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1.2 THE BIOMASS USE TO OBTAIN HIGH-PURITY CARBONACEOUS MATERIALS

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Among the renewable sources, biomass is a promising resource since it is abundant and is the neutral nature of carbon. The term of “biomass” embraces the biodegradable component of products, wastes and residues from agricultural sources (including vegetable substances and animal substances), forestry and the products of related industries, including fish and aquaculture, as well as biodegrading fractions of wastes, including industrial and municipal wastes of biological origin [1].

The biomass resource can be considered as an organic substance, in which the energy of sunlight is stored in chemical bonds. When the bonds between the elements adjacent to carbon, namely, hydrogen and oxygen molecules are broken, for instance, via combustion, these substances release their stored chemical energy. With regard to the European Biomass Association, AEBIOM (currently Europe Bioenergy¹), bioenergy will show stable growth rates by 2020 (Fig. 1). According to the forecasts, the consumption of biomass for heating will increase to 90 ktoc. It is expected that receiving heat for heating will remain the leading issue on bioenergy market. Moreover, the usage of biomass will grow to about 20 ktoc in the industry of electricity generation and 29 ktoc for biofuels for transport.

The main goal of Bioenergy Europe is to develop a sustainable bioenergy market based on fair business conditions. Bioenergy Europe is a non-profit international organisation founded in Brussels in 1990, which brings together about 40 associations and 90 companies, as well as academic and research institutes from all over Europe. Bioenergy Europe is the main organisation, which also includes the European Pellet Council (EPC), the European Industry of Pellet Suppliers (EIPS) and the International Biomass Torrefaction Council (IBTC).

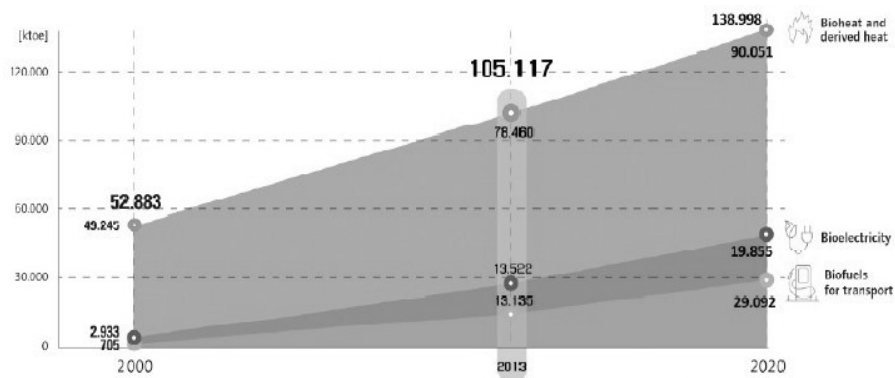


Fig. 1. Biomass Consumption for Bioenergy [5]

It is worth noting that from all European countries only the United Kingdom has adopted the most stringent requirements for the reduction of greenhouse gas emissions within governmental projects which employ solid and gaseous biofuels [4].

Solid biomass and biogas [6] requirements have been expanded and are mainly based on sustainability criteria for biofuels and biofuels liquids.

Thus, the biofuels shall not be made from the raw materials obtained from land with high carbon stock:

- wetlands, namely the lands that are permanently or during a significant part of the year covered or saturated with water;
- lands covering more than one hectare with trees above five meter high and a forest cover of more than 30 % or trees capable of reaching these thresholds in situ;
- lands covering more than one hectare with trees above five meters and a forest cover from 10 % to 30 % or trees capable of reaching these threshold areas in situ.

Further, there are several restrictions, for instance, no biofuels allowed to be made from the biomass which raw materials have been harvested from the lands as follows:

- peat lands used to be in January 2008, unless it is proven that the cultivation and collection of the dedicated raw material do not involve drainage of previously undiluted soils;
- the lands of the countries with national and/or subnational laws applicable in the harvesting area as well as the areas under monitoring and surveillance systems that ensure the observance of certain conditions: 1) harvesting should be carried out in accordance with the terms of the harvest permit within the limits of the officially certain boundaries; 2) there is a reforestation of areas where biomass collection takes place; 3) areas of high conservation value, including wetlands and peatlands; 4) the impact of the forest operation on the quality of the soil and biodiversity is minimized, and the harvest does not exceed the long-term production capacity of the forest.

The agricultural raw material has to be obtained in accordance with the requirements and standards with regard to the provisions of (EC) 73/2009 on the establishment of common rules for direct support of the farmers under the common agricultural policy and the establishment of certain support schemes for farmers and in accordance with the minimum requirements for good agricultural and environmental conditions [1].

Additionally, biofuels and biofuels liquids should not have been obtained from the raw materials derived from lands that are characterised by biodiversity, namely lands that have at least one of the following statuses:

- primary forests and others covered with forest vegetation of the earth, namely forests and other wooded local breeds where there are no clearly visible signs of human activity, and ecological processes are not significantly violated;
- designated areas (by law or by the competent authorities for the protection of nature, or for the protection of rare, extinct, endangered ecosystems, or species recognised by international agreements or included in the lists drawn up by intergovernmental organisations or by the International Union for Conservation of Nature);
- biodiversity grassing, that is natural, namely pasture, which would remain grassing in the absence of human intervention and maintain a natural species composition, ecological characteristics and processes; or unnatural, namely pasture that ceases to be pastures in the absence of human intervention and which are rich in species and are not degraded.

Cheaper and more environmentally friendly or even harmless as compared with non-renewable carbon, biomass is a real alternative to fossil fuels in the production of high-carbon materials. Thus, biomass is readily available raw materials with a low content of mineral components and sulphur. The significant advantage of biomass is its multivariability, both in terms of transformation technologies and end-use methods.

Biomass can be applied in various processes without complex preliminary technological operations. The application of biomass does not cause an increase in the CO₂ balance in the atmosphere during combustion; moreover, when biomass and its products are used in production instead of fossil fuels, there is a negative CO₂ balance for the life cycle of the final product. As a good instance can serve metallurgical final products contained biomass derived carbon, provide negative CO₂ impact.

By nowadays, the technologies to utilize biomass with the objective to obtain motor fuels, fuels for chemical industry and reducing agents for metallurgy have already been developed and they are currently being improved.

Biomass has been and remains to be of a great scientific interest as it is a raw material for the production of high-purity carbonaceous materials, which are widely used for manufacturing modern power sources, carbon-carbon products, products with special thermal, physical, physical and chemical, and sorption properties, etc. In their turn, high-purity carbonaceous materials can be obtained, mainly, by artificial ways as a result of thermal action on carbon-containing raw materials.

The purpose of the current publication is to consider the particularities of the processes that allow obtaining high-purity carbonaceous materials from the biomass, as well as the properties of the obtained materials.

Previous studies [7] of different types of biomass (brushwood, coniferous wood, sunflower husks, walnut shell, straw, corn stalks) allow the conclusion that the most promising raw material for obtaining high-purity carbonaceous materials is the walnut shell.

The main criteria acting in favour of this raw material is that after pyrolysis it shows relatively low residual ash content (3.7 %), almost complete absence of sulphur, the relatively high content of carbon and good mechanical properties that ensure the material's resistance to abrasion during fluidization.

Further, the original properties of the walnut shell are characterized by the following range of particle sizes: lengths of 1.9–29.4 mm, widths of 1.2–27.5 mm, and thicknesses of 0.5–2.8 mm; the surface area varies in the range of 3.4–1000 mm² while bulk density is 392.2–430.4 kg/m³.

After conventional pyrolysis conducted at the different temperatures, the properties of the walnut shell have been studied again with the focus on the features of the oxidative pyrolysis process as the first stage of the two-stage technology for obtaining high-purity carbonaceous materials.

Biomass Pyrolysis. In order to assess whether the walnut shells are acceptable as carbonaceous raw materials, have been conducted the ultimate analyses for the original walnut

shells and their residues after pyrolysis at the temperatures ranged 300 °C–1000 °C. These studies have shown that the unaffected raw walnut shells were characterized by the carbon content of 56.4 % and a relatively high hydrogen content of 6.5 % (refer to the Table1). The content of total sulphur was 0.2 %. After pyrolysis, the carbon content increased significantly and reached 93.20 % at the temperature of 1000 °C (Fig. 2). In its turn, the hydrogen content decreased to 0.63 %. Moreover, the pyrolysis effected the walnut shells and changed the content of nitrogen: for untreated residues it was 0.4 % and after pyrolysis at the temperature of 1000 °C it became 0.29 % while any sulphur compounds were not detected.

Table 1

Ultimate Analysis of the Walnut Shells (Original State and after Pyrolysis)

Pyrolysis Final Temperature, °C	H ^d , %	C ^d , %	H ^{daf} , %	C ^{daf} , %	S ^d , %	N ^d , %
Original State	6.5	56.4	6.52	56.57	0.2	0.4
300	4.46	75.38	4.55	76.81	not available	0.33
400	3.92	79.48	4.00	81.12	not available	0.39
500	2.93	81.57	3.01	83.91	not available	0.52
600	2.87	88.74	2.97	92.09	not available	0.35
700	1.86	89.74	1.90	91.93	not available	0.31
800	1.08	91.86	1.11	94.49	not available	0.28
900	0.98	92.96	1.01	94.81	not available	0.28
1000	0.63	93.20	0.65	96.12	not available	0.29

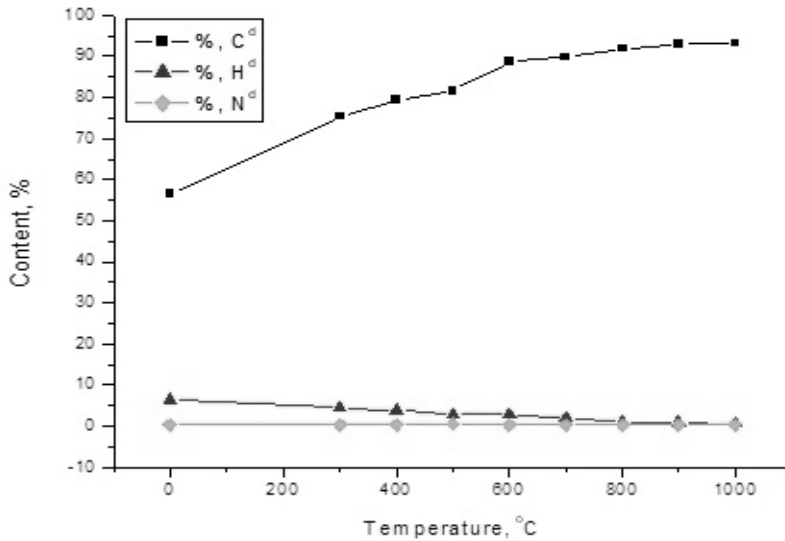


Fig. 2. Dependence of the Walnut Shell Composition in the Dry State (Carbon Content, Hydrogen Content and Nitrogen Content) on the Pyrolysis Final Temperature

With the purpose of the effective usage of pyrolysis products, it is also necessary to determine their technical properties, viz. moisture, ash content, volatile matter release, fixed carbon, and the chemical composition of the mineral part. The mineral components can play an important role in the processing of pyrolysed biomass.

The parameters of the proximate analysis of the solid residue walnut shell after pyrolysis are presented in the Table 2. It is worth noting that the ash content of the residues showed the dependence not only on the original amount of mineral components in the walnut shells, but also on the conditions of the obtained residue pushing and quenching. Due to the high reactivity of the hot-red residue, when it was pushed, there were cases of a slight ignition of the organic part and, as a result, an increase in the concentration of mineral components in the residue.

The results of the proximate analysis allow us to reveal the dependence of the changes in the volatile matter release and in the fixed carbon on the pyrolysis temperature (Fig. 3).

Table 2

Proximate Analysis of the Walnut Shells (Original State and after Pyrolysis)

Pyrolysis Final Temperature, °C	W ^a , %	A ^a , %	A ^d , %	V ^a , %	V ^d , %	V ^{daf} , %	FC ^d , %
Original State	7.2	0.28	0.3	70.4	75.86	76.1	20.53
300	2.21	1.82	1.86	36.66	37.49	38.2	58.0
400	3.25	1.95	2.02	26.27	27.15	27.71	66.3
500	2.64	2.72	2.79	17.51	17.98	18.5	75.09
600	1.62	3.58	3.64	11.07	11.25	11.68	82.37
700	1.4	2.35	2.38	7.83	7.94	8.14	87.18
800	1.55	2.74	2.78	6.74	6.15	7.04	87.59
900	1.59	1.92	1.95	6.33	6.43	6.56	88.73
1000	1.76	2.98	3.03	5.98	6.09	6.28	87.71

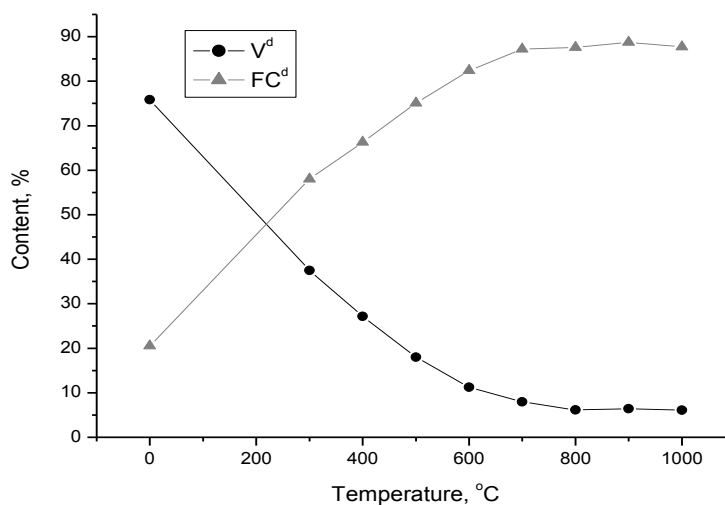


Fig. 3. Dependence of the Change in the Volatile Matter Release and in the Fixed Carbon on the Pyrolysis Temperature

Apparently, when the temperature reaches 700 °C, the value of the fixed carbon stabilises. This is explained primarily by to the stabilisation in volatile matter release when this temperature is reached. At the temperatures of 800–1000 °C, the volatile matter remains almost at the same level. Therefore, it brings the conclusion that when one applies the pyrolysis of the biomass as a preliminary stage of raw materials preparation for the further production of high-purity carbonaceous materials, the optimum final temperature of pyrolysis should be determined in order to reduce processing costs.

Further, the chemical composition of the walnut shells in the original state and their residues after pyrolysis at the temperature of 1000 °C have been carried out to supplement the dedicated characteristics. Thus, in Fig. 4 and in Fig. 5, there have been showed the spectra while Table 1 shows the quantitative composition of its certain elements.

The chemical composition of the studied samples was detected by X-ray fluorescence analysis using the EXPERT 3L precision analyser with the following features: the detection limit of the elements for 100s (from 12Mg to 92U) is ≤ 0.05 %; the detector (SDD) is with a nominal statistical loading of the spectroscopic tract 52000 1/s; the resolution of the detector (for $K\alpha_{Mn}$) at a nominal loading does not exceed 149 eV.

Table 3 evidences that the highest content in a walnut shell is the following chemical elements of K, Ca, Si and Fe.

Table 3

. The Chemical Composition of the Walnut Shells Inorganic Part in the Original State and after Pyrolysis at 1000 °C.

Sample	Chemical Composition												
	O	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Zn
Original	32.74	1.74	1.99	4.99	4.34	1.83	3.42	21.18	18.55	0.70	0.30	7.62	0.33
After Pyrolysis	27.95	1.66	2.11	2.14	0.75	0.43	-	26.54	35.58	0.32	0.17	2.14	-

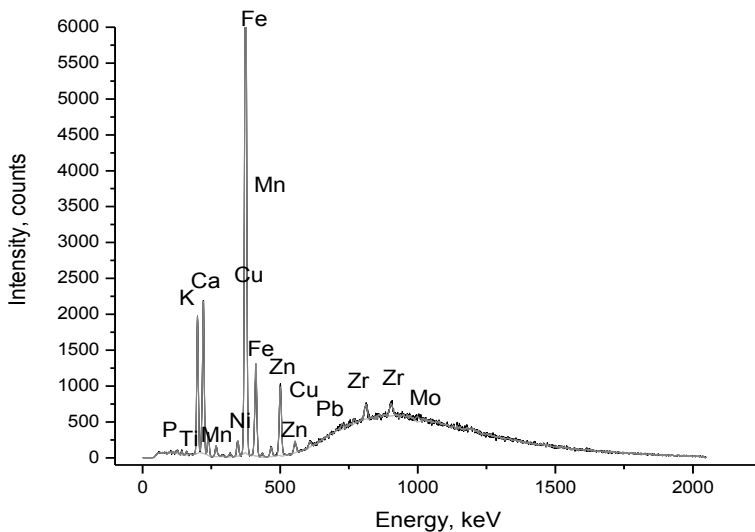


Fig. 4. XRF Spectra of the Walnut Shells in the Original State

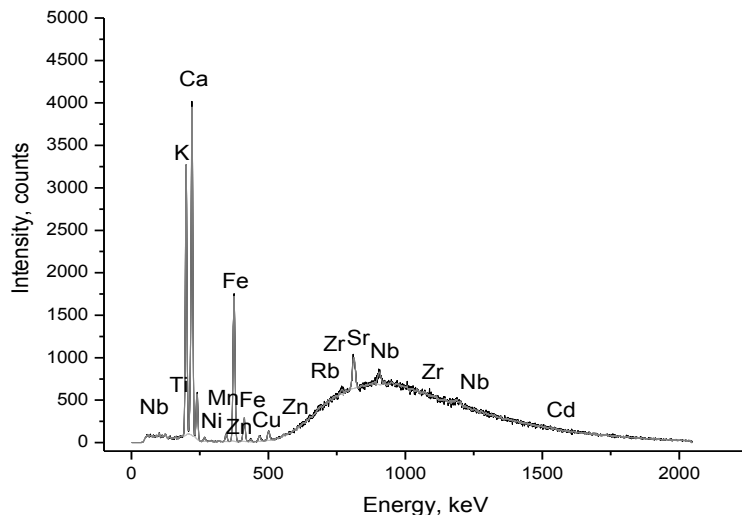


Fig. 5. XRF Spectra of the Walnut Shells after Pyrolysis at the Temperature of 1000 °C

As a result of pyrolysis influence, the increase in the contents of K, Ca, Al can be observed while the contents of Fe, P, Si and S are significantly reduced. Within walnut shell residues subjected to pyrolysis, Cl and Zn have not been detected though these elements were present in the original material.

Nanomaterials Obtaining from Biomass. One of the possible ways for biomass utilization is to prepare carbon nanomaterials from it. For this purposes, have been experimented with the original hazelnut shells to determine the presence of carbon nanoparticles in them. With TEM 125K, equipped with a digital output system for images SEO-SCAN, the images presented in Fig. 6 have been received. The presence of carbon nanoparticles has been determined, their sizes range from 15 nm to 70 nm.

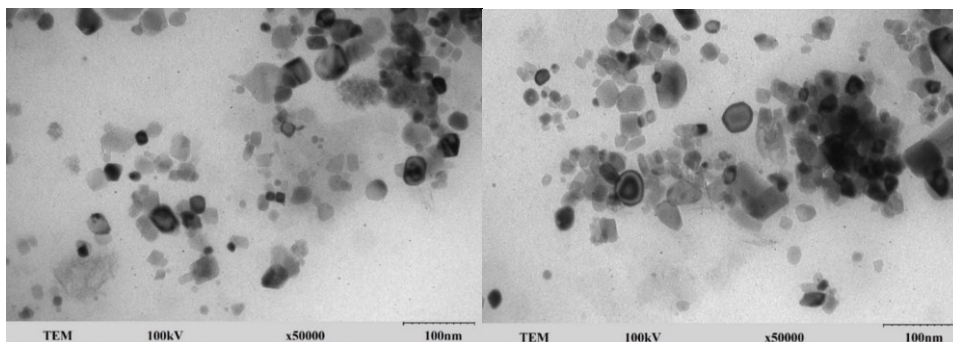


Fig. 6. Carbon Nanomaterials from Hazelnut Shells

The Oxidative Pyrolysis and the Graphitization of the Biomass. The earlier researching results allowed the development and improvement of the multi-stage technology², it enables not

²The technology has been developed at the Department of Industrial Thermal Engineering (National Metallurgical Academy of Ukraine, NMAU) together with the engineers from Thermal & Material Engineering Center (Dnipro, Ukraine).

only obtaining a pure product with the carbon content of $C > 99.95\%$, but also its partial graphitizing [8, 9]. The technology is applicable with walnut shells.

The first stage of this technology involves oxidative pyrolysis of the biomass with the energy consumed from gaseous products. As a result, a semi-finished product has been formed like a coke residue. The second stage is its high-temperature treatment in an electro-thermal fluidized bed at the temperatures up to $3000\text{ }^{\circ}\text{C}$.

According to this technology, the process of oxidative pyrolysis has been carried out in the closed layer of the filtration combustion condition. The process scheme is shown in Fig. 7, the source of the heat is the partial oxidation reaction of the pyrolysis gases [10]. The released heat is used for drying, heating and the pyrolysis occurring below the underlying biomass layers. Air acts as the oxidant.

The biomass layer is ignited from the side opposite to the air supply. The resulting pyrolysis gases contain CO , CO_2 , H_2 , CH_4 , N_2 and a significant amount of tar, these substances react with the oxygen of the air to form a combustion zone that is shifted towards the airflow. This effect is termed as “counter flow heat wave”.

The displacement of the temperature and concentration profiles occurs isomorphically. The reverse motion of the combustion zone is possible due to a sufficiently high thermal conductivity of the layer. The red-hot coke residue is formed behind the combustion zone. the layer due to the action of high temperatures in non-condensable gases (CO , CO_2 , H_2 , etc.).

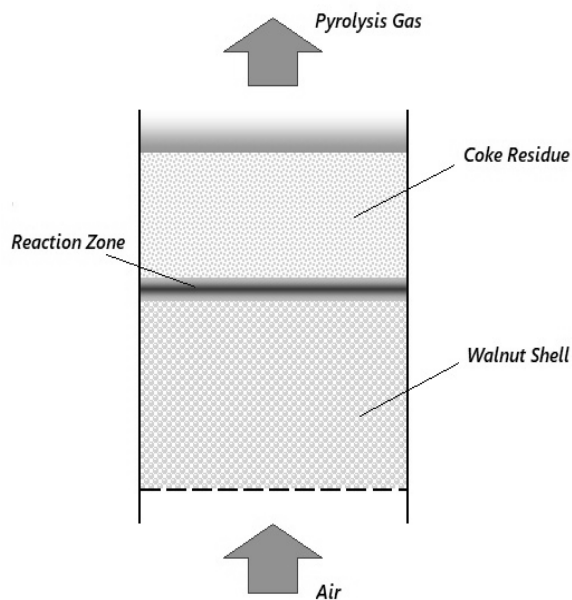


Fig. 7. The Scheme of the Oxidative Pyrolysis Process

Pyrolysis gases and products of their partial oxidation, moving in the same direction as the airflow, pass through the layer of the red-hot coke residue. The tar contained in pyrolysis gases decomposes as the gas moves through

This above introduced scheme allows the process to be conducted without any external source of heat, and also decreasing in the tar content within the pyrolysis gases. Additionally, by regulating the airflow it is possible to change the amount of heat released from the partial oxidation of pyrolysis gases and it is necessary for drying the biomass. This allows application of the biomass with considerable humidity.

The pilot reactor developed for oxidation pyrolysis possesses the capacity of about 100 kW per the original biomass and consists as follows: the reactor, the burner, the TG-0.25 blower, air supply piping system, and the dedicated instruments. The reactor is a vertical shaft-type apparatus with 0.6 m of a diameter and the height of 1 m. The fuel layer was placed on an air supply steel grid with a cell diameter of 10 mm. The sheets of fiber glass shielded with heat-resistant aluminum foil are applied as the thermal insulating means.

The experiments conducted with the purpose to study the process of oxidative pyrolysis have allow defining the optimal range of air flow as 6.5–13.1 m³/h, which corresponds to a specific load on the firebed surface of 27.4–55.2 m³/m²h. The further studies carried out with the observance of the above-mentioned range of the airflow are capable of determining the parameters of different technological conditions of oxidative pyrolysis (Table 4). The qualitative data of the process are the shape of the combustion zone and the uniformity of its movement along the reactor volume. The released gaseous substances contain CO₂, H₂, H₂O, CH₄, CO, O₂, N₂ and tar, which by reacting with the oxygen of the air provide the temperature in the combustion zone of 500–750 °C. This temperature is determined by the processes of combustion and heat exchange between the biomass and the gases, which, in turn, depend on the intensity of the cold air intake and the removal of combustion products from the combustion zone.

Table 4

The Results of the Biomass Oxidative Pyrolysis in the Closed Layer

Parameters	Varieties of Technological Conditions		
	No 1	No 2	No 3
Specific Airflow Rate in the Pyrolysis, m ³ /h	6.5	9.5	13.1
Specific Gas Flow Rate per Square Meter, m ³ /m ² h	27.4	40.0	55.2
Process Time, min	230	180	150
The Average Temperature in the Zone, °C	585	670	741
The Filtration Velocity, m/s	0.105	0.164	0.241
The Average Velocity of the Counter Flow Heat Wave, cm/h	11.4	15.2	18.2
The Sedimentation Velocity of the Fuel Layer, cm/h	6.52	9.67	12.40
The Average Temperature of the Pyrolysis Gases, °C	350	390	425
Content of the Pyrolysis Gases			
CO	5.3	5.6	6.5
H ₂	8.7	9.5	10.1
CH ₄	7.2	6.3	6.2
CO ₂	13.8	12.7	11
N ₂	56.5	57.3	57.6
O ₂	8.5	8.6	8.6
LCV, kJ/m ³	4185.0	3987.0	4129.4
Carbon Content in the Solid Residue, %	79.3	82.2	86.9

During the pyrolysis of the walnut shell, the deposition of the biomass layer has been registered under all technological conditions. At the same time, as the airflow rate increased, the average process temperature for the walnut shells increased as well from 585 °C to 740 °C, and the velocity of the thermal wave was changing within the range of 11.4 cm/h to 18.2 cm/h.

The repeatability of the process character allows the assumption that the process can be implemented on the industrial scale. The gas forming during the pyrolysis can be used for heat generation or for internal combustion engines to generate electricity.

The second stage of the technology is to produce a high-purity carbonaceous material. Preliminary, a number of technologies have been studied for making conclusions concerning the new technology, the materials analyzed embraced the chemical refining, heat treatment in layered electric furnaces of continuous action (calcination unite) and those of periodic action (Acheson furnace).

It has been established that the most reasonable is the treatment of the solid residue of the walnut shell in a high-temperature electro-thermal fluidized bed. The working space of the furnace has an expansion and is divided into two cylindrical parts: the lower one is the zone of the fluidized bed and the upper one is a super layer (separation) zone of the larger diameter. The diameters of these zones provide the ratio of the gas velocity in the lower part and the gas velocity in the upper part as 2:3. The advantage of the technology is in the continuous condition of operation; the material is loaded and unloaded with screw feeders.

The release of the finished product is provided from the bottom of the furnace to the cooling chamber, which is a heat exchanger in the form of four vertical stainless steel pipes lined inside with the graphite and allowing lowering the temperature of the material from 2500 °C to 1100 °C. The further cooling down to 200 °C is carried out in a water-cooled screw feeder.

The summary data of analysis on the existing technologies of graphitisation and refining are reported in Table 5. With regard to the characteristics of the raw materials and the requirements for the ash content in the battery graphite, the electro-thermal fluidized bed furnaces are concluded to be the main competitive method of processing carbon materials with respect to chemical cleaning. In the course of the on-line process implementation, this type of furnaces has better energy indices by 40–60 % than the Acheson furnaces, while at the same time they allow the recovery of thermal waste energy. Moreover, it is worth noting that due to the limited results of practical implementation, technologically these solutions leave issues to be studied, which retards the usage this method in industries.

Table 5

Technological Parameters of the Principle Graphite Refining Techniques

Technology	Content of C _g , %	Fractional Composition of Raw Materials, μm	Process Temperature	Energy Intensity, kW·h/kg
Chemical Refining	> 99.98	< 1000 μm	up to 900 °C	0.2–0.6
Electro-Calcinators	to 97.5	6–25 mm	up to 2500 °C	1.5–2.0
Acheson Furnace	> 99.97	no limits	up to 3000 °C	4.5–9.0
Chlorothermic Methods	> 99.9995	no limits	up to 2300 °C	3.5–7.0
Electro-Thermal Fluidized Bed Furnace	> 99.95	150–1250	up to 3000 °C	2.0–3.0

Taking into account the analysis carried out in the laboratory of the Thermal & Material Engineering Centre, several laboratory facilities related to the electro-thermal fluidized bed technology have been developed:

- high-temperature furnace (up to 3000 °C) for thermal cleaning of the carbonaceous material under conditions simulating the emulsion phase of the fluidized bed (Fig. 8a);
- low-temperature electro-thermal fluidized bed furnace (up to 1000 °C) for hydrodynamic and electrical regimes of the fluidized bed (Fig. 8b).



(a)

(b)

Fig. 8. Electro-Thermal Furnaces by T&MEC Design: (a) fixed bed thermal treatment furnace ($t = 3000\text{ }^{\circ}\text{C}$); (b) the fluidized bed furnace for studying hydrodynamic and electrical parameters

The carried out studies on the usage the above-mention technology allow determining that the carbon residue of the walnut shell after oxidative pyrolysis is a conductive material, which can be applied in electro-thermal heating.

Heat treatment of the residue at $3000\text{ }^{\circ}\text{C}$ enabled us to obtain a high-purity carbonaceous material with impurities content kept within $0.01\text{--}0.05\%$.

In the context of the increasing cost of the conventional carbon reducing agents and with regard to the impact of the combustible fossil fuels on the greenhouse gases emissions, the utilization of renewable CO_2 -neutral substances, such as plant biomass has to be a solution for the issues of obtaining carbon materials of the required quality. Biomass has several advantages when applied for preparing high-purity carbonaceous materials, they are, for instance, availability, relative cheapness, environmental friendliness, low content of mineral components and sulphur. The significant advantage of biomass is its multivariability, both in terms of transformation technologies and end-use techniques. Biomass can be used in various processes without complex preliminary technological operations.

The elemental composition of the organic mass of the walnut shell after pyrolysis from $300\text{ }^{\circ}\text{C}$ to $1000\text{ }^{\circ}\text{C}$ has been analysed with an interval of $100\text{ }^{\circ}\text{C}$. After pyrolysis conducted at the temperature up to $1000\text{ }^{\circ}\text{C}$, the carbon content reached 93.20% . In its turn, the hydrogen content was 0.63% and the nitrogen content was 0.29% . The presence of sulphur compounds were not detected at all. The change in the chemical composition of the mineral part of the shell after pyrolysis has been shown in comparison with the original composition. After pyrolysis at $1000\text{ }^{\circ}\text{C}$, the contents of K, Ca increased and slightly increased Al content in the mineral part of the residue.

Since nanoobjects are high-purity carbonaceous materials, the utilization of biomass for their production seems to be a promising area. The presence of carbon nanoparticles obtained from hazelnut shell has been registered, the size of the particles ranges from 15 nm to 70 nm .

The multi-stage technology for producing high-purity carbonaceous materials ($C > 99.95\%$) based on biomass utilization has been developed and improved, including the stages of oxidative

pyrolysis (700 °C) and heat treatment in an electro-thermal fluidized layer (3000 °C). The analysis on the potential materials has shown that the most suitable for the process is the walnut shell.

The carried out researches at the different intensities of airflow allows determining the parameters of technological conditions for oxidative pyrolysis, and the repeatability of the process permits its implementation on an industrial scale. The resulting pyrolysis gas can be used for heat generation or in internal combustion engines to generate electricity.

The laboratory facilities of the furnaces for oxidative pyrolysis and high-temperature treatment in an electro-thermal fluidized bed have been developed. According to the results of the conducted test runs on the technology, it has been defined that the ash content in the final product does not exceed 0.01–0.05 %.

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ВИКОРИСТАННЯ БІОМАСИ З МЕТОЮ ОТРИМАННЯ КАРБОНОВМІСНИХ МАТЕРІАЛІВ ВИСОКОГО СТУПЕНЯ ЧИСТОТИ

Розглянуто основні критерії використання біомаси замість горючих копалин з метою отримання біопалив. Показано переваги біомаси у порівнянні з традиційною непоновлювальною сировиною. Представлено результати досліджень властивостей шкаралупи волоського горіха після класичного піролізу за температур від 300 °C до 1000 °C та зроблено акцент на особливостях процесу окисного піролізу як першої стадії двостадійної технології отримання високочистих вуглецевих матеріалів із біомаси. Встановлено можливість отримання наноматеріалів з біомаси на прикладі шкаралупи ліщинного горіха. Отримані результати дозволяють говорити про можливість реалізації технології виробництва високочистих вуглецевих матеріалів у промислових масштабах.

Ключові слова: біомаса, піроліз, окисний піроліз, графітизація, високочисті вуглецеві матеріали, наноматеріали

РЕФЕРАТ

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ИСПОЛЬЗОВАНИЕ БИОМАССЫ С ЦЕЛЬЮ ПОЛУЧЕНИЯ КАРБОНОСОДЕРЖАЩИХ МАТЕРИАЛОВ ВЫСОКОЙ СТЕПЕНИ ЧИСТОТЫ

Рассмотрены основные критерии использования биомассы вместо горючих ископаемых с целью получения биотоплив. Показаны преимущества биомассы по сравнению с традиционным невозобновляемым сырьем. Представлены результаты исследований свойств скорлупы грецкого ореха после классического пиролиза при температурах от 300 °C до 1000 °C, показаны особенности процесса окислительного пиролиза как первой стадии двухстадийной технологии получения високочистых углеродных материалов из биомассы, а также установлена возможность получения наноматериалов из биомассы на примере скорлупы лесного ореха. Полученные результаты позволяют говорить о возможности реализации технологии производства високочистых углеродных материалов в промышленных масштабах.

Ключевые слова: биомасса, пиролиз, окислительный пиролиз, графитизация, високочистые углеродные материалы, наноматериалы

ABSTRACT

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THE BIOMASS USE TO OBTAIN HIGH-PURITY CARBONACEOUS MATERIALS

The current publication considers the main criteria for biomass utilization instead of combustible fossils for the purpose of obtaining biofuels. The advantages of the biomass in comparison with the traditional non-renewable precursor materials have been shown. The results of the properties of walnut shell studies after conventional pyrolysis at the temperatures from 300 °C to 1000 °C are presented. Additionally, have been highlighted the peculiarities of the oxidative pyrolysis process as the first stage of a two stage technology for the production of high-purity carbonaceous materials from biomass. The possibility of obtaining nanomaterials from the biomass has been established, as instance can serve the hazelnut shell. The obtained results allow implementing the production technology for high-purity carbonaceous materials on an industrial scale.

Key words: biomass, pyrolysis, oxidative pyrolysis, graphitisation, high-purity carbonaceous materials, nanomaterials.

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1.3 METHODS VIRTUALIZATION IN CHEMMOTOLOGY RESEARCHES

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The usual purpose of mathematical modelling of technological processes is forecasting course of these processes in various conditions, including not covered by natural experiment. Two basic demands are usually made to similar model – universality and adequacy. Universality allows to use model in a wide range of external conditions, including in structure of models of higher