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Investigating the extraction of alcohol from agricultural wastes in Mauritius

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ABSTRACT

Bioethanol production from lignocellulosic biomass has been found to be a potential alternative to mitigate the alarming situation of increasing energy demand, fast consumption of fossil fuels and climate change. The objective of the study was to investigate the optimum conditions for the alcohol extraction process from vegetables and fruit wastes, which make up a large portion of agricultural waste in Mauritius. Focus was made on the different process parameters affecting the hydrolysis and fermentation processes including acid concentration and biomass loading and yeast concentration, pH, temperature and retention time, respectively, to achieve maximum alcohol yield. Dilute acid hydrolysis was found to be a safer and more efficient process compared to concentrated acid hydrolysis, despite its high sugar yield. An optimum value of 4600 mg reducing sugar per 100 ml hydrolysate was achieved after treatment with 5% (w/w) sulphuric acid and at a biomass loading of 20% (w/w). Yeast growth and enzyme activities were found to be optimum at a pH of 5.0 and a temperature of 33 °C when using 5% (w/v) SuperStart yeast (*Saccharomyces cerevisiae*), hence favouring ethanol production. Activated charcoal (10% w/v) was found to successfully remove inhibitors while keeping sugar degradation minimal. Therefore, under optimum extraction conditions, a maximum of 1.88% (v/v) ethanol yield could be produced after 80 h of fermentation. The study indicates that bioethanol production from agricultural waste could be a promising technology in Mauritius due to its low cost, abundance and renewable nature.

Introduction

With the growing energy demand and the rapid exhaustion of fossil fuel reserves, the quest for alternative energy resources is essential. A transition from the utilisation of petroleum-derived fuels in the transportation sector to renewable fuels, such as bioethanol, can be beneficial to society in many ways. Bioethanol has been found to be a prospective substitute to the polluting petroleum transportation fuel due to its renewable nature, reduction in combustion emissions and biodegradability [1]. Bioethanol is typically produced from various feedstock and technologies, which can be classified into first generation feedstock (sugar crops and cereal grains), second generation feedstock (lignocellulosic materials) and third generation feedstock (algae). Currently, bioethanol is mostly derived from expensive sucrose containing crops, such as sugarcane, in Brazil and starchy crops, like corn, in the USA which are known as first generation biofuel [2–4]. However, an increase in ethanol production from such crops would necessitate supplementary land. This would impact on the land available for food production and consumption, considering the rising demand for food as a result of the population boost. Moreover, the possible changes in climate may cause fluctuations in the price of fuel from these sources. Hence, the search for other potential raw material is becoming increasingly indispensable.

As a result, an increase in ethanol production will necessitate the use of lignocellulosic biomass, which is cheap and not directly tied to the food chain. Lignocellulosic biomass is mostly composed of cellulose, hemicellulose and lignin and is considered to be the most promising feedstock for alcohol production due to its abundance and great potential of about 280 l/t biomass [5]. Likewise, agricultural waste, a lignocellulosic feedstock, is considered to be a low valued material, clean and renewable alternative to fossil fuels. The latter has the potential to be transformed from high volume waste disposal environmental problems to a variety of eco-friendly and sustainable products, with the second generation liquid biofuels being the leading ones.

Agricultural wastes, especially those from market infrastructure, are more prone to spoilage due to their nature and composition, which produce an unpleasant smell if improperly

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disposed. As a consequence, reusing these valuable resources for product recovery would bring better return, avoid wastage, and at the same time regulate the market, industries or farm infrastructures. According to the World Energy Outlook 2012, fossil fuel represents the major source of energy and is expected to remain so [6]. However, when comparing the energy demand by fuel in 2010 with forecasts for 2035, it is assumed that countries will reduce their gas emissions by adopting more renewable energy sources [7]. The agricultural by-products can therefore play a crucial role to bring about the evolution to sustainable biofuels in order to reduce the burden on imported transportation fuels and solve disposal problem.

Agricultural wastes represent a higher potential source for low cost ethanol production than sugar crops, but only after being hydrolysed to fermentable sugars [8]. The main barrier for the extraction of alcohol from agricultural wastes lies in their rigid structure which resists degradation. The major steps involved in agricultural waste to bioethanol conversion process are the pretreatment, hydrolysis, fermentation and distillation. Consequently, the main aim of the research focused in investigating the extraction of ethanol from vegetable and fruit wastes, which make up a large portion of agricultural waste in Mauritius, in an ecofriendly and profitable way. The objectives were the efficient pretreatment of the waste, optimisation of the hydrolysis and fermentation process using sulphuric acid and *Saccharomyces cerevesiae* respectively, and detoxification of the hydrolysate using activated charcoal to yield maximum alcohol, and separation and purification of the fermenting medium for alcohol recovery.

Materials and methods

Feedstock collection and preparation

The vegetable and fruit wastes were collected from the local market and stored in plastic bags prior to its use and preparation of the extract. They were properly washed with tap water to remove foreign objects such as rocks, impurities and dirt. The leftovers consisted of equal masses of beetroot leaves and stems, cauliflower and outer cabbage leaves, and peeling and topping of pineapples. These wastes were chosen because of their wide availability and non-consumable aspects. The mixtures were homogeneous and dried in hot air oven at 60 °C for 24–48 h to aid preservation and storage.

Feedstock characterisation

Prior to the extraction, the wastes were processed for determination of approximate composition. The mixture was analysed for moisture content, amount of total solids, ash content, volatile matter, and lignin, hemicellulose and cellulose content. Each analysis was done in duplicate for comparison.

Pretreatment

The first step for alcohol production from agricultural wastes was size reduction. Shredding was found to give uniform pieces and improved the efficiency of the conversion process by

Table 1
Milligrams of reducing sugars required to reduce 10 ml Fehling's solution (Eynon and Lane's Method).

Ml Sugar solution required	Mg reducing Sugar per 100 ml solution, when concentration of sucrose is—									
	0	0.5 g	1 g	2 g	3 g	4 g	5 g	10 g	25 g	50 g
15.	336	335	333	329	325	322	317	307	289	275
16.	316	314	312	309	305	301	297	288	271	257
17.	298	296	295	291	287	284	280	271	255	241
18.	282	280	278	274	271	268	264	256	240	227
19.	267	265	264	260	257	254	250	243	227	215
20.	255	253	251	248	245	242	238	231	215	204
21.	243	241	239	236	233	230	227	220	206	194
22.	232	230	228	225	222	220	216	210	196	185
23.	222	220	219	216	213	210	207	200	187	176
24.	213	211	210	207	204	202	198	192	179	168
25.	205	203	202	198	196	194	190	184	171	161
26.	197	195	194	191	189	186	183	177	164	155
27.	190	189	187	184	182	179	176	170	158	149
28.	184	182	180	178	175	173	170	164	152	143
29.	178	176	174	171	169	167	165	159	147	138
30.	172	170	168	166	164	161	159	153	142	133
31.	166	165	163	161	159	157	154	148	137	129
32.	161	160	158	156	154	152	149	143	132	125
33.	157	155	153	151	149	147	145	139	128	121
34.	152	151	149	147	145	143	140	135	124	117
35.	148	147	145	143	141	139	136	131	121	113
36.	144	143	141	139	137	135	133	127	117	109
37.	140	139	137	135	133	131	129	124	114	106
38.	137	135	134	131	130	128	126	120	111	103
39.	133	132	130	123	126	124	122	117	107	100
40.	130	129	137	125	123	121	119	114	104	97
41.	127	125	124	122	120	118	116	111	102	95
42.	124	123	121	119	117	116	114	109	99	92
43.	121	120	118	116	115	113	111	106	97	90
44.	119	117	116	114	112	110	108	103	94	88
45.	116	114	113	111	110	108	106	101	92	86
46.	114	112	111	109	107	105	104	99	90	84
47.	111	110	108	106	104	103	102	96	88	82
48.	109	108	106	104	103	101	99	94	86	81
49.	107	106	104	102	102	100	97	92	84	79
50.	105	103	102	100	100	98	95	90	82	77
Calculated by extrapolation										