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Utilisation of wood ash from biomass for the production of ceramic products

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HIGHLIGHTS

- 5–60% of the additive of ash can be used for the production of ceramic products.
- The main elements of ash composition are C, O, Si, Ca and Fe (more than 88%).
- Additive of ash reduces shrinkage, density, heat conductivity of ceramic bodies.
- The amount 20% amount of wood ash influences of the ceramic body as natural pigment.
- Calcium pyroxene ($CaFe(Si,Al)_2O_6$) brightens the ceramic body.

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ABSTRACT

Utilisation of biomass as fuel is very attractive from the ecological point of view. Such way of energy extraction is ecologically clean (zero CO_2 emission) and biomass is renewable and theoretically inexhaustible local energy source. However, during the utilisation of secondary raw materials of biomass for energy production, higher amount of ash accumulates. Wood ash analysed in the research consists of two types of particles: first type – nonflammable mineral particles consisting of the following main elements: Si, Ca, Fe, O and C (86%) and the main elements of the particles of second type are C and O (98%). The aim of the research is to analyse the possibility to utilise wood ash from biomass for the production of ceramic products. Formation masses are prepared by incorporating from 5% to 60% of wood ash additive and burned at various temperatures. It is identified that this additive influences the properties of ceramic body, i.e. reduces drying and burning shrinkage, density, compressive strength, thermal conductivity, increases water absorption and porosity. Additive of wood ash from biomass influences the ceramic body as a natural pigment that brightens the ceramic body. Colour change is determined by sufficient amounts of calcium pyroxene in the composition thereof iron is inserted.

1. Introduction

In recent years, the main topics of discussions are related to the utilisation of biomass, renewable energy sources and the utilisation of secondary materials. In other words, it is the transition from linear economy to the circular one, where all new products created could be reused several times, and the amount of waste materials left would be as least as possible. Before 2020, EU aims to produce 20% of energy from the renewable energy sources – wind, sun, waterpower, as well as biomass. The usage of renewable energy could allow EU to reduce the amount of greenhouse gases and become less reliant on the imported energy. Lithuania commits to stimulate the constant increase of the utilisation of renewable energy sources in energetics and transport in order to reach higher than 15% of total balance of initial energy until 2020.

Vegetal biomass dedicated for energy purposes is very important source of renewable energy. Biomass resources cover not only agriculture and forestry production, but also its treatment and processing waste, i.e. waste of disforest as well as chemically untreated wood industry. When prices of natural resources grow, in the countries, where fossil fuel resources are limited, more and more attention is being payed to the biomass. It is considered that the utilisation of biomass for energy production does not increase carbon dioxide emissions to the atmosphere. By growing, all plants remove carbon dioxide from the atmosphere during photosynthesis process. When the amount of newly created biomass corresponds to the amount of biomass used to produce energy, it

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is considered that the biomass transformation to the energy process is neutral in respect to the carbon dioxide. In this respect the utilisation of biomass resources for energy production does not influence climate change, and, in addition, it is one of the ways to utilise biomass waste.

After the beginning of the utilisation of biomass waste for energy production, the cost of energy production decreases. However, high amounts of ash accumulate during the burning process. Ash of biomass cause serious environmental problems. Nowadays, in Lithuania the major part of such waste (25,000–30,000 tonnes of wood ash per year) is transported to the dump areas. Although the researches carried out show that such waste can be effectively utilised in the industry of construction products [1–7].

However, in order to utilise ash from biomass, it is essential to know and evaluate the composition of ash from biomass. This composition might depend on various factors, such as region and conditions of growth, type of soil and biomass, burning parameters and etc. Therefore, the composition might vary in a very wide range [8–11].

It is suggested to use ash from biomass for concrete production [12–14]. The researches implemented show that ash from biomass can partially replace cement during concrete production. In this way expensive binding material can be saved and cost price of such product reduced. Additive of ash from biomass influences the rheological properties of concrete mixture, concrete's physical and mechanical properties (shrinkage, water absorption, density, compressive strength), product's porosity, frost resistance and thermal conductivity.

In addition, ash from biomass can be used for the production of multi-purpose ceramic products [15–17] introduce up to 50% of ash from biomass into the formation masses. After ash introduction, the density and compressive strength of ceramic products burned at temperature of 950 °C decrease, shrinkage and water absorption increase. The authors state that the optimal amount of ash to be utilised for the production of ceramic products shall not exceed 20%. Other authors state that from 5% to 10% of ash from biomass additive decreases the density of ceramic products by 210 kg/m^3, thermal conductivity up to 0.13–0.16 W/(m·K) and increases water absorption by 7%. However, these ash must be additionally rinsed before the utilisation for the production of ceramic products, thus impeding and increasing its production costs [18]. In addition, there is data confirming that the additive of ash from biomass changes colour of ceramic products [16].

During the recent years, the utilisation of biomass for energy production in Lithuania has increased considerably in both, private and industry sectors. However, the problem of the utilisation of ash from biomass has not been solved so far. It can be assumed that waste of ash from biomass can be effectively utilised for the production of ceramic products, thus saving the expensive traditional raw materials.

The research has been carried out in order to improve knowledge as well as to estimate the possibilities of the utilisation of wood ash from biomass for the production of ceramic products. Therefore, the objective of the research is to determine the influence of wood ash on physical and mechanical properties, structural parameters and microstructure of the ceramic body burned at 950 °C and 1000 °C temperatures. In addition, it is assumed that wood ash can influence the ceramic body as natural pigment that dyes it in brighter colours.

2. Materials and methods

Low-melting illite clay obtained in bags from the factory of ceramic products is used for the research. This clay has been shredded and sieved through 0.63 mm sieve. Ash is produced after the burning of various waste materials of biofuel. It is easy to insert ash into formation mass, as well as to easily mix it with the clay. Initially, dry mixture of components is mixed and the obtained mixture is watered till the humidity reached the level suitable for the formation. This formation mass is kept for three days at (95 ± 5)% of humidity in order to achieve even distribution of water in the formation mass. After three days (70 × 70 × 70) mm sized samples are formed from formation masses. 12 specimens are prepared for each forming mixture. 6 of them are burned at 950 °C temperature and other 6 specimens – at 1000 °C temperature. Composition of formation masses (% by mass) is provided in Table 1.

Formed semi-finished products are initially dried at natural laboratory conditions and later additionally dried in an oven for 2 more days. First day, samples are dried at temperature of (60 ± 5) °C and second day – at temperature of (105 ± 5) °C. Burning of the samples is carried out at temperatures of 950 °C and 1000 °C, overall burning period is 34 h by keeping at the highest burning temperature for 4 h.

Chemical compositions of the clay and ash used in the research are determined through the classical methodologies of chemical analysis of silicate materials and by employing Oxford Instruments INCA penta FET×3.

Compressive strength of the ceramic body is determined according to LST EN 772-1:2003, net dry density based on the requirements of LST EN 772-13:2003, water absorption (Wh) in

Table 1
Formation masses.

Raw materials	Formation masses (%)					
	A0	A5	A10	A20	A40	A60
Clay	100	95	90	80	60	40
Ash	0	5	10	20	40	60

Table 2
Chemical and granulometric composition of clay, %.

Clay	Chemical composition of clay, %						
C	SO_2	$Al_2O_3 + TiO_2$	Fe_2O_3	CaO	MgO	K_2O	Loss on ignition
	48.70	18.43	8.52	6.80	2.50	4.52	10.53
	Granulometric composition of clay, %						
	Amount of sandy fraction (>0.05 mm of particles)		Amount of dust fraction (0.05–0.005 mm of particles)			Clay fraction (<0.005 mm of particles)	
	8.5		22.4			69.1	