along with the increase in the share of biochar in the substrate[13] (Figure 1).

Figure 1. An increase in root size and parts of the plant above-ground, concerning increases of biochar (BC) in the substrate



	Root	Aboveground parts
	g/plant	kg/variant
0% BC	2,3	2,4
10% BC	2,7	2,6
25% BC	3,1,	3,3,
50 % BC	3,1	4,2
75% BC	6,1	5,0

Source: A. Medyńska-Juraszek, I. Ćwieląg-Piasecka, M. Dębicka, P. Chohura, C. Uklańska-Pusz, W. Pusz, A. Latawiec, J. Królczyk, *Possibility of using biochar in agriculture, horticulture and reclamation*. 1st Conference *Biochar in Poland: science, technology, business,* May 30-31, 2016, Serock, Poland.

A very useful role is played by biochar as an addition to animal feed, reducing susceptibility to digestive system diseases, absorbing dioxins from the body, purifying meat, and limiting the excretion of (greenhouse) gases.

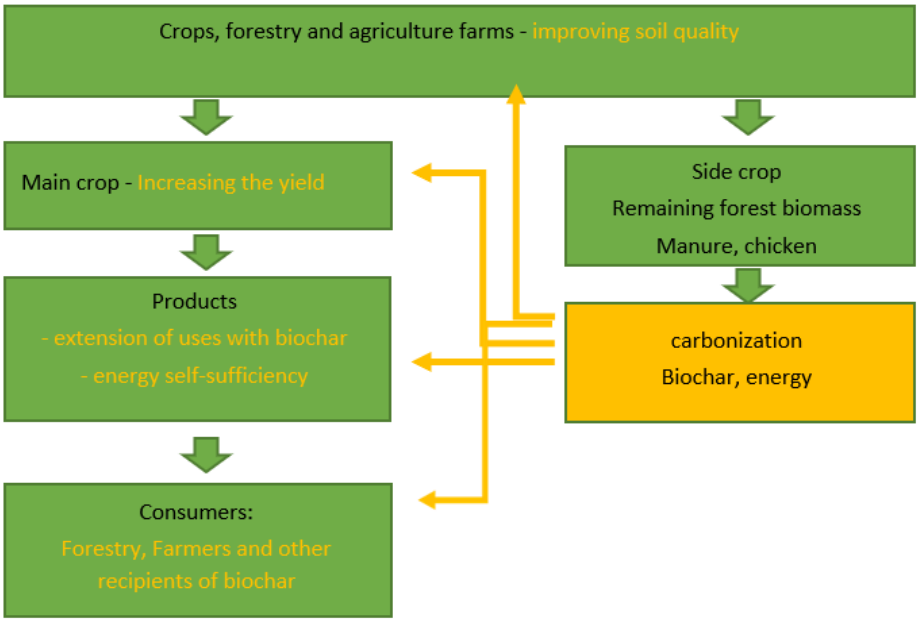
Examples of conclusions from the use of biochar in construction:

1. In addition to external insulating plasters,
2. In addition to masonry mortars during the renovation of historic buildings,
3. In addition to the supplementary layer in historic buildings.

In many unsuccessful renovations or repair procedures, it has been documented that neither pure lime mortars nor cement mortars are effective in carrying out permanent repairs of walls loaded with moisture and salts. Therefore, based on the information available in the literature on renovation works and supplementary mortars, biochar was selected as the basic component of the designed cement mix[11].

[11] D. Tokarski, *The impact of the supplementary layer with the addition of Biochar on the thermal and mycological properties of partitions in historic buildings (doctoral dissertation)*, Białystok University of Technology, Białystok 2019, pp. 7-15; E. Wojnicka-Szyc, *The Polish Innovative System from the Perspective of Enterprises*, Gdańsk 2004, p. 128.

Figure 2. Integration of the Carbonization Process into the Bioproduct Production Cycle



Source: own source.

Work on the development of modern biochar production technologies has been ongoing in Poland and around the world for 15 years. For over 10 years, research work on the use of biochar has been carried out. We can see that this is a new, little-known product. Among the obstacles hindering the development of innovative forms of using biochar in companies is the lack of sufficient information and knowledge about biochar production technology, lack of knowledge about the results of research on the properties of biocarbon, and lack of knowledge about the biochar market. The use of innovative technologies in the form of biochar as a soil conditioner will also increase the size of the cultivation area on inferior soils that are not used for agriculture, including for food production. Innovation policy in the European Union is currently gaining particular importance. In the era of knowledge-based economies, innovation and innovation policy must have an impact on all policy areas. This is the so-called 'third-generation innovation policy', which recognizes the central importance of innovation for all aspects of economic life. It is important to disseminate knowledge about innovative forms of development and access to the research database.

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