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GERVALOR: Valorization of Food Waste in a Hospital Food Service Unit

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Background

In the food sector, waste is a major social, nutritional and environmental issue, affecting the sustainability of the food chain as a whole. In the EU alone, we waste 90 million tons of food every year, i.e. 180 kg per person (1). Moreover, the growing concerns about hunger, preservation of the environment and the economic crisis have raised public awareness of food waste (2, 3). As several authors now assert, there is a need to investigate the social and environmental implications of waste at different stages of the supply chain. Indeed, food waste has an impact on food security, on food quality and safety, on economic development and on the environment (4). Some of the wasted products simply cannot be consumed, as they are not fit for human consumption and thus they must be considered “losses” in all respects. Instead, a part of the wasted products is still suitable for human consumption (5). Halving this edible waste is one of the goals in the Roadmap to a Resource-Efficient Europe, not least because the food value chain in the EU is responsible for 17% of Europe's direct greenhouse gas emissions and 28% of its material resource use (1). In order to prevent and reduce food wastage, the European Parliament declared 2014 the European Year against Food Waste, inspired by Last Minute Market1 and its campaign “One year against waste”. The literature on food waste has so far focused on the quantification of the total food losses along the supply chain (2, 6, 7) to highlight the negative implications of this phenomenon as well as its impact on the whole food system as a whole (8). However, the retail stage has long been neglected by such studies, although its contribution in limiting the implication of food waste might be consistent and, at the same time, sustainability is becoming an important business issue for retailers, as their practices may influence the whole supply chain process and its economic, environmental and social consequences (9).

Staggering amounts of food waste thus generate enormous energy, chemical and material potentials due to the functionalized molecules stored in them (10). The idea of harvesting high value-added products from food waste streams aligns with the current concept of sustainable development, which aims to achieve food security, environmental protection, and energy efficiency. Collective efforts have been made in the recent years to exploit food waste as a bio resource for our next generation of energy, chemical, pharmaceutical, cosmetic, food and other high value-added products (11). GERTAL is the largest

Portuguese company in the catering sector, serving in Portugal 61.3 million meals in the year 2016. These meals represented a volume of purchases of 40,000 tons of raw material food, which corresponds to a cost of € 60,475,906, which after being introduced into the chain generate approximately 7,854 Ton of food waste in the year 2016.

GERValor project - Valorisation of Organic Food Waste – intends to allow GERTAL, a Portuguese food service company, sign in the objectives of the European Plan for the Circular Economy and fight against food waste. Through this project, GERTAL enables contribute to the development of a pioneering strategy for the recovery of waste and reducing food waste in Portugal, thus encouraging the reduction of barriers to the entry of technologies and business models for the sector.

Objective

To characterize food waste in hospital food unit and identify it possible sub products. Additionally, analysis of environmental impact of meals production, with and without food waste valorisation.

Methods

The evaluation of food waste was conducted in a hospital food unit selected by convenience attending the fact that health sector is the one with great amounts of food waste. The food unit selected serves on average 2.870 meals a day and 1.062.100 meals by year. Food waste produced was evaluated during 14 days, without any connection with the planned menus. Food waste was separated in Cereals and tubers (pasta, rice and potatoes), bread, mixed meals, meat, fish, pimples / bones, soup, fruit and vegetable and milk. Food waste was monitored in cafeterias, during meal preparation, and after service of meals. The quantification of the food waste was carried out by weighing the components of the meal. A calibrated balance (maximum 100 kg, minimum 1Kg and precision of 30g) to weigh the total amount of food produced, plate waste and leftovers. Selective aggregate weighing method was used.

This method involves weighing the aggregate food by type of food. Food remains from ingestion, for all the individuals, are separated into different containers according to the type of food. The average value of the waste, per food item and per meal, is determined by dividing of the overall value of wastage found by the number of subjects who ate the meal (12). To identify possible sub-products of food waste characterized in the unit under analysis, bromatologic analysis was conducted. For this analysis, a sample of food waste before and after food production was selected randomly. Sciantec Analytical Services carried out Bromatological analysis. Environmental impact of meals production was analysed through Life Cycle Analysis.

Results

Food Waste Characterization

During the period under analysis, was observed an average of 22% of food waste by meal produced.

Table 1 – Plate waste according different distribution options by food group

Unit	Kg							L
Food waste	**Cereals and Tubers**	**Bread**	**Mixed Meals**	**Meat**	**Fish**	**Soup**	**F&V**	**Milk**
Served in tray	1560.83	153.14	671.34	460.47	311.14	2000.88	1547.39	1716.00
Served in Cafeteria	7.00	0.00	0.00	0.00	0.00	0.00	426.51	0.00
Self-line	0.00	0.00	0.00	135.74	61.21	0.00	478.16	0.00
Total/food group	1567.83	153.14	671.34	596.21	372.34	2000.88	2452.06	1716.00
Total	9530							
N.º of meals produced	42484							
% Food Waste by meal	22%							

Differences in meals components were observed before and after production waste. As shown in table 2 the waste after production is higher than before.

Table 2 – Food waste before and after food production

	Before		After	
	Kg	**%**	**Kg**	**%**
Meat	135.74	20	105.85	16
Fish	61.21	9		
F&V	478.16	71	80.75	12
Carbohydrates Sources	-	-	226.65	34
Soup	-	-	146.7	22
Mixed meals	-	-	105.85	16
Total	675	100	11836	100

Bromatological analysis of food waste

Composition analysis samples is vital to assess their potential valorisation applications. As shown in table 3, food waste samples have high moisture content, moderate levels of sugars and starch, low ash contents and low gross energy values. Differences between composition items under analysis sample before and after food production were observed, being the sample after food production globally richer to valorisation.

Table 3 – Bromatological Analysis of Food Waste

	Before food production	After food production
Total oil (%)	<0.30	0.60
Crude fibre content (%)	0.80	0.90
Ash (%)	0.90	0.70
Protein content (%)	1.20	1.90
Starch content (%)	3.00	0.60
Sugar content (as sucrose) (%)	1.13	4.79
Gross energy (MJ/kg)	1.40	2.24
Calcium (%)	0.04	0.02
Sodium (%)	0.01	0.02
Magnesium (%)	0.02	0.01
Copper (mg/kg)	1.00	1.00
Iron (mg/kg)	5.00	5.00
Manganese (mg/kg)	1.00	3.00
Zinc (mg/kg)	2.00	2.00
Potassium (%)	0.28	0.21
Phosphorous (%)	0.03	0.04
pH	6.20	4.80
Moisture content (%)	91.80	87.40
Gas yield (m^3/tonne of fresh matter)	40.60	65.90
Total methane content (%)	53.90	54.10

Possible routes of valorisation

Taking into consideration the composition and properties of food waste sample under analysis, various valorisation routes could be identified. A biorefinery is a facility for the total conversion of biomass material or waste into fuels, power, chemicals, materials, bio-based polymers and fibers. The biorefinery concept takes advantages of biomass components and intermediates to maximise the value derived from these materials. To be economically viable, it is important to produce a range of different products to maximise the value of the biomass feedstock, open new markets and reduce the cost of installation. Food waste under analysis seems to be a suitable feedstock for biorefineries as it can contain considerable amounts of carbohydrates, protein and oil, as shown in table 3. Possible routes of valorisation are presented in table 4.

Table 4 – Possible routes of valorisation of food waste identified

		Potential Usage	Constrains
Applications in the food industry	**Animal (livestock and pet) feed**	a) Carbohydrates and Proteins from food waste used as ingredient in livestock feed b) Incorporated into pet feed(13)	a) EU legislation(10, 14-16) b) Low starch and protein content c) Variability of food waste d) High moisture content e) Cost of technological process prior to

			incorporation process(17)
	Processing into flour	a) Drying and grinding into a fine powder ("flour") that can be incorporated as a functional ingredient in a variety of food products(18, 19)	a) Variability of food waste b) High moisture content c) Cost of technological process prior to incorporation process(18)
Anaerobic digestion	**Biogas (biomethane)**	a) Heat b) Electricity(20)	a) Depends on biomethane potential of food waste samples(21)
	Digestate	a) Fertiliser	
	Volatile fatty acids (VFA)	a) High content in organic matter, carbon and nutrients used in the production of VFA(22, 23)	a) Further studies would be required to determine the most promising conditions to produce VFA(24)
Production of energy and fuels	**Production of biohydrogen**	a) Produced from waste biomass(25)	a) Uptake of hydrogen fuels cells remains low. b) pH c) Moisture content(26)
	Production of biohythane	a) Sugar content of mixed samples could be promising to usage of food waste to biohythane production.(27)	a) Pre-treatment b) Scale-up(27)
	Production of bioethanol	a) Produced from biomass materials	a) Pre-treatment(24) b) Low content of starch in food waste samples c) Storage processes of food waste
	Production of biobutanol	a) Solvent b) Extraction agent c) Supplement d) Eluent e) Biofuel(24)	a) Low content of starch in food waste samples b) Low yields(28)
	Production of biodiesel	a) Fuel produced from natural biological sources.	a) Variability of food waste(29)

	Pyrolysis and gasification	a) Non-condensables b) Bio-oil c) Bio-char(30)	a) High moisture content
	Combustion	a) Produce energy through biomass(31)	a) High moisture content b) Low calorific value
Extraction of high value products	**Bioactive compounds**	a) Incorporated as functional ingredients in a variety of industry products(32, 33)	a) Variability of food waste
	Proteins	a) Extract protein as bio component(33)	a) Variability of food waste composition
Production of chemicals and other materials	**Bioplastics**	a) Polymers production from renewable materials(24, 29)	a) Further studies needed to analyse economic viability of this process(34)
	Succinic acid	a) Interesting applications in food, chemical and pharmaceutic industries	a) Production costs b) Operability for the large-scale fermentation(35)
	Butanediol	a) Chemical component used in a variety of manufacturing industries b) As precursor for the production of various industrially-relevant compounds	a) Pre-treatment for some food products(36)
	Industrial enzymes	a) Biological catalysts that can be used in a variety of manufacturing industries(37)	a) Production cost(37)
Other applications	**Composting**	a) Compost production(24)	a) Moisture content b) Variability of food waste
	Landspreading	a) Non-chemical fertiliser	a) EU and PT legislation(38)

Limitations of food waste to valorisation

The mixed nature of food waste and variation in sample composition due to foodstuff availability, market trens and demands will have major impact on the potential of the valorisation routes. Additionally, the high moisture content observed in samples may reduce the potential valorisation applications. Furthermore, the high organic matter content of food waste may pose additional challenges in terms of storage and transportation.

Environmental impact of meals production

Meals production have different environmental impact if considering the valorisation of food waste.

Table 5 – Comparison of environmental impacts with and without food waste valorisation

Environmental Impact	Unit	Without Food Waste Valorisation	With Food Waste valorisation
Climate change	Kg CO2 eq	307.9283	123.1114
Ozone depletion	Kg CFC -11 eq	3.19E-07	-3.14E-06
Terrestrial acidification	Kg SO2 eq	0.0421	-6.4782
Freshwater eutrophication	Kg P eq	0.2240	-0.0340
Marine eutrophication	Kg N eq	-0.0017	-0.2837
Human toxicity	Kg 1,4-DB eq	-0.4338	-15.5839
Photochemical oxidant formation	Kg NMVOC	0.2002	-0.0656
Particulate matter formation	Kg PM10 eq	0.1144	-0.7716
Terrestrial ecotoxicity	Kg 1,4-DB eq	-0.1510	-0.1555
Freshwater ecotoxicity	Kg 1,4-DB q	-0.0362	-6.4545
Marine ecotoxicity	Kg 1,4-DB eq	-0.0143	-5.5042
Ionising radiation	KBq U235 eq	0.5993	1.8037
Agricultural land occupation	m2a	-2.6543	42.5119
Urban land occupation	m2a	-0.0571	-0.4271
Natural land transformation	m2	0.0089	0.0106
Water depletion	m3	0.0051	1.1087
Metal depletion	Kg Fe eq	0.2464	-3.8147
Fossil depletion	Kg oil eq	4.1634	1.2912

Conclusion

This study shown a high level of food waste and demonstrate that valorisation of food waste is possible through some routes and that valorisation have a positive environmental impact. Further studies are needed to understand which is the best model to implement valorisation of food waste in food service unit. The GERValor project is studding valued solution according to Gertal's business model. Defined solutions could be allow a great potential of replicability in other companies that work in the food sector.

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