ASSESSMENT OF BREWER GRAIN UTILIZATION TECHNOLOGICAL PROCESS AND CHARACTERISTICS OF OBTAINED GRANULATED PRODUCT

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Abstract. In the course of the research, brewery industry waste product – brewer's grains – was used for producing a granulated product that has an improved nutritional value and better physical as well as mechanical properties. This does not allow efficient utilisation of this organic waste but to use it as feed irrespective of the season. The process of producing granules from brewer's grains by adding an organic binding material is environmentally safe and allows for efficient utilisation of the main waste produced in brewery. This article presents the results of the research in the physical and mechanical properties of the granular product as well as short characteristics of the product user-attractive properties. The research has been performed with granules of different composition. It has been established that a higher content of glycerol used in granules as a binding material results in better strength properties and varied physical characteristics of the product.

Keywords: organic waste**,** utilisation, brewer's grains, granules, physical and mechanical properties.

Introduction

The problem of waste management and disposal is characteristic to all areas of production. As a result, the need emerges to sort waste into reusable and not reusable waste, and find the ways of efficient waste utilization.

Agricultural and food production plants produce extremely high amounts of plant and animal waste annually. In many countries, legal framework providing for large fines forces owners of recycling companies to look for the ways to recycle, utilize or store safely the waste that was generated during the production process. One of these agricultural product processing and food manufacturing industries is brewing, and the key waste produced during the production process is brewer's grains.

Out of 100 kg of cereal product being processed 125-170 kg of wet brewer's grains are obtained [1; 2]. The amount and chemical composition of the brewer's grains produced depend on the quality of grist used, and the type of beer that is produced. In freshly produced brewer's grains the moisture content is usually 70-80 %, and the dry material amount to 20-30 %. Dry brewer's grains contain (%): proteins – 19-25; fat 8.2-12; nitrogen-free extractive matter – 41-55; mineral materials – 4-5.5; cellulose – 17.5-20 [2]. The chemical composition of the material (%): CaO – 11.9; K_2O – 3.9; Na_2O – 0.5; MgO – 11.5, P_2O_5 – 405; S_iO_2 – 25.3 [2; 3].

By fully and rationally utilising brewer's grains as waste of primary production it could be attributed to secondary material resources. The latter would expand and supplement the product range of feed products, food products as well as technical and medicinal products, and serve as an additional source of raw materials, reduce the cost of wastewater management for processing plants, etc.

Breweries are interested in selling brewer's grains as their waste, especially during summertime since in its liquid form the product starts spoiling very quickly (in a period of 72 hours) accompanied by a number of unpleasant effects. Lately, brewer's grain has been used mainly for animal feed. This affects the productivity of dairy cows and weight increase for bovines and swine. This product substantially enriches feed with proteins, and improves absorption of calcium and phosphorus. In dry fraction of brewer's grains the amount of proteins is three times larger than in barley (1, 3).

Various preservation methods for brewer's grains to be used as feed are offered: drying, dewatering, ensilage, conservation, and granulation.

Processing of brewer's grains by drying is very common in Germany, the USA, and other countries. For drying, simple tumble driers of various constructions are used. Dried brewer's grain does not require any further processing. A high quality feed is obtained.

Dewatering of brewer's grains is applied in order to reduce the volume of the transported product. The weakness of this process is that a significant part of water-soluble materials are removed together with water, which reduces the nutritional properties of the final product. Therefore, liquid fraction is better suitable for using as food or feed additive.

When solving the problems of brewer's grains conservation, the most widely applied method is ensilage. However, having low acid-balance, brewer's grains silage is not suitable for long-term storage.

Dried and granulated brewer's grains are easier to store, and they preserve the nutritional properties. However, this way of processing requires higher energy costs.

Granulation is the process of changing the initial volume, form, physical-mechanical and chemical properties. The properties of granulated materials essentially depend on the method of granular formation and their features. In order to achieve the required parameters of quality, the process of granulation becomes quite complicated due to a number of interrelated parameters. Also the quality of raw materials is important and the impact of technical equipment.

For recycling this type of waste, rotary granulators with a circular or flat matrix are used. Therefore, there are some questions arising as to how should the matter for granulation be prepared and what composition should it have, including the additives that improve the nutritional value of feed, what type of binding materials should be used, and what content should they have in the final product to obtain the composition of the material that ensures easiness of pressing, and stability of granules (5).

The dynamics of granule formation, and the required properties (tasks) of granules as the target product depend on the composition and physical-mechanic properties of the material (matter) being granulated.

Various additives and binding materials affect plasticity and integrity of the material being granulated, and also influence the physical-mechanic properties of the very granules. By adding the binding material into the matter being granulated, it is possible to change the initial characteristics of this material into new rheological properties, alter the kinetics of granule formation, and regulate the efficiency of granulation [4; 6].

During the mechanical process of granule formation, not only physical but also chemical processes take place affecting the properties of the target product. Designing of an optimum technological scheme for a granulation process, and proper management of the process remains a serious issue to deal with for science and industry.

The objective of the work: assess the possibilities of granulating brewer's grains as by-products retaining the energy-nutritive value of the product observing the requirements of environmental protection and considering the economic and energy costs.

The work tasks – to analyse the impact of brewer's grains and the granule binding material on the energy as well as physical and mechanical properties of granules.

The subject of this research is brewer's grains – the by-product of brewery industry granulated using additional binding material – glycerol.

Materials and methods

The initial humidity of the natural grain product was 74-76 %. The excess humidity was removed by mechanical means – centrifugation. Afterwards, the matter of brewer's grains was dried in a drying chamber in temperature of 70 ºC. During the production process of granules, glycerol was used as the binding material. Glycerol is a by-product of producing bio diesel from rapeseed oil, which is used as an energy source in animal diet. Before mixing glycerol with the dried material brewer's grains having the humidity level of 10-12 %, glycerol was warmed up to the temperature of 40 ºC. For the purpose of research, four types of granules were produced using different percentage of glycerol as a binding material by help of combined feed production equipment. The content of the binding material in the material being granulated was varied as follows: 1-0 %, 2-3 %, 3-6 %, 4-10 %.

The nutritional value of brewer's grain granules was tested under laboratory conditions identifying the amounts of green proteins, fat, fiber content (%) in the material, gross energy and metabolizable energy ($MJ \cdot kg^{-1}$). The initial density of the granules was determined using the mass method by repeating the testing procedure five times. The natural fall angles were determined by measuring: a container was filled with granules afterwards allowing them to fall out naturally. The dynamic coefficients of friction were determined based on the velocity of the granule mass flow given different surfaces of friction (steel, plastic, wood). The granule strength was measured using the computer-controlled tool Petrotest PNR21. The testing results were obtained by calculating arithmetical mean of the estimates.

Results

The results of nutritional value analysis have demonstrated that the gross energy of the primary product brewer's grain as a by-product was 5.25 MJ·kg^{-1}, while metabolizable energy was 3.6 MJ·kg^{-1}.

The gross energy of dried up to 10 % humidity content and granulated brewer's grain increased up 19.95 MJ·kg^{-1}, and metabolizable – respectively to 13.85 MJ·kg^{-1}. Increase of the gross and metabolizable energy in the product mass unit may be explained by a significantly reduced level of humidity.

An important property of granulated products significantly affecting the costs of transportation and storage is the bulk density of granules. It depends on thickening of the material in the very granule as well as on the geometrical parameters of granules. It may be argued that thickening of the material in the granule depends on the amount of the binding material used. Increase in the amount of the binding material (%) results in higher bulk density of granules (Fig. 1).

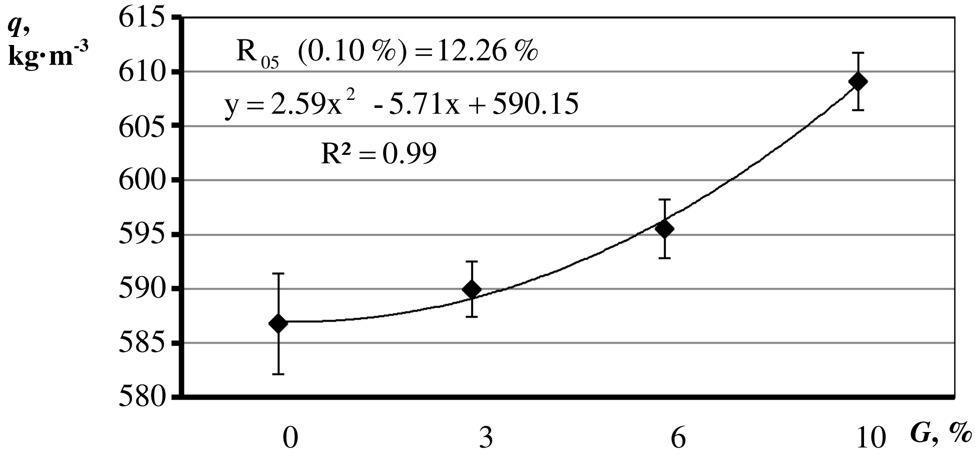

Fig. 1. **Dependence of granule bulk density (*q*) on the amount of the binding material (*G*)**

The bulk density in the granules without the binding material was 586 kg·m^{-3}, and in the granules with 10 % of the binding material, the bulk density increased up to 609 kg·m^{-3}.

Increase in the amount of the binding material in the granules did not have any significant effect on crumble and natural fall angles. The results of the research have revealed that increasing the amount of the binding material, i.e., glycerol, results in slight increase in the granule crumble angle, and the natural fall angle demonstrated the tendency to decrease.

The dynamic friction coefficient is directly related to the slope angle of the friction surface which is characteristic to technological machinery, such as dispensers, storage tanks, transportation and handling chutes, etc.

The research results using different material friction angles have demonstrated a tendency of the dynamic friction coefficient to decrease. It has been established that the numerical value of the friction coefficient is also affected by the amount of glycerol in granules (Fig. 2, 3).

The numerical value of the dynamic friction coefficient of granules using plastic friction surface in the specific speed range varied from 0.25 to 0.18. In case of steel friction surface, the values were respectively from 0.68 to 0.46.

Granule resistance to dynamic loads of compression is presented in Fig. 4, where it can be observed that when the speed of the dynamic load is 3.0, 5.0 and 8.0 mm·s^{-1}, the numerical value increases depending on the amount of the binding material in the product (Fig. 4).

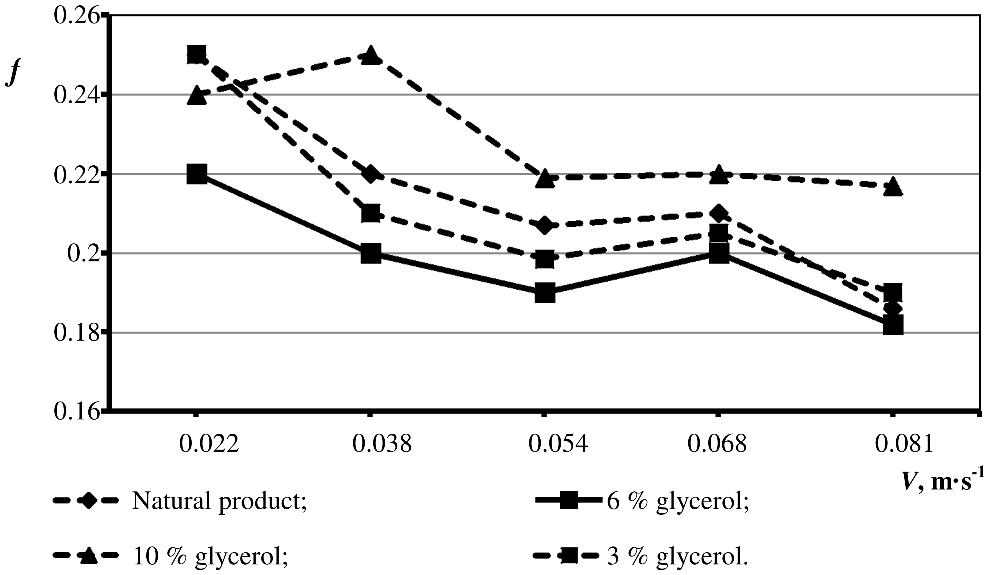

Fig. 2. **Dependence of the granule dynamic friction coefficient (*f*) on the velocity (*V*), when the friction surface is plastic**

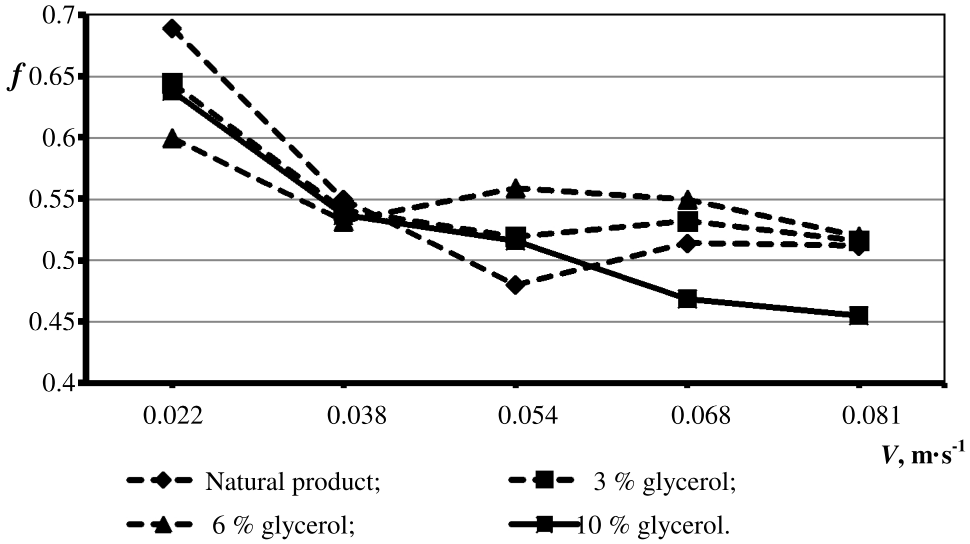

Fig. 3. **Dependence of the granule dynamic friction coefficient (*f*) on the velocity (*V*), when the friction surface is plastic**

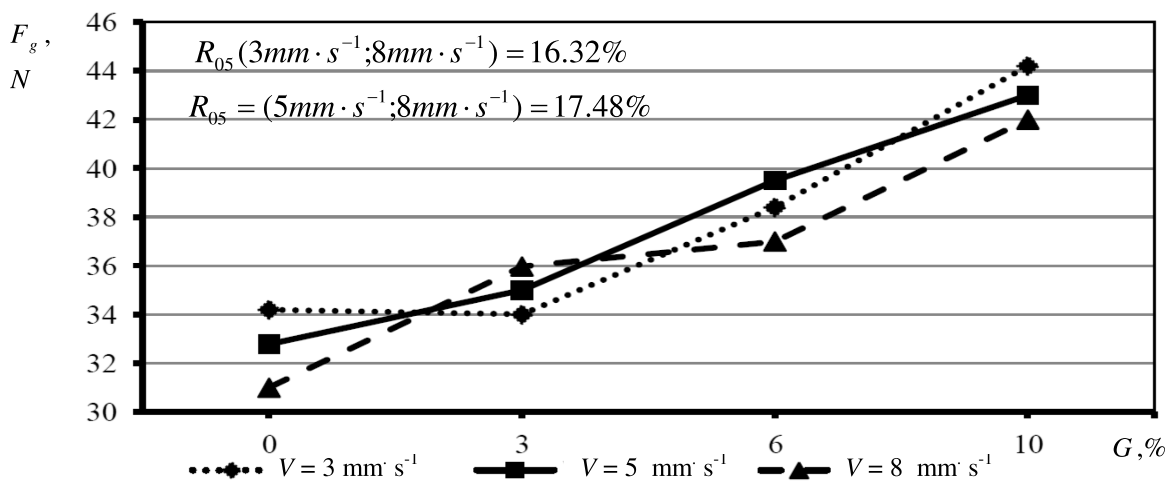

Fig. 4. **Dependence of the dynamic compression load (F_g) on the amount of glycerol in the material (*G*) with different velocities of load (*V*)**

This increase of compression load can be explained by increase of the density in the granulated object, and reduction of material porosity.

Conclusions

1. When assessing the suitability of brewer's grains for granulation, it has been established that this organic waste dried up to 10-12 % content humidity may be granulated using traditional feed granulators. The very process of granulation does not require any special equipment.
2. In the course of research, brewer's grains – the waste produced in the brewery process – were used for producing a granulated product that has a higher nutritional value, better energy and physical as well mechanical properties.
3. The technology of producing brewer's grains granules is environmentally safe and allows for efficient utilization of the main waste produced in the brewery process.
4. The studies have shown that increasing the content of glycerol, the binding material used in the material being granulated, results in changes in the nutritional, energy value of feed as well as its physical and mechanical properties; increased density of granules; different crumbles and fall angles; and changes in the coefficient of dynamic friction. This is due to different product rheological properties, and kinetics of granule formation.

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