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Informative Article

USE OF AGRICULTURAL WASTE AS RAW MATERIALS FOR OBTAINING GLASS AND GLASS-CERAMICS: A REVIEW

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Abstract

Global trends are moving towards a circular economy to replace the deeply grounded linear economics and waste management. Circular economy implies and the protection of human rights through sustainable development, global security natural resources, combating climate change, energy security, insurance sufficient amounts of food, reducing inequalities, preservation of health and a cleaner environment and the rights of future generations to resources, etc. The policy of procurement of raw materials in the circular economy is focused on the use of secondary raw materials. A big challenge for modern production is to use different types of waste to obtain new products without the use of raw materials. This kind of production requires new knowledge, adaptation of existing technologies or new technologies, new jobs, etc. Large amounts of vegetative residues are produced annually by agriculture. Agricultural waste is very often incinerated or disposed of on land and is still not used. Most of the agricultural waste ashes consist of silicon dioxide along with other oxides which may vary according to region and atmosphere of the local conditions. This paper gives an overview of the possibilities of using agricultural waste for obtaining glass and glass ceramics. Previous research has shown that various types of glass and glass-ceramics can be successfully obtained from agricultural waste, which can be used in construction, medicine, various composites, etc.

Keywords: glass, agricultural waste, recycling.

Introduction

Minerals in organic waste have been used for a long time in the concrete industry, production of carbides, nitrides and others. This type of waste is not widely used primarily because it is less known which minerals are present in plants. What is more, plants have a significant content of water and organic components that must be removed before use.
Glass and glass ceramics are most often (traditionally) produced from high purity proportions of pure chemicals. They can also be prepared from cheaper raw materials such as wastes because the glass-ceramic process has been established as a suitable way to valorise mining and industrial wastes (Giro-Paloma et al., 2019). Most of the elements from the periodic table necessary for obtaining different types of glass are found in various plants, except for B, Li, Ge and Sn (for example, B is important element for display glasses). The amount of certain minerals that are undesirable in glass, Fe_2O_3, for example, is not significant in plants. On the other hand, S and Cl are present in some plant, that are desirable as fining agents for glass production (Cornejo et al., 2014). In recent times, a few researchers have reported that the food waste could be used as the resource material to obtaining the glasses and

glass-ceramics for numerous applications. In this paper, a brief overview of previous research is given.

Materials and Methods

In order to obtain glass from food waste, it is necessary to first dry the waste and then heat it at a certain temperature to remove unwanted components (such as H_2O, CO_x and NO_x). Typically, a second heat treatment produces the mineral desired for glass batching. Certain food wastes, such as eggshells, which are primarily $CaCO_3$, do not need this heat treatment and may be used directly as a raw material.

Results and discussion

The mineral content of organic waste varies widely depending on the type of plant, thereby providing the ability to batch a variety of glass and glass-ceramic compositions. This diversity allows significant flexibility in production these engineered materials. In Table 1 present the chemical compositions of three common glasses and the ash of various food wastes.

Table 1. Oxide content in three common glasses and present in ash of various food waste (Cornejo et al., 2014)

	SiO_2	CaO	K_2O	Na_2O	MgO	Al_2O_3	P_2O_5	Fe_2O_3	SO_3	B_2O_3
GLASS										
Containers	65-75	10	0	14	3	<1	0	0	<1	0
Display	50-60	0-4	0-5	0-5	0-3	10-17	0	0	0	8-15
Bioactive	0-55	22-27	0-9	6-24	0-8	0-28	1-3	-	0	0-51
FOOD WASTE										
Rice husk	97.8	0.6	1.3	-	0.24	trace	-	trace	-	-
Corn husk	35.7	5.8	20.2	5.1	9.9	0.4	22.5	0.3	-	-
Egg shell	0.1	98.6	0.1	0.1	0.8	-	-	-	-	-

Naghizadeh et al. (2015) have fabricated a 3 D scaffold using polycaprolactone and silicate based bioactive glass-ceramic. Bioactive glass ($50SiO_2$–$25Na_2O$–25CaO (mol %)) was obtained by the sol-gel process, and rice slag was used as a source of Si. In vitro test showed the formation of HA after both 7 and 14 days, on the surface of the scaffold. The toxicity rate of the glass powder demonstrated that it was not directly toxic to the hMSCs and cell proliferation in culture after 3 days. For a series of bioactive glasses, Kaur et al. (2021) used rice husk and eggshells to obtain bioactive glasses (basic composition SiO_2-P_2O_5-MgO-CaO) that can be employed in bone implants and drug delivery applications. Using the sol-gel process, Essien et al. (2016) obtained bioactive glass of ternary system of CaO-MgO-SiO_2, as raw materials they also used rice slag and eggshells. Their results show that there was absence of agglomeration of glass particles. Consequently, a good surface area is achieved, which is important for the reaction of glass in the body fluid. In the study of Chen et al. (2017), they used rice husk, to develop a novel mesoporous bioactive glass and found that the glass a well-ordered hexagonal mesoscopic structure, high surface area, high pore volume and the capacity to support the formation of hydroxyapatite layer that can be attached to the bone.

The study of Sharma & Singh (2019) demonstrated that wheat straw ash and mineral oxides based glass-ceramic can be promising sealant materials for solid oxide fuel cells application. Wheat straw ash exhibits good thermal stability with insulating nature even at 700 °C. The same authors (2020) prepared four samples with varying (wt%) of rice husk (RHA) and eggshells (ESP), composition (100-x)RHA*(x)ESP, where x=30, 40, 50 and 60 (only 70RHA*30ESP did not have glassy nature). The as-quenched samples are transparent with a blue tint. They assumed that the blue color may arise due to the presence of some transition trace elements like Ti as observed in EDS and XPS analysis.

Two different crystalline forms of SiO_2, cristoballite and tridymite, were formed. The calculated density of the present glasses is lower, while the hardness is slightly higher than the similar type of glass-ceramics synthetized from commercially available oxides. The hardness of the samples is 590-630 HV. Optical band gap is in wide semiconductor range, 3.2-3.5 eV. Low/moderate dielectric constant with low dielecric loss is observed in the present glasses and glass-ceramics, which can be exploited to use them in microelectronic applications.
Optical properties of soda-lime-silica glasses doped with peanut shell powder investigate by Aktas et al. (2016). They are different amounts of the peanut shell powders (0.5, 1, 3 and 5 wt.%) mixed with the soda-lime-silica glass powder and the melt-quench technique prepared glasses. The density of the glasses decreased with increasing peanut shell powder content. The pure soda-lime-silica glass was colourless and transparent, wheras it became dark green after adding the peanut shell powder.
Andreola et al. (2013) described the fabrication of glass-ceramic tiles by using rice husk ash. The RHA glass frit was prepared from a composition (wt.%) of 46.52RHA, 13.84Al_2O_3, 13.16MgO, 22.17Na_2CO_3 and 4.33B_2O_3 by melting at 1450 °C followed by quenching in water. These glass-ceramics were found to produce nepheline ($Na_2O{\cdot}Al_2O_3{\cdot}2SiO_2$) and forsterite $2MgO{\cdot}SiO_2$) crystal phases. Their bending strength, Young′s modulus, shear modulus, Poisson′s ratio and Mohs hardness were found to vary in the ranges of 24-39 MPa, 43-61 GPa, 17-23 GPa, 0.14-0.30 and 6-9, respectively. Regarding technological features, the sintered materials showed bending strength values and Mohs hardness higher with respect to commercial glass-ceramics. Bottom ash from biomass combustion, coming from a thermoelectric power plant in Faenza (Italy), was exploited as an alternative raw material in porcelain stoneware bodies (Conte et al., 2022). No significant variations with respect to technological parameters, such as particle size distribution, springback, green and dry bulk density were identified, indicating that the introduction of ash, within certain limits, guarantees the maintenance of the required properties of the semi-finished products along the production line.
Farias et al. (2022) used coffee husk ash, highly attractive raw material with potential as a low cost K_2O source to produce glass-ceramics for solid oxide cell applications. They determined that this glass-ceramic consists of two distinct crystalline phases, diopside and nepheline, embedded into the glassy matrix. Thermal expansion coefficients were found between 9 and $10x10^{-6}$ $°C^{-1}$, suggesting excellent mechanical compatibility with other cell components operating at intermediate temperatures.
The research of Iwaszko et al. (2020) showed that vitrified material is characterized by very low ion leachibility, comparable to the ion leachibility of glass, therefore its potential use e.g. in the building materials industry does not require additional protective or adaptation activities. They research has shown the possibility of vitrifying wastes (The Virginia mallow) generated during biomass torrefaction.
A group of researchers from Spain (Jordan et al., 2018) examined the possibilities of obtaining glass and glass-ceramics from different types of waste. They concluded that vitrification of waste (palm wood, natural peat and earthworm humus) occurs at lower melting temperatures (from 1200 to 1300 °C). The straw and palm leaf could be located in the K_2O-CaO-SiO_2 ternary system, far from the eutectic points. The high K_2O content in these wastes will facilitate the vitrification process and could give rise to controlled soluble glasses. The peat and humus biomass wastes can be located in the CaO-Al_2O_3-SiO_2 system, which is a very common ternary composition diagram for waste such as slags, fly ash, etc. The composition are close to the eutectic triple point formed by wollastonite, anorthite and gehlenite.

Conclusion

This paper presents some of the research into the possibility of using food waste to obtain different glasses and glass ceramics. Most food wastes contain valuable minerals that could serve as raw materials for the production of glass, ceramics and glass-ceramics. Previous research has shown that glass, ceramics and glass-ceramics obtained from food waste can be successfully used as biomaterials or sealing materials at high temperatures. Additionally, they can be used in the production of ceramic tiles, as well as construction material in the building industry, etc. The goal of our research is to show the possibilities of using materials that we consider waste. Also, our goal is to show what treasures are hidden in food waste.

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