Valorization of restaurant food waste under the concept of a biorefinery

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Introduction

Food waste is an issue of importance to global food security and good environmental governance, directly linked with environmental (e.g. energy, climate change, water, availability of resources), economic (e.g. resource efficiency, price volatility, increasing costs, consumption, waste management, commodity markets) and social (e.g. health, equality) impacts. The total amounts of food produced in EU for 2011 were around 865 kg / person; this would mean that in total 20 % of the total food produced is wasted. Food waste derive from the following main sectors: primary production, processing, wholesale and logistics combined with retail and markets, food service and households. The food service sector generated almost 88 million tonnes (± 2 million tonnes) of food waste in the EU-28 during 2012. This corresponds to 173 kilograms per person (± 13 kg / person). Based on the normalisation factor used, the amounts are equivalent to 20 tonnes of food waste for every million Euro in turnover number (PPP adjusted). The amounts include the total food waste; that is both the edible and the inedible food waste are included. Thus, there is a pressing need to prevent, reduce and valorize food waste to make the transition to a resource efficient Europe.

Materials and Methods

The restaurant food waste (FW) utilized in the present study came from a typical Greek restaurant located in center of Athens. The biowaste was source separated and was transferred to the Unit of Environmental Science and Technology (UEST), School of Chemical Engineering, NTUA, where it was dried by a GAIA food waste dryer (model GC-100). The dried material was milled to an average particle size of 3 mm in a laboratory mill.

Oil extraction process

Oil extraction was carried out by the Sohxlet method, in a 500 mL Sohxlet apparatus, recirculating hexane for analysis CODEX (95% purity, J.T. Baker, from Merck) during four hours. Finally, hexane was removed by rotary evaporation under vacuum at 65 °C, until complete removal of hexane. Subsequently, oil content on a dry basis was calculated.

Enzymatic hydrolysis

Enzymatic hydrolysis of untreated and pretreated raw material solids (20%w/w) was performed in 250 mL Erlenmeyer flask. The initial pH of the mixture was around 4.8 and was not adjusted since it was within the range of optimum pH for the operation of the enzymes. The hydrolysis of starch in biowaste using NS22109 (amylase) was conducted at 65ºC for 1h in a water bath. Enzyme loadings of 110, 170, 220, 280, 560, 830 and 1120 μL/g starch were used. At the end of each experiment, the samples were analyzed. The performance of enzymatic hydrolysis was also evaluated based on the glucose yield (Y_G) (gg^{-1} of dry FW); Y_G was calculated using Equation (1), where G indicates the glucose concentration:

$$Y_G = \frac{(G_{final} - G_{initial})\ (g)}{\text{Substrate (g)}} \quad (1)$$

Ethanol Fermentation

Sugar hydrolysates were prepared for ethanol fermentation trials by adding 1.5% Saccharomyces cerevisiae. Fermentations were conducted in 200 mL autoclavable bottles with a working volume of 100 mL and were incubated at 30ºC with agitation (50 rpm). Samples were taken at regular time intervals, centrifuged at 8000g for 5 min, syringe filtered with a 0.45 lm Minisart (Sartorius, Germany) and stored at 20ºC for further analysis. Sugars and ethanol were quantified by marketable kits Biosis S.A., Athens, Greece and Megazyme respectively.

All chemicals used were of analytical grade. Non-commercial enzymatic formulations NS22109 (amylase) were kindly donated by Novozymes (Denmark). Moisture, extractives, ash, total starch, cellulose, fat in raw and pretreated materials were analyzed following NREL laboratory analytical procedures. All the samples were centrifuged at 3600 rpm for 10 min and filtered before being analyzed. All analyses were performed in duplicate.

Results and discussion

The production rate of restaurant food waste was estimated equal to 50kg/d, while its average composition is presented in Table 1.

Table 1. Composition of restaurant dried food waste produced from households and restaurants

Parameter		**Household % w/w (d.b.)**	**Restaurant Food waste % w/w (d.b.)**
pH		4.88	5.65
VS		86.83	96.23
TN		2.16	1.67
Nutritional Value			
Proteins[1]		13.50	10.43
Fats and Oils		11.65	10.55
Total Soluble Solids		35.01	46.65
	TRS	7.83	
	Glucose	0.84	1.37
Carbohydrates			
	Cellulose	7.81	6.4
	Hemicellulose	11.00	11.95
	Starch	8.06	52.49

[1]Proteins = 6.25 * Total Nitrogen

According to Table 1, the restaurant food waste presents much higher starch content, reflecting an elevated potential for bioethanol production.

In the concept of an integrated biorefinery, a scenario involving the production of bioethanol and biodiesel was investigated. In this scenario, glycerol, biogas and organic fertilizer were also produced. This scenario was set up on the experimental results and on extended literature review, adopting well-established and efficient technologies appropriate for restaurant food waste and making moderate assumptions for all efficiencies involved.
Three main processes were included in the integrated biorefinery (Figure 1):

i) Biodiesel production from oil extracted from restaurant food waste with glycerol as by-product.
ii) Bioethanol production from the defatted residues of restaurant food waste obtained from oil extraction unit operations.
iii) Stillage bioconversion to methane and biofertilizer via anaerobic digestion.

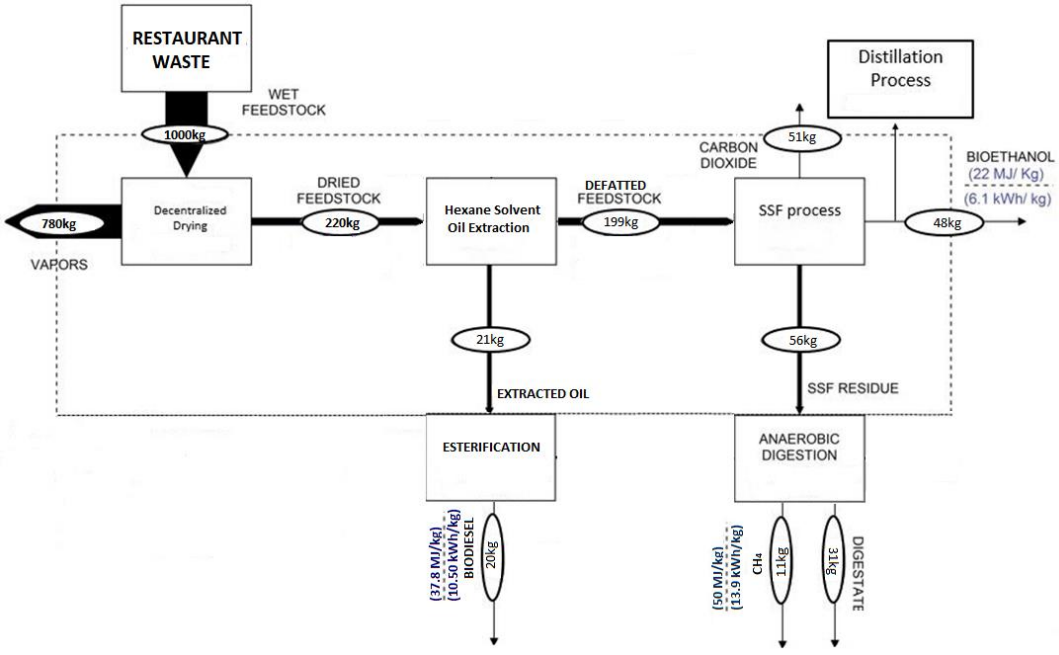

Figure 1. The unit operations and mass flows in an integrated simplified biorefinery producing bioethanol, biodiesel and methane from restaurant food waste