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Perspective of apple processing wastes as low-cost substrates for bioproduction of high value products: A review

Gurpreet Singh Dhillon [a,*], Surinder Kaur [b], Satinder Kaur Brar [a]

[a] INRS-ETE, Université du Québec, 490, Rue de la Couronne, Québec, Canada G1K 9A9
[b] Department of Mycology & Plant Pathology, Institute of Agricultural Sciences, Banaras Hindu University (BHU), Varanasi 221005, India

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ABSTRACT

The fruit processing industries are experiencing surge due to the increasing demand of food products as a result of burgeoning human population. Apple and apple products are one of the major fruit and fruit products consumed all over the world. Apple processing industries generate huge quantities of solid and liquid sludge wastes. The solid residues consist of a mixture of skin, pulp and seeds derived from the production of concentrated apple juice, jam, and sweets and are collectively known as 'apple pomace'. Being highly biodegradable, the disposal of these wastes represents a serious environmental problem and presents many challenges. Often only 20% is retrieved as animal feed and the rest 80% goes to landfill, is incinerated or is sent to composting sites which results in release of greenhouse gases. However, advancement in technology has led to the alternative options of utilization of apple pomace. It can be used as a promising raw material for direct extraction of bioactive compounds and bioproduction of high value-added products, such as enzymes, organic acids, biofuels, among other products. This article reviews the work done for value-addition of this precious biomass which can help in setting up integrated process in the existing apple industries itself or separate small scale industries.
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Abbreviations: AP, apple pomace; APS, apple pomace ultrafiltration sludge; BGL, β-glucosidase; CA, citric acid; CM, codling moth larvae; CTS, chitosan; GHGs, greenhouse gases; GRAS, generally recognized as safe; FDA, Foods and Drug administration; LA, lactic acid; TCA, tricarboxylic acid cycle; SmF, submerged fermentation; SSF, solid-state fermentation; SCP, single cell protein; WHO, World Health Organization; VAPs, value added products

* Corresponding author. Tel.: +1 4186544472.
E-mail addresses: garry_dhillons@yahoo.com, garrydhillons9@gmail.com (G.S. Dhillon).

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1. Introduction

Agro-based industries, especially apple processing industries, are experiencing a surge in their growth around the globe. This enormous increase in fruit processing has been generating million of tons of agro-industrial wastes worldwide. Every year, thousands of tons of apple pomace (AP) and apple pomace sludge (APS) are generated by apple processing industries in Canada. In 2008–2009, worldwide apple production exceeded 69,603,640 tons [Food and agriculture organization (FAO) of the United Nations, http://faostat.fao.org] out of which Canada contributed 455,361 tons (Table 1). This growth in turn has generated several million tons of wastes [25–30% solid pomace waste and 5–10% liquid sludge] during the processing of apple products, such as apple juice, jelly and cider, among others (Fig. 1). The direct disposal of agro-industrial by-products as a waste in the environment represents a major cause for environmental pollution and also an important loss of biomass which could be used for the production of different high value products. Nowadays, there is an increasing global trend towards the efficient utilization of natural resources. Sustainable food production and value-addition of wastes is the most important issue in the agro and food processing industries.

AP and APS being rich in carbohydrates and other vital nutrients and having high moisture content (70–75%, pomace), biodegradable organic load [high biological oxidation demand (BOD) and chemical oxidation demand (COD) values] are highly susceptible to microbial attack. For instance, the BOD of APS is 72,000 mg/l and the BOD to COD ratio is high (0.6), and AP has high COD value of 250–300 g/kg which indicates their high biodegradable nature [151,44]. It starts fermenting directly on the filter press during juice extraction. The wastes generated from the fruit processing industry cannot be directly dumped into the environment. These by-products must be managed properly in order to avoid their noxious effects. AP represents significant waste sources in many countries, as globally, several million tons of AP are generated annually. The management of agro-industrial wastes is a serious problem in the world [37,38].

Currently, these by-products are treated in traditional ways, such as landfilling, incineration, composting, low quality animal feed and land spreading. The dumping of these by-products can have several adverse impacts: (1) produce greenhouse gases (GHGs); (2) source of secondary pollution, such as emit foul smell due to microbial attack, and land spreading results in contaminated underground water table due to run off in rainy seasons; (3) negative effects on human health as the landfills and land spreading create breeding grounds for many human disease vectors which can cause epidemics; and (4) the industries incur losses due to treatment of waste and transportation costs for dumping into landfills, which is not cost-effective. Currently, only a small proportion of AP is utilized as a feed for the ruminants, added to soil as a fertilizer, and the large proportion of this inexpensive biomass goes to the composting sites and landfills, resulting in the release of GHGs and causing environmental nuisance and jeopardizing the health of people.

Nowadays, environmental biotechnology is emerging as a good option to tackle the adverse impacts of agro-industrial wastes. The use of agro-industrial wastes for bioproduction of valuable bio-products through microbial fermentation is economically important and can minimize various environmental hazards. AP and APS can be used as substrates for the microbial production of carboxylic acids, enzymes, biofuels, biopolymers and for the direct extraction of bioactive compounds, such as antioxidants.

Solid-state fermentation (SSF) also known as koji fermentation is gaining wide interest these days for the production of organic acids, enzymes and other biotechnological products [20,6,38–42,47,48]. Agro-industrial residues are generally considered the best substrates for koji fermentation processes, especially for

Table 1
Apple production and estimated waste generation in Canada and worldwide.

Producer	Apple production (tons)	Production (year)	Estimated production of waste (tons) (25–30% AP and 5–10 % APS)
Canada	455,361	2009	113,84–136,61 (AP) 22,768–45,536 (APS)
(Québec)	(116,088)		(29,022–34,826) (AP) 5804–11,609 (APS)
World	69,603,640	2008	17,400,910–20,881,092 (AP) 3,480,182–6,960,364 (APS)

Source: [15,39,172].

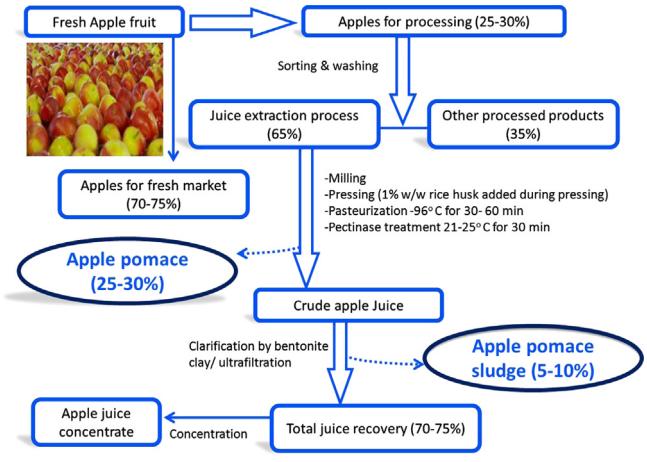

Fig. 1. Flowchart showing the production of AP and APS during processing of apples in the juice industry.

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