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Review

Antimicrobial colorants in molasses distillery wastewater and their removal technologies

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A B S T R A C T

Molasses is a widely used feedstock in the bioethanol distilleries, which generate the dark colored wastewater known as molasses distillery wastewater (MDWW). This type of wastewater leads to pollution problems in the local environment where it is disposed of due to the high content of pollutants, among which colorants are of great concern. The main MDWW colorants are polyphenols, melanoidin, alkaline degradation products of hexoses, and caramels whose formation, concentration and antimicrobial effects are summarized in this review. A lot of efforts have been made in the community to remove the colorants. Effective treatment methods are discussed, including biological treatment, enzymatic treatment, chemical oxidation, and coagulation. These technologies could also be applied to remove the colorants as a final treatment step after the anaerobic digestion.

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1. Introduction

Sugar molasses is a viscous dark brown liquid by-product which is generated in the sugar production process with sugarcane, grapes or sugar beets. The main application of molasses is the bioethanol production, which in turn produces a lot of wastewater, called molasses distillery wastewater (MDWW) or vinasse. Bioethanol is increasingly used as an alternative fuel because of the high global fuel demand and the need to reduce greenhouse gas emissions. The worldwide production of bioethanol was above 50 billion litres in 2007 and over 60 billion litres in 2008 which represents almost 4% of world gasoline consumption (Sanchez and Cardona, 2008; Balat and Balat, 2009; Mussatto et al., 2010). The demand for bioethanol is projected to rise beyond 120,000 million litres in 2020 (Demirbas, 2007). Assuming that 40% bioethanol came from sugarcane and sugar beet sources (Mussatto et al., 2010) and a 1:10 ratio of bioethanol to vinasse in the production, the world sugarcane/beet MDWW can be estimated to be over 200 million tons in year 2007. India, the fourth largest world producer of bioethanol, exclusively uses sugar molasses as raw material for bioethanol production. The same applies to most bioethanol producing countries in the tropics (Sanchez and Cardona, 2008). In the Mediterranean region and in parts of Europe, sugar beet and beet molasses are also used to produce bioethanol. Recent advances in technology like the application of surface-engineered yeast and whole cell biocatalysis are expected to boost bioethanol production in the future (Fukuda et al., 2009).

The disposal of MDWW is problematic due to its high content of pollutants: 50–100 g/l chemical oxygen demand (COD), >50 g/l total dissolved solid (TDS), and strong acidity (pH 4–6). In addition, it has a strong odour and a dark brown color. All these characteristics, plus the high daily production volume, could cause potential environmental problems unless appropriate treatment processes are applied. On the other hand, MDWW also contains a lot of nutrients: ~1000 mg/l total nitrogen, ~100 mg/l total phosphorus, and >4000 mg/l potassium (Espana-Gamboa et al., 2011), which might point to advantages of MDWW being used as an agricultural fertilizer. However, this application is questionable due to the acidic pH, strong dark color and other chemical substances which may lead to groundwater contamination and soil compaction (Gemtos et al., 1999). In addition, molasses has also been applied as a cheap carbon source in white biotechnology, e.g., the production of yeast (Ferrari et al., 2001), lactic acid (Nandasana and Kumar 2008), pharmaceutical intermediates (Olbrich, 1963; Küçükaşik et al., 2011), and enzymes (Chapla et al., 2010). These production processes generate wastewater with similar characteristics to MDWW (Mutlu et al., 2002). As a result, the effort to tackle the problem of MDWW will be beneficial to these industries as well.

This review will discuss the properties of the main MDWW colorants, including their formation, concentration and antimicrobial effects. Finally, some technologies for the removal of those colorants will also be discussed.

2. Cane MDWW generation and characteristics

The entire process of MDWW generation from raw cane reeds is shown in Fig. 1 where the data is calculated from publications (Olbrich, 1963; Wilkie et al., 2000; Sirianuntapiboon and Prasertsong, 2008; Espana-Gamboa et al., 2011; Yadav and Chandra, 2012). First, the sugarcane is milled and sugar is extracted with water. The solid semi-cellulose by-product called bagasse is used as boiler fuel or treated for fermentation. The sugar extract is heated and most of the water evaporates. The supersaturated solution is passed through a crystallizer where the sugar is crystallized and recovered. The effluent after a maximum of three crystallization steps is called molasses, which contains a high content of sugars

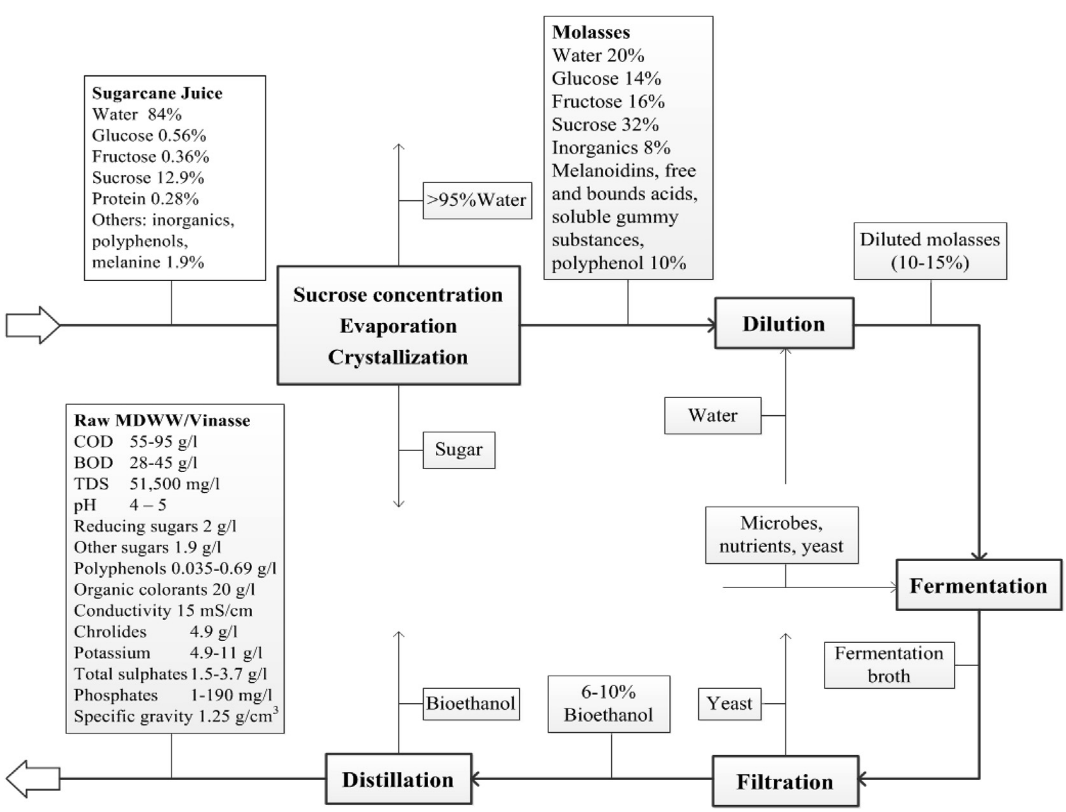

Fig. 1. The general process from the sugar extraction to the MDWW generation.