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An overview: Recycling of solid barley waste generated as a by-product in distillery and brewery

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ABSTRACT

This overview has focused on the options available for the utilisation of residual-biomass generated in distillery and brewery for the production of added-value products. Bio-processing approaches have been reviewed and discussed for the economical bioconversion and utilisation of this waste for the production of bioproducts, such as lactic acid, enzymes, xylitol and animal feed. Though this overview provides several options for the bioprocessing of this residual material, a more suitable one could be chosen according to the processing-facilities available and the amount of residue available in local area. The feasibility of any chosen process should be evaluated on the basis of cost of material available, its local utilisation for animal feed, and the overall economical advantages that could be gained by changing its current traditional landfill use to produce higher added value products.

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1. Introduction

The distilled-spirits industry has a large market in various countries producing distilled alcohol (spirit) for several products, such as whisky, gin, rum, brandy, and for different mixed-recipes. Similarly, another important industry is brewing, which produces a large volume of beer annually. The main ingredient used as the raw material for the production of potable alcohol in both industries, is barley grains. In a conventional production process, barley grains are mashed and fermented to produce an alcohol/water solution that is then distilled to concentrate the alcohol, if it is used for making spirit. A summarised description of the process is that

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Fig. 1. BSG sample from Bushmills Distillery, Northern Ireland, UK (http://www.bushmills.com).

first the barley grains are ground to a coarse flour or 'grist' that is then mixed with hot water in a large mixing vessel, or a mash tun, to produce a sweet liquid called 'wort'. The sugars in the wort are essential in obtaining alcohol in the next stage. Yeast is added to this sweet malty liquid wort, which starts alcoholic fermentation for the conversion of the wort's sugars into alcohol (http://www.bushmills.com). The use of barley in this process generates a substantial amount of residual by-product, generally referred as spent barley grains (BSG).

It is a significant by-product in the overall brewing process, accounting for approximately 85% of total by-products, contributing to on average 30–60% of the biochemical oxygen demand and suspended solids (Fillaudeau et al., 2006). BSG is generated on average 31% of the original malt weight, therefore, it is necessary to overview all options available for the recycling of this residue for the economical processing and bioconversion into added-value products.

Fig. 1 shows BSG collected from a local licensed distillery – The Old Bushmills Distillery, Northern Ireland (http://www.ballycastle.info/places/distillery/distillery.htm). This solid residual material BSG is being used as a substrate in one of our current biotechnology research projects.

2. Recycling of BSG

The significant quantity of this by-product generated in distilleries and breweries can be utilised as a valuable bioresource, which is produced annually in many countries. The traditional method used at many places is composting, which is a simple low-cost treatment for the utilisation of this residue.

Composting is also an environmentally acceptable technology to convert this material into useful agricultural product, thereby eliminating profitless conventional landfilling. For composting purpose the nitrogen deficit in barley wastes can be supplemented with a co-composting material such as solid or liquid poultry manure (Guerra-Rodríguez et al., 2006). EU legislation, through the Council Directive 1999/31/EC, states that the amount of biodegradable organic waste that is disposed in landfills should be decreased by 65% by July 2016, relatively to the total amount of organic fraction of municipal solid waste (OFMSW) produced in 1995 (Neves et al., 2006).

Therefore, there is a great political and social pressure to reduce the pollution arising from industrial activities. Almost all industries in developed and developing countries are working to act on this issue by modifying their production strategies so that the by-products and residues of production system can be recycled, emphasizing to the point of focus on **"Reuse and not to waste"**. Consequently, most large companies no longer consider residues as a **"waste"**, but as a **"raw material"** for their use in other processes (Mussatto et al., 2006; Nigam and Pandey, 2009a,b; Ward and Nigam, 2009).

The barley wastes can be used as a carbon source in fermentation for microbial-biomass cultivation, production of microbial-enzymes, sugars, proteins, organic acids, antioxidants and food additives (Nigam and Luke, 2016), or simply as an adsorbent for removing organic materials from effluents and immobilization of various substances (Aliyu and Bala, 2010). There have been several efforts made to find an alternative use for barley waste. This overview describes the possibilities of utilisation of the barley waste for few value added products, the current knowledge for its bioprocessing is mainly focused for its bioconversion into animal feed, production of value-added compounds, such as xylitol, enzymes and lactic acid (Fig. 2).

3. Added-value products

Currently, there is an increased focus on minimizing the wastes generated by industries. In this overview, we have focused on two large-revenue industries – Distillery and Brewery, both generate a large amount of residual-mass; in form of brewers' spent grain (BSG). The production of BSG in Europe itself is approximately over 3.4 million tons (Stojceska et al., 2008). BSG is the most abundant brewing by-product, comprising of 85% of the all by-products generated, 31% of original malt weight and 20 kg per 100 l of beer produced. Therefore, a significant amount of this by – product is available for the potential production of bio-industrial product, such as ethanol through biotechnology, but in many regions its conventional reuse is still as animal feed, or landfill refuge (Buffington, 2014).

With respect to animal feed, BSG has been found to be an excellent feed source for ruminants. Beyond its reuse as an animal food product, some of its components could be useful as precursors for

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