Renewable and Sustainable Energy Reviews 26 (2013) 521–531

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Food processing waste: Problems, current management and prospects for utilisation of the lignocellulose component through enzyme synergistic degradation

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ARTICLE INFO

Article history:
Received 29 January 2013
Received in revised form
3 June 2013
Accepted 16 June 2013
Available online 5 July 2013

Keywords:
Enzyme
Fruit waste
Lignocellulose
Pectin
Polysaccharide
Synergy

ABSTRACT

Waste from the food processing industry (e.g. juice production) is produced in large quantities worldwide and contains high levels of lignocellulose. To some extent, value-added products are extracted from this waste, but the majority of the waste is currently unutilised and discarded. Energy generation from this waste has been investigated in the form of production of biogas, hydrogen and bioethanol. Efficient bioethanol production requires the enzymatic hydrolysis of the total polysaccharides within this waste into monomer sugars for further fermentation into ethanol. Factors limiting this process are the complexity of the lignocellulose, its recalcitrance and insolubility and the number of enzymes required to degrade it. Obtaining complete enzymatic hydrolysis of these substrates requires an understanding of the composition of the polysaccharides and their associations within the overall substrate. This will allow appropriate selection of enzymes. It has also been established from work on other lignocellulose substrates that the associations between polysaccharides pose an obstacle to their hydrolysis and cooperative enzyme interaction is required to overcome these obstacles. With respect to the enzymatic hydrolysis of food waste, the knowledge gaps have been identified as: (1) accurate knowledge of the polysaccharide composition and structures; (2) knowledge about the associations that exist between different polysaccharides; (3) and the enzymes required for hydrolysis of the overall polysaccharide component and the synergistic interactions between these enzymes. This review investigates these aspects in literature, exposing the gaps in knowledge, while making proposals for future work that could assist in the utilisation of food waste, through enzyme synergistic degradation, as a potential feedstock for biofuel production.

Contents

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1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2013.06.016

1. Introduction

Large quantities of waste material are generated annually from agricultural activities and processing of agricultural products. This includes wastes such as corn stover, sugarcane bagasse, rice and wheat straw, many of which are currently under investigation as potential feedstocks for value-added products such as bioethanol production. However, a different category of waste from the food processing industry remains largely underutilised and should be investigated for further beneficiation. Examples of such wastes include citrus, apple and grape waste, often referred to as pomace, as well as sugar beet pulp remaining after processing of sugar beet. These wastes contain high levels of polysaccharides which could potentially also be utilised for production of bioethanol.

Food processing wastes are produced as solid and liquid wastes. The solid waste is the portion of the starting material that cannot be utilised in the production of the intended products, such as the skins, pips and fibres of fruit which are removed in the production of juice. This review will only focus on solid waste, as the polysaccharides are found mainly in this waste type. Significant volumes of solid waste are produced globally from just a few of the main food processing industries (see Table 1).

1.1. Current management of food processing waste

Solid waste from food processing is currently managed in various ways. Many factories simply dump the waste close to the plant. Since these wastes have high nutrient levels and water content and can support bacterial growth and fermentation, these may cause odours and other environmental problems [11,12]. In some cases, the waste may be transported to a landfill site for disposal, which could lead to additional costs as some countries may charge landfill disposal fees [12]. It is estimated, for example, that $10 million is spent annually on the disposal of apple pomace in the USA [13]. Occasionally, waste disposal may take place through incineration. However, the energy input is costly due to the low calorific value and the high water content [12]. Incineration also results in air and environmental pollution [14].

A further means of disposal of food waste is through its utilisation as animal feed, mostly for cattle feed [12]. The waste may be dried and formed into pellets prior to sale as animal feed [15,3]. However, most food wastes have low protein content and are therefore not ideal for animal feed. High lignin content in some wastes, for example olive waste and sugarcane bagasse, also limits utilisation as animal feed as it makes the waste difficult to digest [12]. Different wastes have different potentials for use as animal feed. For example, potato waste is very high in potassium and can therefore only be utilised for cattle feed as it is not suitable for other animals [12]. Where wastes are dried prior to being used as animal feed, additional costs may be incurred, which are rarely recovered from the cost of sales. The use of apple pulp, particularly, as an animal feed is limited due to its rapid spoilage unless drying can take place immediately after processing [11]. Protein content and digestibility of pomace may be enriched through growth of microorganisms (such as *Pleurotus ostreatus* and *Candida utilis*), on the pomace which makes it more suitable for animal feeding [16].

Food waste can also be utilised as a soil conditioner or fertiliser [17]. This can be done through spreading of the untreated food waste on the soil, thereby increasing the organic content and microbial biomass of the soil. Tomato waste and olive husks have been utilised in this manner. Citrus waste contains compounds

Table 1
Reported quantities of fruit and vegetables produced worldwide and the waste generated as a result. Waste figures are approximate and based on literature reports of the percentage of the original fruit or vegetable that is not utilised for generating products such as juice. (MT=metric tons).

Fruit/vegetable	Total global production in 2010 [1]	Approximate waste produced in 2010	Reference
Apple	69 569 612 MT	Approximately 25–35% of the dry mass is waste – 17,392,403–24,349,364 MT	[2]
Citrus: Grapefruit	6,957,837 MT	Approximately 3,478,918 MT of Grapefruit waste	[3]
Citrus: Lemons and limes	14,244,782 MT	Approximately 4,985,673 MT to 6,410,151 MT of waste (half of the fruit)	[4]
Citrus: oranges	69,416,336 MT	Up to 70% of global production is used in the manufacture of juices, marmalades, etc. Between 50% and 60% of the fresh fruit weight are waste – 24,295,717 MT and 29,154,861 MT of waste	[3]
Sugar beet	228,452,073 MT	For every 1 t of Sugar beet processed, 70 kg of exhausted dried pulp or 250 kg of exhausted pressed pulp are produced. This equals 22,845,207 MT of dry SBP or 57,113,018 MT of pressed SBP.	[5]
Olive	20,578,186 MT	For every 100 kg of olives processed for oil, between 50 kg and 110 kg of "Black water" (runoff rich in antioxidants and protein) is produced. Approximately 20% of the olive fresh weight will be the endocarp fragments - 3,704,073 MT of olive endocarp waste.	[6,7]
Grapes	68,311,466 MT	Approximately 10,929,834 MT of grape pomace was produced (20% of grapes become pomace in winemaking)	[7]
Banana	102,114,819 MT	30–40% waste	[8], [9]
Pineapple	19,418,478 MT	40–80% waste. At 45% waste, 8,738,315 MT of waste is produced every year.	[10]
Potatoes	324,181,889 MT	Peel waste can be between 15% and 40% depending on the processing method used. This will approximate to 48,627,283 MT and 129,672,755 MT of waste generated annually.	[7]
Tomatoes	145,751,507 MT	In the processing between 3% and 7% is lost as waste. Approximately 4,372,545 MT and 10,202,605 MT of waste were generated in 2010.	[7]