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PREDICTIVE ANALYSIS AND MANAGEMENT OF FOOD WASTE FOR SUB-SAHARAN AFRICA

Research article

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Abstract

Taking into consideration the food security needs, research are concentrating on reducing food waste (FW) and food loss (FL) in the Sub-Saharan African region (SSAR). Practically, FW cannot be eliminated fully, thus it is also important to implement proper FW management systems to eliminate the environmental and health hazards created due to its unscientific disposal. Taking into consideration the technological and socio-economic condition of SSAR, FW management is essential. The study found that huge quantity of food material is being wasted in the upstream of the food supply chain (FSC) and needs urgent attention for both ensuring food security and avoiding the pollution caused due to its unscientific disposal. Agriculture is the major employer of the SSAR, the production levels are low due to the unavailability of essential farm inputs. In addition to this, major portion of the people in the SSAR are facing energy crisis. Anerobic treatment of FW can solve both their energy and farm nutrient requirement. To effectively implement the anerobic treatment system, it must be both effective in cost and operation. Taking into consideration the quantity of FW produced by different centers, the heterogenic nature of the waste, logistic problems, and the socio-economic condition of the people in SSAR. The study proposes a two-system approach in managing FW in the region. Small-scale biogas plants for homes, small hotels, canteens, restaurants etc., to treat the FW generated at source and phase-separated biogas plants for larger installations treating FW collected from centres that cannot treat the FW generated by them.

Keywords: food waste, food lose, food supply chain, landfill, greenhouse gas.

ПРОГНОСТИЧЕСКИЙ АНАЛИЗ ПИЩЕВЫХ ОТХОДОВ И УПРАВЛЕНИЕ ИМИ ДЛЯ СТРАН АФРИКИ К ЮГУ ОТ САХАРЫ

Научная статья

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Аннотация

Принимая во внимание потребности продовольственной безопасности, исследования сосредоточены на сокращении пищевых отходов (ПОО) и пищевых потерь (ПП) в регионе Африки к югу от Сахары. Практически полностью избавиться от ПТО невозможно, поэтому важно внедрить надлежащие системы управления ПТО, чтобы устранить угрозы для окружающей среды и здоровья, возникающие в результате их ненаучной утилизации. Принимая во внимание технологическое и социально-экономическое состояние SSAR, управление FW имеет важное значение. Исследование показало, что огромное количество пищевых материалов выбрасывается впустую в верхних звеньях цепи поставок продовольствия (ЦППП) и требует срочного внимания как для обеспечения продовольственной безопасности, так и для предотвращения загрязнения окружающей среды, вызванного их ненаучной утилизацией. Сельское хозяйство является основным работодателем в ЮАР, но уровень производства низкий из-за отсутствия необходимых средств производства. В дополнение к этому, большая часть населения ЮАР сталкивается с энергетическим кризисом. Анаэробная обработка ФВ может решить как энергетическую, так и сельскохозяйственную потребность в питательных веществах. Чтобы эффективно внедрить систему анаэробной обработки, она должна быть эффективной как по стоимости, так и по эксплуатации. Принимая во внимание количество ФВ, производимых различными центрами, гетерогенную природу отходов, логистические проблемы и социально-экономическое положение населения в ЮАР. В исследовании предлагается двухсистемный подход к управлению ЖО в регионе. Малогабаритные биогазовые установки для домов, небольших гостиниц, столовых, ресторанов и т.д. для переработки ФОВ, образующихся у источника, и фазово-разделенные биогазовые установки для более крупных объектов, перерабатывающие ФОВ, собранные из центров, которые не могут перерабатывать ФОВ, образующиеся у них.

Ключевые слова: пищевые отходы, потеря продуктов питания, цепочка поставок продуктов питания, свалка, парниковый газ.

Introduction

Globally, about 33.3% of the food produced is being wasted [1]. The wastage starts from the initial stage of production, continues during the processing and consumption process [2]. Going through the research publications, it was found that there are a lot of ambiguities among the researchers while FL and FW while in consideration of the guidelines interpreted by the FAO [3], [4], [5]. Food material is being wasted throughout the FSC, right from harvesting, on-field and off-field processing process, transportation, handling, retailing, storage during different stages, preparation for consumption and consumption [4].

In addition to this, peels and rinds which are part of the food materials but generally not consumed by human should also be considered as they are also part of the waste that requires proper management [6]. Thus, taking into consideration the waste management point of view any loss in nutritional value of food material can be considered as FL and any loss in food quantity (both intentional and unintentional) can be considered as FW. Thus, in this study, loss in food quality is considered as FL and loss in food quantity is called as FW.

Few decades ago, FW was not considered as a problem, as they were used as animal feed, dumped as landfill, or used for composting. As the population density started increasing, the waste which was once not considered as a problem started creating serious environmental problems and affecting human health globally [7], in fact globally FW is responsible for 8% contribution to the climate change inducing gasses [8]. In addition to this, it is estimated that nearly 820 million people will suffer from food shortage by 2050 [9], [10], [11]. Taking into consideration the current consumption and FW, to feed the people the agricultural production by 2050 has to be increased by 70% [12] which is a high ask. It was found that the food wasted in the marriage ceremonies in Pakistan was sufficient enough to feed the entire population of Somalia and Haiti [13]. This in simple terms highlights the practical implication with regard to the quantity of food being wasted and has attracted the attention of both researchers and policy makers globally in finding solutions for both management and reduction of FW [14]. When analysing ways for curbing FW, one should acknowledge the fact that, practically, FW cannot be totally eliminated but can be reduced [15]. Thus, reducing the FW will help in reducing the pressure on the production sector by reducing the gap between the production and demand [16], [17] and treating the FW generated will help in reducing the environmental and health hazards caused by it [18].

Major portion of the food wasted in retail and consumption phase is mainly due to the irresponsible behaviour of society [19], [20]. It is not only the quantity of material that they waste, but the total energy, time and resources used to produce it. In addition, their attitude results in environmental effects caused by the Green House Gas (GHG) emitted and other associated pollution caused by FW decomposition on landfills [21]. Due to the poor infrastructural facilities, the developing countries have their major losses (about 40%) during production and post-harvest operations, while the same quantity is wasted during consumption phase in the developed countries due to consumer behaviour. The SSAR is wasting food material worth 4 billion USD every year, while the food producing farmers are earning around 2 USD per day [22]. The SSAR comprises 46 countries with a total population of 1.14 billion [23]. It accounts for 16.35% of the world land area and 80.34% of the African continent [24], but still 38.3% of its population is living in poverty [23] and have the highest global hunger index score (27.1) than the rest of the world [25].

In SSAR, both rural and urban population is highly dependent on food production [4], it is estimated that only 68% of the food produced is reaching the consumer, accounting for an annual per capita loss between 120-170 kg. The seriousness of this wastage raises concern knowing the fact that more than 230 million in SSAR is undernourishment [26]. In addition, it is estimated that the decomposition of organic wastes from cultivation and FW accounts for about 7% of the total Green House Gas (GHG) contribution towards climate change. The SSAR is found to be more vulnerable to climate change than the rest of the world due to their lower adaption capability. The population in the SSAR is growing at a faster rate and so is the FW but is lacking proper waste management facilities and increasing health problems among the people. Considering the limited healthcare facilities, lower economic status of the people, urgent attention must be given in implementing proper FW management systems in a way that can be adopted and beneficial for the people of the region.

This paper analyses in SSAR the type and quantity of FW generated along the food supply chain (FSC), the environmental effects caused by the improper FW management, the nature and physicochemical properties of the food waste generated along the FSC, the possible method of managing the FW and the appropriate method of FW management suitable for SSAR.

Methodology adopted

This study focuses on the quantity of food material loss in SSAR and not the quality loss. The FW generated from production to consumption for different food commodity groups (FCG) based on published data is considered for the study. To analyse any problem and propose suitable interventions, systems and technologies, sufficient data of the region regarding the problem considered for the study should be available. Availability of in sufficient data is the major problem with regard to studies related to SSAR and same is in the case of FW [3], [4], [27], [28].

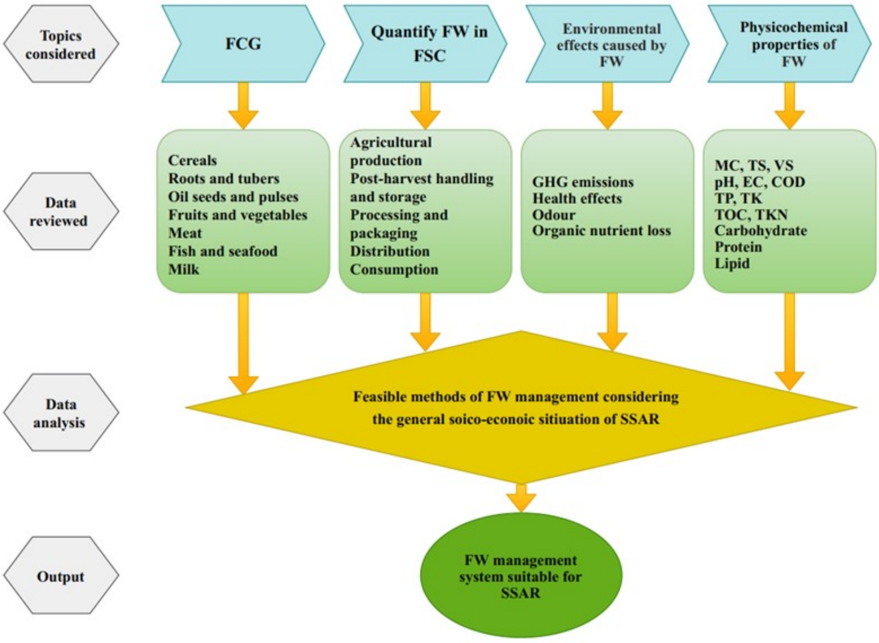

Figure 1 - The methodology adopted for the study

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It was found that almost all the studies published in peer-reviewed journals used the data published by FAO and the same was also used for the present study. In addition to the FAO reports, to give a comprehensive understanding about the quantity, problems created and the possible solution for managing FW, published peer reviewed literatures were also analysed. The way in which the available data was collected and analysed is portrayed in figure 1.

Status of FW generation in SSAR

The FW generated during different stages of the food supply chain (FSC) in SSAR as a whole and South Africa (SA) in particular is displayed in figure 2. Generally, in SSAR the major wastage occurred during production and processing of food material, while in SA the FW was higher than SSAR during post-harvest handling, storage, processing, and consumption phase. Considering losses during production for different FCG, the maximum loss was seen in meat (15%), fish and seafood had the lowest loss (5.7%) and four out of the seven FCG had losses above 10% in SSAR, while in SA it was only the loss in roots and tubers reached 10% and 4 out of the seven FCG had losses ≤ 1%. During post-harvest handling and storage phase the major FW was produced by roots and tubers (18%) and Milk (11%) in the SSAR, while oil seeds and pulses (38.4%), Fruits and vegetables (18.3%) and milk (12%) contributed more to SA. In the processing and packaging phase, there was considerable difference in FW between SSAR and SA, with SA producing huge wastage than SSAR. In SSAR only two out of the seven FCG produced losses greater than 10% (fruits and vegetables 25% and roots and tubers 15%) while in SA four out of the seven FCG had losses greater than 30% (cereals 36.5%, oil seeds and pulses 60%, fruits and vegetables 31.6% and fish and seafood 31.1%). In the distribution phase the losses were below 10% (7% maximum) on all FCG in SA, while three out of the four had losses ≤ 10% in SSAR (milk 10%, fish and seafood 15% and fruits and vegetables 17%). SSAR displayed considerably lower losses than SA in the consumption phase, with six out of the seven FCG wasting ≤ 2%, while six out of the seven FCG wasted ≤ 10% in SA.

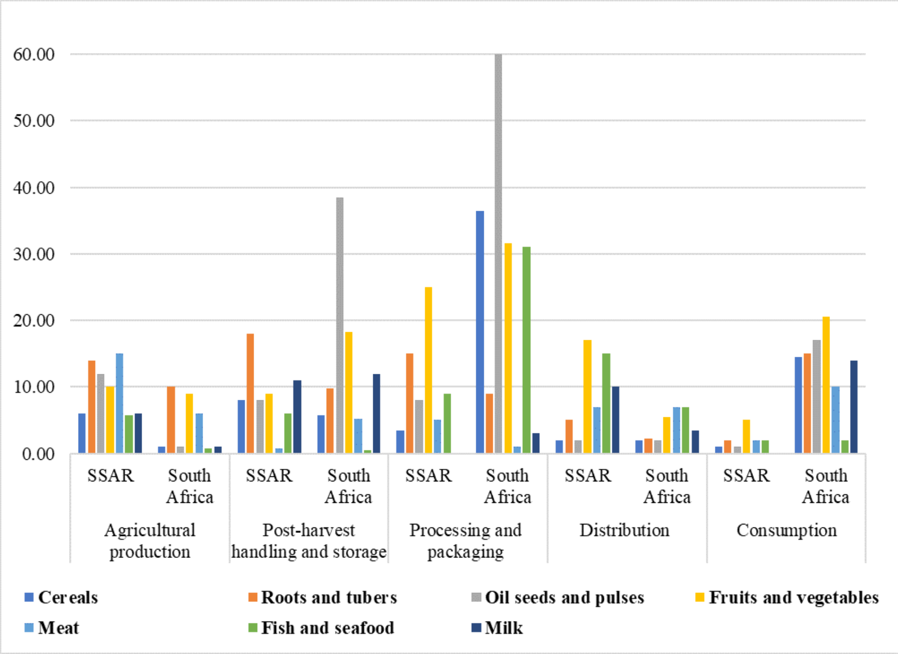

Figure 2 - Comparison of food wasted by different commodity groups at different stages of the food supply chain in SSAR and SA

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Note: source: [29], [30]

The amount of FW indicates the extent of inefficiency of the FSC of the country [31], [32]. The initial three stages of the FSC (agricultural production, post-harvest handling and storage and processing and packaging) are called as the upstream and the remaining stages are called as the downstream of the FSC [33]. The increased losses in the upstream is a common phenomenon in the developing countries [33] like those in the SSAR. This is mainly due to the lower technological adoption, higher dependence on human labour, larger amount of small scale farmers and poor marketing facilities [34]. The difference in waste pattern of SA with that of the whole of SSAR describes the food consumption pattern and preferences. SA is far ahead in developments concerned with the rest of SSAR so will be the consumption behaviour. The huge increase in the waste generated by the processing and packaging sector indicates that the people in the country prefers processed food and the presence of low-profile sectors lacking proper technology in producing finished products with lower FW. In addition, the FW in the consumption phase is almost like the developed countries. This explains the consumer behaviour and lack of proper commitment to the society and environment, which must be removed through proper education and awareness. This sort of consumer behaviour in wasting food material during the consumption phase is also explained by Akram and Javed [13].

It was reported by Aragie [35] that the FW produced in SSAR during the production and post-harvest handling stages are respectively 38% and 34% and if the avoidable losses are recovered, the farm income will be enhanced by 20%. Further it was found that in Benin, Chad, Ethiopia, Kenya, Madagascar, Malawi, Mali, Mozambique, Niger, and Rwanda FW in production was 38%, 34% in post-harvest handling and 18% in processing stages. It was inferred by Cronjé et al. [36] that the FW in SA is mainly caused due to the lack of planning and bulk purchasing of food materials. This behaviour of the people resulted in the production of 0.15 kg per person per day of FW in SA [8], while the whole of SSAR recorded a FW of 0.02-0.03 kg per person per day [37]. The data obtained by the above cited studies support the results used in the present study and that can be effectively used to plan management systems for FW generated in the SSAR.

Environmental effects caused by FW

Presently in SSAR, a large portion of the FW is used as landfill. This forms the source of huge GHG emissions, unhealthy surrounding, bad odour and key nutrients present in the organic not being used, which in turn is making the farmer more dependent on chemical fertilizers leading to land degradation and associated pollution [37]. It is estimated that about 22% of water used for irrigation is wasted in SSAR taking into consideration the FW [35]. The overall GHG emissions in SSAR has increased by four-fold between 1994-2014 [38] and is estimated that it will increase by additional 30% by 2030 [39]. The uncontrolled decomposition of organic matter results in the emission of nitrous oxide and methane into the atmosphere, which respectively have 196 and 25 times more atmosphere warming potential than CO2 [40]. Among all the regions in the world, SSAR is highly vulnerable to climate change as it is highly dependent on agriculture, which in turn is highly dependent on natural resources due to low technological advancements [41]. The agricultural sector in SSAR is the major employer [42], it is estimated that climate change will result in production decline of cereals by 3.2%. Thus, climate change not only affects the environment but also the economy of SSAR [43]. The other problem associated with the improper waste management is water pollution and bad order [44]. This will lead to the water as a reservoir of bacteria, viruses and other pollutants, making it unsafe for drinking without treatment [45]. This unhealthy condition not only affects human but also the other lives of the ecosystem.

The lack of proper infrastructure, sanitation and health facilities worsen the situation further. This situation mainly affects the poor and the middleclass population of the region [46].

Properties of FW generated in FSC and their influence in its management

The waste produced from the FSC is highly heterogeneous nature, creating complicity in its management. It is essential to know the physicochemical properties of FW for proposing possible interventions in its management [37]. The physicochemical property in turn depends on nature and type of FW generated. The nature, quantity and type of FW produced in the FSC of SSAR is described in figure 3. Knowing the amount of volatile solids (VS), fixed carbon and ash content are useful for estimating the energy that can be generated from the FW [47], moisture content (MC) indicates the suitability for different treatment technologies and chemical properties such as pH, EC, COD, total phosphorus, total potassium [37], total organic carbon (TOC), total Kjeldahl nitrogen (TKN) indicate the suitability for microbial activity [48]. In addition, knowing the quantity of carbohydrate, protein, and lipid in FW are helpful to estimate the pace of degradation, toxicity and help in setting a proper balance between the nutrients and selecting suitable treatment strategies [37].

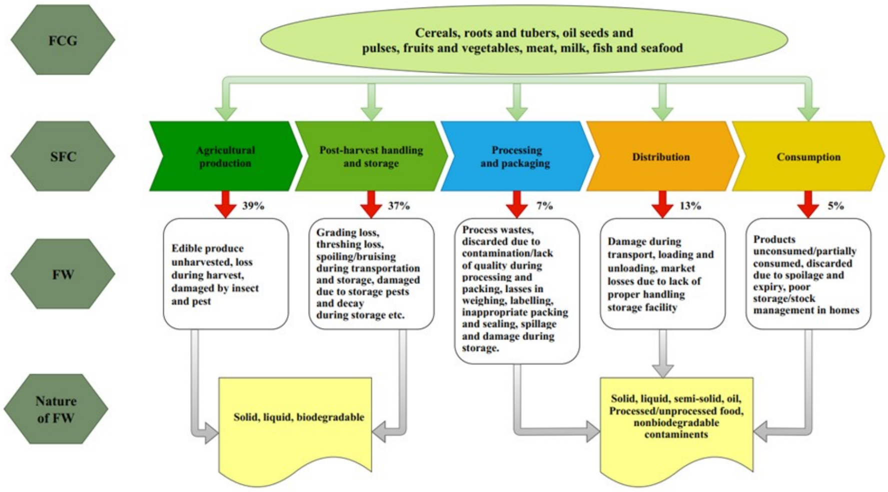

Figure 3 - Type and nature of the FW produced
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Note: source: [37], [49]

Depending on the source and nature of FW, MC varies between 48-95%. Generally, the FW from households have an MC of 70%, those generated from hotels, restaurants and canteens range between 75-85% and in rare cases MC goes beyond 90% [50], [51]. The higher MC of FW from hotels and restaurants is due to the mixing of water used for cleaning, this results in increasing of the bulk volume of the waste generated. The bulk density of FW is correlated with the MC and in general it is found to Varey between 505-860 kg/m3, TS and VS respectively range between 5.4-51.5% and 73-98% [37]. It was found that the calorific value of FW also depends on the MC, and as the MC increases, the calorific value decreases. There can be a reduction up to 78.3% of the calorific value of FW with the increase in MC [52]. The pH (4.5) of the FW is generally found to be in the acidic range, with an EC about 1.9 mS/cm. Thus, making it different from the other organic wastes such as animal manure, blood meal, green waste, and sewage sludge [53], [54], [55]. The total COD of FW ranges between 868-1522 g/kg, having a soluble fraction in the range between 58-1085 g/kg. Generally, the ratio of total to soluble COD of FW is in the range between 35-85% [56]. The TOC and TKN respectively ranged between 29.7-56.3% and 1.3-3.25% [51]. Similarly, TP, TK [57], C/N ratio, Ca, Mg, Na [58], C, H, O, N, and S [37] contents in FW in general ranged between 0.05–0.98%, 0.29–1.43%, 9.3-24.5, 1.3-30.0 mg/g, 0.5-2.0 mg/g, 7.8-23 mg/g, 39.5-53.3%, 5.53-7.3%, 29.1-47.7%, 1.7-5.7% and 0.1-47.2% respectively.

Feasible methods of FW management

The FW produced from the upstream of the FSC is generally associated with higher MC, while the downstream is associated with lower MC [37]. The MC below 50% is preferable for incineration. Thus, FW produced from the upstream of the FSC has to be mixed with other wastes to satisfy the MC requirement for incineration [59]. Composting is another technique that can be adopted for the management of FW [60], which is also hindered by higher MC posing the requirement of bulking agents. The bulking agents used should also not hinder the optimum CN ratio and the pore space required for composting. pH lower than the neutral value can highly affect the composting process. Generally the pH of the FW from the upstream of the FSC is found to be acidic which can result in inhibiting the microorganisms involved in the composting process, unless amendments are provided for increasing the pH to neutral value [61]. Protein is needed for cell differentiation and C forms the energy source for the microorganisms, 25-35 is considered as the optimum CN ratio range for composting. In general, the CN ratio of FW is lower or near the optimum range, thus composting FW having high TKN (FW with high protein content) will result in increase ammonia emission, thus high protein FW has to be mixed with high C wastes for better composting and reducing ammonia emission [37].

Though the higher MC of FW produced from the upstream FSC hinders the process of incineration and composting, it is favourable for anaerobic digestion process [37]. In addition to MC, the percentage of VS present in FW also favours the process of anaerobic treatment [62]. But the presence of high number of soluble COD generally associated with FW will affect the feeding rate to the digester. The feeding rate has to be reduced to avoid the digester from being acidic and in turn inhibit the working of the methanogenic bacteria [53], [63]. Similar is the case when using feed stock containing high carbohydrates and FW generally contains high amount of carbohydrates [64], [65]. In these circumstances, adopting two-phase system in which acidogenic and methanogenic phase are separated is more appropriate. The two-phase system of approach is gaining popularity globally [53], [63]. The CN ratio between 10 and 30 is considered optimum for anaerobic digestion, the CN ratio of FW satisfies this requirement, making it a suitable feed stock [66], [67]. The presence of Na+, Ca2+, and Mg2+ are reported to enhance the toxicity posed by ammonia in anaerobic digester. But it is also found that the presence of Na+ and K+ or Na+ and Mg2+ combinations can enhance methane production by 10% [58]. In addition, the toxicity imposed by these ions depends on the microorganisms involved in the process and variations have been reported by many studies [37].

FW management suitable for SSAR

The SSAR accounts for about 13% of the global population and lacks far behind in terms of development and energy supply [68]. Agriculture is the major livelihood of the population, but the productivity is very low due to the lack of basic inputs such as fertilizers [69]. The success of adoption and sustainably of any FW management system will depend on the benefits the common population can get. Energy is the basic demand of the people in SSAR and plant nutrients is their sustainability requirement [70], [71].

Thus, FW management using biogas technology will result in providing the people with clean cooking fuel, benefit the environment by reducing the GHG emissions and get value added manure which can be used as fertilizer for crop production [72], [73]. As the methane in the biogas produced is consumed totally, it eliminates the environments effects that it can cause. Taking this aspect into consideration, biogas technology is promoted by both developed and developing countries for bio-stabilizing their fermentable organic waste [74]. While methods like incineration, gasification and pyrolysis are more complicated and have lower benefits than anaerobic digestion [75]. The other commonly adopted methods such as landfill and composting have more area and labour requirements and produces

lesser energy than anaerobic digestion [76]. Anaerobic digestion of FW is being successfully adopted by many countries, both developed and developing [77], [78], thus can be effectively used in SSAR also.

Due to the prevailing logistic problems in SSAR, implementing only a large-scale anaerobic treatment facility will not solve the problem [79]. The waste treatment facilities must be divided into two as treatment at source using small scale bigas plants (for waste generated from homes, small hotels, canteens, restaurants, and processing units) and large-scale biogas plants for treating FW collected from centres which cannot implement treatment facility. Small scale biogas plants will have higher demand in SSAR [80]. Taking the socio-economic situation of SSAR into consideration, for wider acceptance the cost of the biogas plant has to be in the affordable range. Portable biogas plants similar to the ones studied by Augastian et al. [81] can be effective. Taking the heterogeneous nature of the FW, biogas plants with phase separation system will be successful for large-scale units.

Conclusion

Taking into consideration the type, nature, quantity, and the physicochemical properties of the FW generated in SSAR and the socioeconomic conditions and requirements of the people in the region, the present study found that anaerobic digestion of FW is the feasible, suitable, and sustainable method of FW management in SSAR. Adopting the proposed system of FW management, it not only eliminates the problems caused by the FW, but also provide the people with clean cooking fuel, healthy cooking environment, reduce their dependence on firewood for cooking and chemical fertilizers for cultivation. In addition, it will create a hygienic environment and improve socioeconomic status through better job opportunities.

Конфликт интересов

Не указан.

Рецензия

Все статьи проходят рецензирование. Но рецензент или автор статьи предпочли не публиковать рецензию к этой статье в открытом доступе. Рецензия может быть предоставлена компетентным органам по запросу.

Conflict of Interest

None declared.

Review

All articles are peer-reviewed. But the reviewer or the author of the article chose not to publish a review of this article in the public domain. The review can be provided to the competent authorities upon request.

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