



RESEARCH ARTICLE

Vegetable Waste as a Source of Wealth: A Novel Approach

Neha Sharma¹, Shivam Sharma^{1*}, D.R. Chaudhary¹, Harish B.M^{1*}, Diksha Rana¹ and Anuj choudhary²

¹ Department of Vegetable Science and Floriculture, CSK HPKV Palampur (H.P)-176062

² Department of Biology and Environmental Sciences, CSK HPKV Palampur (H.P)-176062

ABSTRACT

India is one of the world's largest agricultural nations, producing a large number of fruits and vegetables. The amount of waste produced daily by each household has increased as the global population has risen due to demand for food and other necessities. Every year, 18 percent of India's fruit and vegetable production, worth Rs. 13300 crore is wasted. Due to a lack of proper cold storage facilities, approximately 30 % of the fruits and vegetables grown in India are wasted each year at any point of the supply chain, from harvesting to processing to postharvest to consumption. Therefore, this waste content should be used in such a way that the greatest possible benefits should be achieved and extracted without incurring any financial loss or posing any environmental risks. As a result, waste materials generated by these industries can be composted and landfilled through aerobic or anaerobic treatment, biogas production, animal feed, and value-added products. Hence, waste disposal is a serious issue; therefore, vegetable waste should be used in such a way that the most significant possible benefits can be achieved and extracted without incurring any financial loss or posing any environmental risks. Vegetable waste material can produce economically or commercially viable products such as biofuel, biogas, manure, and other applications as an effective waste management solution that does not harm the environment.

Received: 27 Feb 2024

Revised: 03 Mar 2024

Accepted: 17 Mar 2024

Keywords: Bioethanol, Vermicomposting, Green particle board, Briquetting

INTRODUCTION

Fruits and vegetables play an essential role in human diet, and as a result of the increasing global population and evolving eating preferences, demand for these important food resources has risen dramatically (Vilariño *et al.* 2017). Every year, 18 percent of India's fruit and vegetable production, worth Rs. 13300 crores is wasted. Due to a lack of proper cold storage facilities, approximately 30 % of the fruits and vegetables grown in India are wasted each year at any point of the supply chain, from harvesting to processing, from postharvest to consumption, which is a cause for concern (Parfitt *et al.* 2010). Vegetable waste is a biodegradable material that is manufactured in vast amounts, most of which is discarded on land to rot in the open, producing a foul odour and attracting birds, rodents, and pigs, all of which are disease vectors (Singh *et al.* 2012).

Landfills emit a foul odour, produce methane, a common greenhouse gas, and produce a significant volume of hazardous leachate that can contaminate groundwater and soil. As a result, waste disposal is a serious issue therefore vegetable waste should be used in such a way that the greatest possible benefits can be achieved and extracted without incurring any financial loss or posing any environmental risks. The present review deals with studies conducted on vegetable waste and for its utilization using various methods.

The supervision of vegetable left-over is very much problematic due to its far wastage Even in the

situation of 21st century surge in yield of vegetables has developed a challenge for researchers as biodegradable material is dumped freely on soil know to deplete its fertility and quality. This incessant intensification in vegetable production has also leads to 60% rise in wastage in terms of stale/peels. According to Food and Agriculture Organization estimation (FAO, 2011) pre-consumer phases are particularly critical in terms of vegetable waste generation. In this regard, Segrè and Falasconi (2011), reported that in Italy, up to 87 % of fruits, vegetables, and cereals are discarded before reaching consumer with multiple cause. Due to seasonality, which results in unsaleable gluts and the lack of proper conservation strategies for perishable crops, wastes are primarily produced in agricultural production, postharvest, and distribution stages in developing countries. Wastes in agricultural production are a problem in both developed and developing countries. However, in this case, they are primarily due to post-harvest crop evaluations based on quality requirements demanded by retailers, as well as planned overproduction as per Food and Agriculture Organization (FAO, 2011; Segrè & Falasconi, 2011; Mena *et al.* 2014).

Vegetable Waste Management

Due to its high biodegradability, fruit and vegetable waste raises disposal and environmental concerns and therefore, different means of vegetable waste

management is the need of hour (Fig. 1.). It also results in the depletion of important biomass, and nutrients, as well as a financial loss. As a result, much attention has been paid in recent years to policies and methods for its management (Laufenber *et al.* 2003). Waste management methods can be categorized and prioritized based on how the waste will be disposed of in the end: waste minimization and avoidance (reduction), recycling and reuse, energy recovery, and landfilling. The waste hierarchy is the order in which these choices are classified in order of priority (Demirbas, 2011). In the past, fruits and vegetable waste was mixed into municipal waste streams and sent to landfills or incinerators for final disposal (Nawirska and Kwaśniewska, 2005). However, this is not a good option for fruit and vegetable waste, due to its high-water content which is, in turn, responsible for microbiological instability, and the formation of off-odors and leachate (Lin *et al.* 2011; Zhang *et al.* 2007). As a result, the following portion of this paper explores how we can use vegetable waste to generate wealth through the production of bio-fuel, bio-gas, biofertilizer, bio-active compounds, bioethanol, animal feed, enzyme production and many more products using traditional and new innovative technology.

Bioethanol from vegetable waste

Research on the usage of fruit and vegetable wastes for the manufacture of biofuel is gaining attraction in

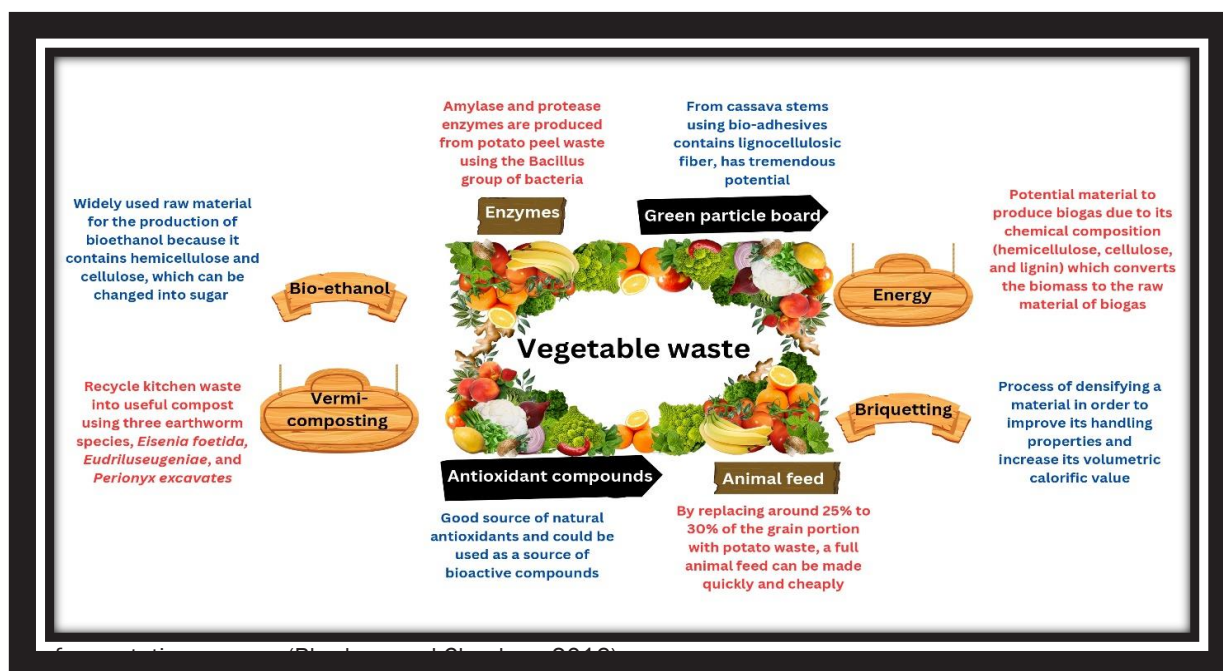


Fig. 1. Different means of Vegetable Waste Management

different countries as they have abstracted a halal biorefinery for the production of bioethanol biodiesel and value-added products in Malaysia. Vegetable waste is a widely used raw material for the production of bioethanol because it contains hemicellulose and cellulose, which can be changed into sugar by the hydrolysis method in the presence of microorganisms (Del *et al.* 2006). The sugar content in vegetable waste extracts is around 5 % (Supriyanto *et al.* 2006). Yeast, fungi, and bacteria can be used for the fermentation process (Bhadana and Chauhan, 2016).

Ethyl alcohol is the main component of the power alcohol and its main advantage is that it can also be prepared from agricultural waste. Potato peels are available as feed material, in large quantities across the world and can be used for bio-ethanol production (Gul and Gul, 2016). Chibuzor *et al.* 2016 investigated the potential of bioethanol production using different microbial inoculants for the simultaneous saccharification and fermentation of cassava peels from three cassava cultivars and reported that TME4779 gives the highest yield of ethanol. Chohan *et al.* 2020 studied the valorization of potato peel wastes for bioethanol production using simultaneous saccharification and fermentation and the results of this study provide valuable details for starch-based bioethanol production processes.

Composting of vegetable waste

Vegetable waste with highly biodegradable organic matter can be successfully composted for its reuse of nutrients as fertilizer and soil conditioner. Anton *et al.* 2005 reported that composting vegetable waste may reduce the environmental impact of climate change by 40–70 % compared to landfilling and incineration. Katre (2012) in his study revealed that recycling vegetable waste by aerobic composting is an easy process and operation that is hassle-free, environmentally sustainable, aesthetically pleasing, cost-effective in the long run, and socially acceptable since the final product has good fertilizer value. Rich *et al.* 2018 used vegetable waste in their study as the main feedstock with local organic wastes as bulking agents (BAs) to make the compost stable and mature in combination with cow dung as a source of inoculant.

Vermicomposting from vegetable waste

Microbes are responsible for the biochemical degradation of organic matter, earthworms are the important drivers of the process, conditioning the substrate and altering the biological activity

(Suthar, 2009). The findings of Chatterjee *et al.* 2014 can be promoted as a sound vegetable waste recycling technology for organic carrot production to conserve natural resources and to minimize the harmful impact of vegetable wastes. Hence, without any pre-composting or cow dung supplementation, sustainable vermicomposting of vegetable waste is feasible, and the overall process is much simpler and therefore potentially more economical. The idea of Family Net Vessel Compost (FNVC) being cost-effective and efficient technology was created to recycle kitchen waste into useful compost using three earthworm species, *Eisenia foetida*, *Eudrilus eugeniae*, and *Perionyx excavates*.

Animal feed and enzymes from potato waste

During harvest, roughly 35 % of the total processed potato crop is discarded as waste. By replacing around 25 % to 30 % of the grain portion with potato waste, a full animal feed can be made quickly and cheaply. A commercial feed plant can be set up and operated (on an annual basis) for a total capital expenditure of Rs. 27 lakhs, yielding a profit of Rs. 4.0-4.5 lakhs per year. Amylase and protease enzymes are produced from potato peel waste using the Bacillus group of bacteria. From potato processing industry waste, amylase and protease enzymes are made. 4665 gm/50 hr batch of amylase; 14.76 gm/50 hr batch of protease.

Green particle board from cassava stems using bio-adhesives

Cassava (*Manihot esculenta*) is mainly cultivated for its root starch. Cassava stems and leaves make up the non-root biomass. The stem-to-root ratio ranged from 0.19 to 0.85, with an average of 0.50, and only 15 % of the crop is used for planting, with the rest being reincorporated into the soil or burned off in the field. On a dry weight basis, the cassava stem contains about 15-39 % starch, 22.80-40 % cellulose, 10-28.8 % hemicellulose, and 11.8-22.10 % lignin. These findings revealed that cassava stem, which contains lignocellulosic fiber, has tremendous potential as a raw material for particle board manufacturing.

Antioxidant compounds from vegetable waste

Several vegetables have been investigated on an industrial scale as sources of potentially safe natural antioxidants. Vegetable wastes have gained special attention because they are a rich source of



phenolic compounds (Spiesky *et al.* 2012). Potato peel is a significantly underutilized by-product in the potato processing industry and a potentially useful source of bioactive molecules. Glycoalkaloids and polyphenols, for example, are essential precursors for steroid hormones and natural antioxidants (Calcio Gaudino *et al.* 2020). Munir *et al.* 2018 investigated the antioxidant potential of vegetable waste (Onion, garlic, and cauliflower) using ethanol and concluded that vegetable wastes are a good source of natural antioxidants and could be used as a source of bioactive compounds.

Energy from vegetable waste

Energy recovery, also called waste to energy, is performed in order to recover the energy contained in the waste material (Kothari *et al.* 2010). According to Telangana Today, 2nd Feb, 2021 the traders at Bowenpally Sabzi Mandi (Telangana) produced 500 units of electricity out of 10 tonnes of vegetable waste (Li *et al.* 2011; Sheets *et al.* 2015). Vegetable waste from the market is a potential material to produce biogas due to its chemical composition (hemicellulose, cellulose, and lignin) which converts the biomass to the raw material of biogas (Abdullah and Pandebesie, 2018). Vegetable waste has recently been treated with microbial fuel cells. This technique refers to biologically catalyzed electrochemical systems that use redox reactions to transform the chemical energy of an organic substrate into electrical energy (Pant *et al.* 2010). However, this technique is limited to carbohydrate-rich wastes (El Mekawy *et al.* 2015).

Briquetting

Briquetting is the process of densifying a material in order to improve its handling properties and increase its volumetric calorific value. Lignin in biomass is thought to aid in particle binding. Srivastava *et al.* 2014 studied the strategic application of thermochemical conversion of vegetable wastes into biofuel production that is both environmentally sustainable and low-cost. Akande and Olorunnisola, 2018 also concluded that cabbage and carrot waste can best be converted into good-quality briquettes after torrefaction.

CONCLUSION

In today's world, waste management is the most serious problem. Food industries produce by-products that are high in nutrients and have several health benefits. Bioactive chemicals, nutraceuticals, and other functional foods can be found in these by-

products. Utilization of by-products provides companies with a new source of revenue, which helps to improve economic productivity. Vegetable wastes can be converted into bioenergy and byproducts to produce revenue from food processing wastes. However, the implementation of such waste management techniques should be financially viable for businesses and in accordance with the requirements of the law.

Funding and Acknowledgment

No funding was received to assist with the preparation of this manuscript

Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this review

Originality and plagiarism

Authors ensure that we have written and submitted only entirely original review article

Data availability

Not applicable

Consent for publication

All the authors agreed to publish the content

Conflict of interest

There were no conflicts of interest in the publication of this content

Author contributions

Idea conceptualization-DRC, DR, Writing original draft-SS, NS, Writing-reviewing & editing-AC, HBM, SS

REFERENCES

- Abdullah, N. O. and E. S. Pandebesie. 2018, March. The influences of stirring and cow manure added on biogas production from vegetable waste using anaerobic digester. In IOP conference series: *Earth Environ. Sci.*, **135(1)**: 1-7. DOI: [10.1088/1755-1315/135/1/012005](https://doi.org/10.1088/1755-1315/135/1/012005).
- Akande, O. M. and A. O. Olorunnisola. 2018. The potential of briquetting as a waste management option for handling market-generated vegetable waste in Port Harcourt, Nigeria. *Recycling*, **3(2)**: 11. DOI: [10.3390/recycling3020011](https://doi.org/10.3390/recycling3020011).
- Anton, M. A., Munoz, P., Montero, J. I. and M. Soliva. 2005. Improving waste management in protected horticulture. *Agron. Sustain. Dev.*, **25**: 447-453. DOI: [10.1051/agro:2005045](https://doi.org/10.1051/agro:2005045).



- Bhadana, B. and M. Chauhan. 2016. Bioethanol Production Using *Saccharomyces cerevisiae* with different perspectives: Substrates, growth variables, inhibitor reduction, and immobilization. *Ferment. Technol.*, **5(2)**: 1-5. DOI: [10.4172/2167-7972.1000131](https://doi.org/10.4172/2167-7972.1000131).
- Calcio Gaudino, E., Colletti, A., Grillo, G., Tabasso, S. and G. Cravotto. 2020. Emerging processing technologies for the recovery of valuable bioactive compounds from potato peels. *Foods*, **9(11)**, p.1598. DOI: [10.3390/foods9111598](https://doi.org/10.3390/foods9111598).
- Chatterjee, R., Bandyopadhyay, S. and J. C. Jana. 2014. Evaluation of vegetable wastes recycled for vermicomposting and its response on yield and quality of carrot (*Daucus carota* L.). *Int. J. Recycl. Org. Waste Agric.*, **3(2)**, p.60. DOI: [10.1007/s40093-014-0060-4](https://doi.org/10.1007/s40093-014-0060-4).
- Chibuzor, U. E. A. and G. Igile. 2016. Bioethanol production from cassava peels using different microbial inoculants. *Afr. J. Biotechnol.*, **15(30)**: 1608-1612. DOI: [10.5897/AJB2016.15391](https://doi.org/10.5897/AJB2016.15391).
- Chohan, N. A., Aruwajoye, G. S., Sewsynker-Sukai, Y. and E. G. Kana. 2020. Valorization of potato peel wastes for bioethanol production using simultaneous saccharification and fermentation: process optimization and kinetic assessment. *Renew. Energy*, **146**: DOI: [1031-1040](https://doi.org/10.1016/j.renene.2019.07.042). DOI: [10.1016/j.renene.2019.07.042](https://doi.org/10.1016/j.renene.2019.07.042).
- Demirbas, A. 2011. Waste management, waste resource facilities and waste conversion processes. *Energy Convers. Manag.*, **52(2)**: 1280-1287. DOI: [10.1016/j.enconman.2010.09.025](https://doi.org/10.1016/j.enconman.2010.09.025).
- El Mekawy, A., Srikanth, S., Bajracharya, S., Hegab, H. M., Nigam, P. S., Singh, A. and D. Pant. 2015. Food and agricultural wastes as substrates for bioelectrochemical system (BES): The synchronized recovery of sustainable energy and waste treatment. *Food Res. Int.*, **73**: 213-225. DOI: [10.1016/j.foodres.2014.11.045](https://doi.org/10.1016/j.foodres.2014.11.045).
- FAO. 2011. Global food losses and food waste - Extent, causes, and prevention. Rome. <https://www.fao.org/3/mb060e/mb060e00.htm>.
- FAO. 2014. Definitional framework of food losses and waste. Rome, Italy. <https://www.fao.org/3/mb060e/mb060e00.htm>.
- Gul, Y. and S. Gul. 2016. Process Design for Bio-Ethanol fermentation from potato peel waste simultaneous saccharification and fermentation of starch by *Very*. In 3rd on sustainability in process industry p. 33
- Katre, N. H. 2012. Use of vegetable waste through aerobic composting of village bamhani, district: Gondia (Maharashtra state), India. *Int. J. Life Sci. Biotechnol. Pharma Res.*, **1**: 134-142. DOI: [10.4028/www.scientific.net/AMM.898.16](https://doi.org/10.4028/www.scientific.net/AMM.898.16).
- Kothari, R., Tyagi, V. V. and A. Pathak. 2010. Waste-to-energy: A way from renewable energy sources to sustainable development. *Renew. Sustain. Energy Rev.*, **14(9)**: 3164-3170. DOI: [10.1016/J.rser.2010.05.005](https://doi.org/10.1016/j.rser.2010.05.005).
- Kunamneni, A., Permaul, K. and S. Singh. 2005. Amylase production in solid state fermentation by the thermophilic fungus *Thermomyces lanuginosus*. *J. Biosci. Bioeng.*, **100(2)**: 168-171. DOI: [10.1263/jbb.100.168](https://doi.org/10.1263/jbb.100.168).
- Laufenberg, G., Kunz, B. and M. Nystroem. 2003. Transformation of vegetable waste into value-added products: (A) the upgrading concept; (B) practical implementations. *Bioresour. Technol.*, **87(2)**: 167-198. DOI: [10.1016/S0960-8524\(02\)00167-0](https://doi.org/10.1016/S0960-8524(02)00167-0)
- Li, Y., Park, S. Y. and J. Zhu. 2011. Solid-state anaerobic digestion for methane production from 531 organic waste. *Renew. Sustain. Energy Rev.*, **15(1)**: 821-826. DOI: [10.1016/j.rser.2010.07.042](https://doi.org/10.1016/j.rser.2010.07.042).
- Lin, J., Zuo, J., Gan, L., Li, P., Liu, F., Wang, K. and H. Gan. 2011. Effects of mixture ratio on 536 anaerobic co-digestion with fruit and vegetable waste and food waste of China. *J. Environ. Sci.*, **23(8)**: 1403-1408. DOI: [10.1016/s1001-0742\(10\)60572-4](https://doi.org/10.1016/s1001-0742(10)60572-4).
- Mena, C., Terry, L. A., Williams, A. and L. Ellram. 2014. Causes of waste across multi-tier supply networks: Cases in the UK food sector. *Int. J. Prod. Econ.* **152**: 144-158.
- Munir, A., Sultana, B., Bashir, A., Ghaffar, A., Munir, B., Shar, G.A., Nazir, A. and M. Iqbal. 2018. Evaluation of Antioxidant Potential of Vegetables Waste. *Pol. J. Environ. Stud.*, **27(2)**: 947-952. DOI: [10.1016/j.ijpe.2014.03.012](https://doi.org/10.1016/j.ijpe.2014.03.012).
- Nawirska, A. and M. Kwaśniewska. 2005. Dietary fiber fractions from fruit and vegetable processing waste. *Food Chem.*, **91(2)**: 221-225. DOI: [10.1016/j.foodchem.2003.10.005](https://doi.org/10.1016/j.foodchem.2003.10.005).
- Pant, D., Van Bogaert, G., Diels, L. and K. Vanbroekhoven. 2010. A review of the substrates used in microbial fuel cells (MFCs) for sustainable energy

- production. *Bioresour. Technol.*, **101(6)**: 1533-1543. DOI: [10.1016/j.biortech.2009.10.017](https://doi.org/10.1016/j.biortech.2009.10.017).
- Parfitt, J., Barthel, M. and S. Macnaughton, 2010. Food waste within food supply chains: quantification and potential for change to 2050. *Philos. Trans. R. Soc.*, **365(30)**: 65-81. DOI: [10.1098/rstb.2010.0126](https://doi.org/10.1098/rstb.2010.0126).
- Rich N, Bharti A and S. Kumar. 2018. Effect of bulking agents and cow dung as inoculant on vegetable waste compost quality. *Bioresour. Technol.*, **252**: DOI: [83-90. 10.1016/j.biortech.2017.12.080](https://doi.org/10.1016/j.biortech.2017.12.080).
- Segrè, A. and L. Falasconi. 2011. Il libro nero dello spreco in Italia: il cibo. Milan: Ambiente Edizioni. ISBN:9788866270003.
- Sheets, J. P., Yang, L., Ge, X., Wang, Z. and Y. Li. 2015. Beyond land application: Emerging technologies for the treatment and reuse of anaerobically digested agricultural and food waste. *Waste Manag. Res.*, **44**: 94-115. DOI: [10.1016/j.wasman.2015.07.037](https://doi.org/10.1016/j.wasman.2015.07.037).
- Singh, A., Kuila, A., Adak, S., Bishai, M. and R. Banerjee. 2012. Utilization of Vegetable Wastes for Bioenergy Generation. *Agric. Res.*, **1(3)**: 213-222. DOI: [10.1007/s40003-012-0030-x](https://doi.org/10.1007/s40003-012-0030-x).
- Speisky, H., Lopez-alarcon, C., Gomez, M., Fuentes, J., Sandovalacuna, C. and H. Peisky. 2012. First web-based database on total phenolics and oxygen radical absorbance capacity (ORAC) of fruits produced and consumed within the south Andes region of South America. *J. Agric. Food Chem.* **60**: DOI: [8851. 10.1021/jf205167k](https://doi.org/10.1021/jf205167k)
- Srivastava, N. S. L, Narnaware, S. L., Makwana, J. P., Singh, S. N. and Vahora. 2014. Investigating the energy use of vegetable market waste by briquetting. *Renew. Energy*, **68**: 270-275. DOI: [10.1016/j.renene.2014.01.047](https://doi.org/10.1016/j.renene.2014.01.047).
- Supriyanto, A., Lestari, I., Citrasari, N. and S. S. Putri. 2019. The bioconversion of vegetable waste extract from Osowilangun Central Market Surabaya into bioethanol using *Saccharomyces cerevisiae*. 2019. IOP Conf. Series: *Earth Environ. Sci.*, **245**: 012042. [10.1088/1755-1315/245/1/012042](https://doi.org/10.1088/1755-1315/245/1/012042).
- Suthar, S. 2009. Vermicomposting of vegetable-market solid waste using *Eisenia foetida*: Impact of bulking material on earthworm growth and decomposition rate. *Ecol. Eng.*, **35(5)**: 914-920. DOI: [10.1016/j.ecoleng.2008.12.019](https://doi.org/10.1016/j.ecoleng.2008.12.019).
- Vilarino, M. V., Franco, C. and C. Quarrington. 2017. Food loss and waste reduction as an integral part of a circular economy. *Front. Environ. Sci.* **5**: 1-5. DOI: [10.3389/fenvs.2017.00021](https://doi.org/10.3389/fenvs.2017.00021).
- Zhang, R., El-Mashad, H. M., Hartman, K., Wang, F., Liu, G., Choate, C. and P. Gamble. 2007. Characterization of food waste as feedstock for anaerobic digestion. *Bioresour. Technol.*, **98(4)**: 929-935. DOI: [10.1016/j.biortech.2006.02.039](https://doi.org/10.1016/j.biortech.2006.02.039).