RESEARCH IN BREWER'S SPENT GRAIN DRYING PROCESS

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Abstract. The treatment of organic solid waste is currently a growing area of investigation. Brewers' spent grain (BSG) is the major by-product of the brewing industry, representing around 85 % of the total by-products generated. BSG have food characteristics and are available in large quantities throughout the year. While BSG contain significant energy resources from their organic contents, they have some major problems such as high moisture and nutrient content, handling difficulties. Drying has been the most effective method of preserving BSG and to prolong the storage time. Drying also reduces the product volume, and decreases transport and storage costs. In this paper we compared two drying methods: drying by free convection and drying by forced convection (ventilation). The results show that the BSG drying with free convection permitted only a thin layer with a periodical or continuous regular mixing. Ventilation is more efficient BSG drying method and can be applied in a thicker layer with lower temperatures. It is an effective way for BSG drying in small beer brewing companies, particularly if previously free water separated.

Keywords: drying, spent grain, free convection, ventilation.

Introduction

As a step towards achieving the status of green environmental policy and cleaner technology approach, diversification of huge waste production and environmental preservation have focused attention on the recycling and preservation of bioresources including the brewer's spent grain (BSG). However, time, location and composition, environmental effectiveness, technological feasibility, social acceptability and economical affordability are among the key challenges associated with reliable and sustainable utilization of BSG.

According to Gunter Pauli of the Zero Waste Research Institute 92 % of brewing ingredients are wasted. Most of the waste is BSG that still have lots of useful protein, fat and fiber [1-3]. BSG (beer dregs) are the major brewery by-product with difficulties and potential in disposal. BD are composed by dry weight of dry matter (26.3 %): crude protein (23.4 %) and crude fibre (17.6 %) [4]. The treatment of organic solid waste is currently a growing area of investigation as new options are explored. Since BSG is a beverage industry waste having food characteristics, it is thought that this waste can be used in agriculture due to its high organic matter.

Beer residue can be used in animal feeding, primarily for beef cattle, dairy cows and also for pigs, goats, birds, fish, and just about any other livestock. It is quite tasty and ready for consumption by animals [5; 6]. It is a water-soluble vitamin. However, it has bulky food sources and low-energy components. These materials are considered to be good sources of undegradable protein and water soluble vitamins. The protein content is relatively high and lower rumen degradation than other vegetable sources, so it is often used in dairy and beef cattle that require additional protein rumen escape. Cancellation of protein in the rumen lower dry beer residue is directly related to the amount of heat in the drying process.

Brewers' spent grain, because of the high nutritive value, have been evaluated for their usage in the manufacture of breakfast cereals, bread and other baked goods, and snacks. Unfortunately, brewer's spent grain usually must be milled into flour before use in food products because the grains are too coarse otherwise [7]. Up to 15 % addition of BSG was acceptable for addition into cookies and did not significantly alter the organoleptic properties [8].

According to the International Soil Conservation Organization, 65 % of the world's soil is degraded. Directly staunching the causes of topsoil loss (poor agriculture and forestry practices) may be difficult for brewers, but compost is an effective and accessible way they can help revive soil health [7; 9]. Spent grain compost can also be used as a growing medium for mushrooms [10].

The usage of brewers spent grain (BSG) to create biogas is typically seen with larger brewers. However, with advances in technology and fermentation techniques, smaller brewers are now able to take advantage of biogas. However, even with advances in technology, the start up costs are high (possibly prohibitive) and the payoff does not justify the effort [10].

The low amount of ash coupled with the high amount of fibrous material (lignin, hemicellulose and cellulose) makes BSG suitable for use in building materials. It is specified that finished bricks produced with BSG have a characteristic higher strength, higher porosity (higher water absorption capacity) and a lower density, which give them better properties of thermal insulation than those produced from similar production clay [11; 12].

New research into the polyphenolic compounds found in hop, used in beer brewing, has successfully identified the anticaries and antiperiodontitis properties [13; 14].

While BSG contain significant energy resources from their organic contents they have some major difficulties in a sustainable energy balance: wet BSG contain 77-81 % [3; 11]. Due to the high moisture and fermentable sugar contents, BSG is a very unstable material and is liable to deteriorate rapidly due to microbial activity.

Several methods have been proposed to prolong brewer's spent grain (BSG) storage time as a result of their high moisture content. Drying is a possible alternative for BSG preservation with the advantage that it also reduces the product volume, and therefore, decreases transport and storage costs [15].

From all current research done by the Richards Engineering Group Ltd, it was discovered that marketing spent grain instead of wet spent grain, provide a higher margin of return. Drying and milling spent grain into flour is also necessary if we want to bake them into favorite cookies, or dog biscuits. It is also better to dry the spent grain if one wants to feed animals with them [10].

The traditional process for drying BSG is based on the use of direct rotary-drum driers, a procedure considered to be very energy-intensive. In oven drying, there is a risk that the grain temperature near the dryer exit may rise leading to toasting or burning of the dried grains. Thin layer drying using superheated steam was proposed by Tang et al. [16] as an alternative method. The circulation of superheated steam occurred in a closed -loop system; this reduces the energy wastage that occurs with hot air drying and gives additional advantages including reduction in environmental impact, improved drying efficiency, elimination of fire or explosion risk, and enhanced recovery of valuable organic compounds.

Steadily rising prices for fossil fuels such as oil or gas due to limited availability and increased global demand should encourage breweries to intensify their efforts towards the utilization of renewable energies. The Best Available Techniques Reference Documents (BREFs) published by the EU commission in the context of Integrated Pollution Prevention and Control also stipulate the efficient use of energy, sustainable utilization of raw materials and systematic reduction of emissions and effluents.

This paper compares the brewers' spent grain drying dynamics using free convection and forced ventilation with warmed air.

Materials and methods

We used the brewery "Valmiermuiža" spent grains (dregs) with humidity of 76 %. Dregs were placed in cassettes with a mesh base and a layer thickness of 2.5 cm each. Cassettes were placed one on another. We used two-layer thickness: 7.5 cm thick (3 cassettes)) and 10 cm thick layer (4 cassettes). These cassettes were placed in the heating cabinet "MEMMERT" and dried at a temperature of 60 degrees, Fig. 1 b). The moisture content of the beer dregs was identified by gravimetric measurement in time intervals. The samples were weighed on the digital laboratory balance KERN-440-35N with maximum load weight 400 g and with resolution 0.01 g. We weighed each cassette in the same 2 layer (for each thickness) and the change in weight was expressed per 100 g of material. We take average of this value and the difference was less than 1 %. The total drying time was adapted to the need for determination of the final moisture content. The MEMMERT drying cabinet provides assigned temperature regimes.

The forced ventilation experiments took place in "Grain drying and storage scientific laboratory " of the Latvia University of Agriculture in July 2014. There is used laboratory facility Fig. 1 c), which provides constant operating conditions. The experiments were performed with two different thicknesses BSG (5 cm and 12.5 cm, respectively 2 and 5 cassettes) and temperatures 35 ºC and 52 ºC.

Weight and temperature were fixed every 30 minutes. The dry matter content was determined by heating the samples to 133 degrees, while there were no changes in weight [17]. Moisture was calculated on 100 grams in order to compare the different weight cassettes.

Results and discussion

We compared two types of drying: drying with free convection and drying by forced convection (ventilation).

1. Drying with free convection

The research aim was to investigate dreg drying using only free convection. We compared two different layers drying (7.5 cm or 3 cassettes and 10 cm or 4 cassettes). The both layers were dried at 60 ºC, which does not reduce the nutritional value.

a) b) c)

Fig. 1. **Material and experimental equipment:** a) dried beer dregs, b) cassettes with beer dregs in drying cabinet "EMMERT", c) beer dregs drying by ventilation

The average amount of water removal per 100 g of product for each layer, depending on the drying time, can be seen in Fig. 2 and Fig. 3. It can be seen that the layer in direct contact with the environment in the drying cabinet (cassette 1 (top) and the cassette 4 (bottom) dries best). Moisture changes in the middle layer are negligible. After 20 h of drying of the upper and lower layers there is of the average 24.8 g water removal from 100 g spent grains, compared with 4.7 g of the average in the middle, Fig.2.

The same occurs in the thinnest layer, Fig. 3. Here, too, the drying of the lower and upper layer occurs most actively than of the middle layer. Layer thickness reduction allows the top and bottom layers dry faster. Comparing 7.5 cm and 10 cm thick layers after 20 h of drying, water removal from the top and bottom 2.5 cm thick layers is more than 16 % for the 7.5 cm thick layer than the 10 cm thick layer. This could be explained by the diffusion of water from the middle layer on either side.

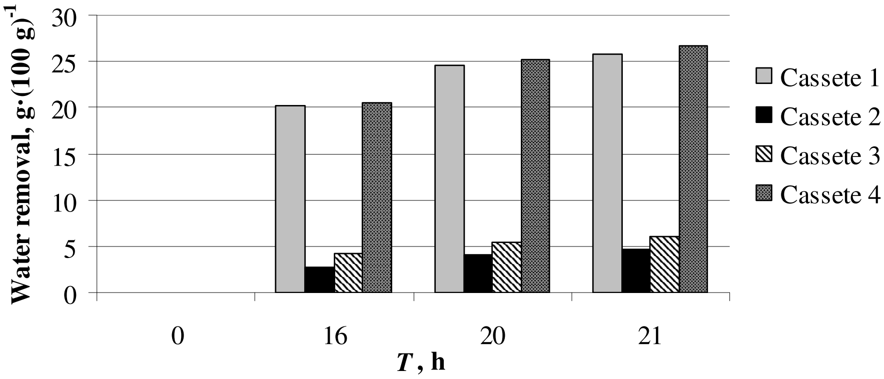

Fig. 2. **Average moisture removal from 4 cassettes in 10 cm thick layer depending on the drying time *T***

The results show that the dregs drying with free convection is permitted only to a thin layer with periodical or continuous regular mixing, which prevents clumping and speed up drying. This is explained by sintering of the spent grain during drying, which prevents the diffusion of moisture from deeper layers.

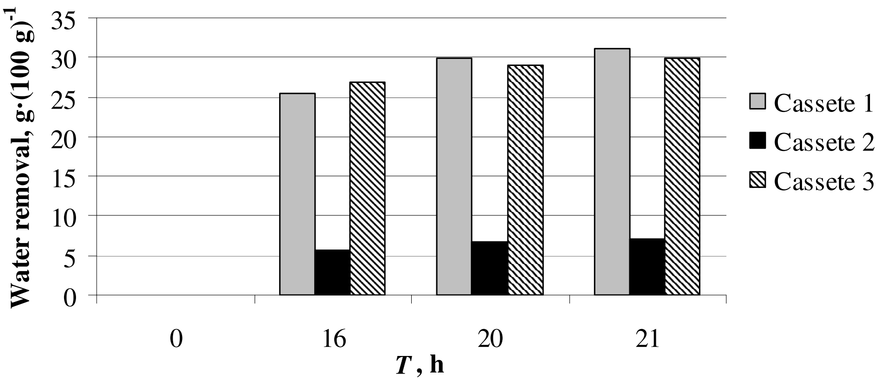

Fig. 3. **Average moisture removal from 3 cassettes in 7.5 cm thick layer depending on the drying time *T***

2. Drying by ventilation

In order to improve the efficiency of drying brewing grains, they were dried by forced ventilation. Air velocity in the layer was 3.2 ± 0.2 ms^{-1}. Two thickness (5 cm and 12.5 cm) layers of drying are compared.

It is seen that 100 grams dregs weight changes during drying at 35 ºC (Fig. 4). Fig. 5 shows the moisture migration of each of the 2.5 cm thick layers (cassettes). It can be seen that the lower layer dries most rapidly.

Water removal from the bottom layer in the first 30 minutes is the most effective and reached up to 70 g of water per 100 g drying material at 52 ºC. Moisture removal in the following 30 min rapidly falls and is only 6g and the next time shows that the lower layer has practically dried, material weight changes are practically not seen, Fig. 5.

The experiments showed that the upper layer (10-12.5 cm) dries faster (moisture removal dynamics are more) than the previous (7.5-10 cm) layer, Fig. 5. It can be explained by the moisture gradient difference in the boundary between the 2 material layers and the layer with the environment.

During the first 30 min of drying, the difference of moisture removal was 3.7 g, in the next half hour it reached 9.2 g, in the third half hour the difference decreased to 3.9 g but at the fourth half-hour of drying moisture removal from the lower layer had decreased by 2.7 g compared with the previous one. This indicates that the environment does not affect the top layer drying much.

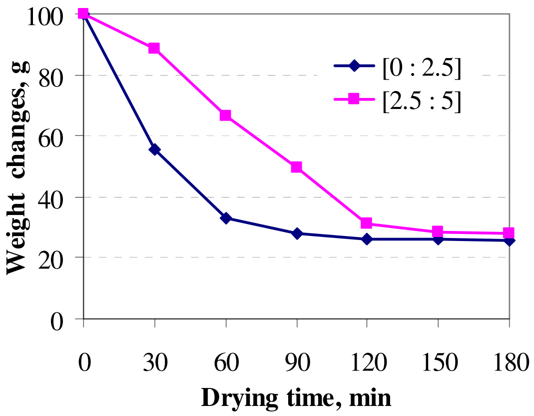

Fig. 4. **Beer dregs layers weight changes during venting with temperature 35 °C**

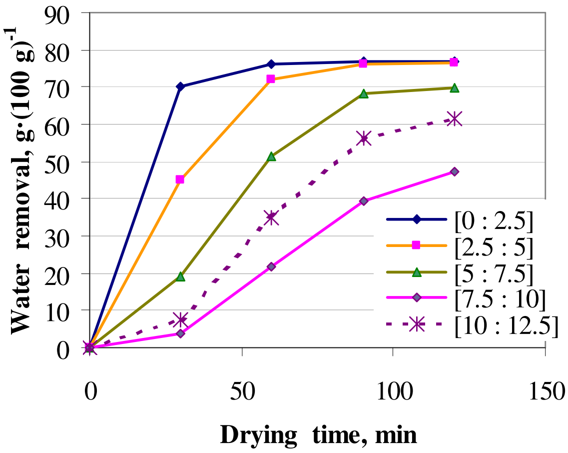

Fig. 5. **Average amount of water removal from beer dregs layers by venting with temperature 52 °C**

Looking at drying at 35 ºC it can be seen that in the first 30 min of drying water removal from the bottom layer was 4 times more than from the top layer, (Fig. 4). Continuing drying, the moisture removal dynamics difference decreases and in the next 30 min it was already equal – 22 g per 100 g product. After 2 hours of drying it can be seen that all the material is practically dried.

The drying temperature also significantly affects the drying rate. Comparing the effect of temperature on moisture removal dynamics of the first layer in the first 30 minutes of the experiments it follows that increasing the drying temperature by 1 degree C water removal increased by 1.49 grams per 100 grams of product (BSG).

Conclusions

1. Wet BSG drying with free convection goes very slowly. After 20 h of drying at 60 ºC the upper and lower 2.5 cm layers lose 24.8 g water in average from 100 g spent grains, compared with 4.7 g in the middle.
2. Increasing the temperature from 35 to 52 degrees average water removal by ventilation from the 2.5 cm thick layer changes from 55g to 70 g water per 100 g wet material during 30 minutes of drying. The 5 cm thick layer dried up in 2 hours at 35 degrees Celsius by ventilation.
3. The experimental results show that active ventilation can be used for BSG drying in small beer brewing companies. Surplus heat received from beer production can be used for ventilated air heating. The drying efficiency can be increased if the brewer's spent grains are previously exempt from free water.

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