MODELING SUSTAINABLE CHALLENGES TO WASTE REDUCTION IN THE FOOD INDUSTRY

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ABSTRACT
Food waste is one of the main problems in food chain management all over the world. This waste happens at different stages of the supply chain. Previous studies on food waste have not well defined the main drivers of and outlines to reduce it. To address these gaps, we have proposed a best-worst method (BWM) as a framework to assess the environmental criteria for sustainability of food industries in over the world. The purpose of this paper is to analyze the main drivers and barriers to food waste reduction in the consumption phase and analyze pathways to anti-wastage behaviors. This finding will help the food industry to work toward sustainability across supply chains. This study revealed that "waste management" was the most important indicator for establishing environmental sustainability.

1. INTRODUCTION

Food Waste has now become a global concern. Food waste means food that was thrown away as it was not needed. Food waste occurs when we put too much food in our bowls or plate without understanding how much we can consume. Food waste can occur at every level of the food supply chain, including manufacturing, processing, and packing because it must eventually reach the market for sale and consumption.

Food waste can be unintentional or purposeful, but in any case, it results in a lack of food for other people. Food wastage can occur at any point in the food supply chain, including harvesting, storage, packing, transportation, and market conditions (i.e. infrastructure).

According to recent reports, food is wasted at a rate ranging from 25% to 50% throughout the food supply chain. According to the United Nations' Food and Agricultural Organization (FAO), food waste accounts for 30% of worldwide food output (FAO 2011). On a weight basis, this equates to over 1.3 billion tons, or nearly 190 kg of edible food each person. In Europe and North America, consumers throw away between 95 and 180 kilograms per year, whereas consumers in Sub-Saharan Africa and South and Southeast Asia each toss away only 6–11 kg per year (FAO 2011) (Gjerris and Gaiani, 2013). Individual nations and international organizations have set the goal of reducing food loss and waste as a priority.

Throughout the food chain, waste is produced. Discovering ways to resolve food waste requires a complete understanding of why food is wasted throughout its entire value cycle. On the one hand, there may be poor business decisions or processes that result in food waste, while on the other hand, consumers have an impact on the phenomenon due to a variety of behavioral aspects, such as refusing to buy food that no longer looks desirable, refusing to buy food that is approaching the "best before" date, and buying more food than required but not consuming within time) (Chinie, 2020).

According to FAO data, food waste at the consuming stage accounts for roughly 35% of all food waste in Europe, while food waste at the distribution stage accounts for close to 10% of all food waste. According to research conducted by LEI for the European Commission, homes account for 31% of food waste across the supply chain, while trade and catering account for 14% (Aschemann-Witzel *et al.*, 2015). Food is being wasted in the initial phases of the supply chain in developing countries, and in the latter stages of the supply chain in developed countries, according to FAO (Gustavsson et al., 2011) and prior study (Chinie, 2020).

Population and economic expansion, as well as urbanization, are driving upwards global food consumption. This upward trend is predicted to continue in the next decades, with total current food consumption expected to rise by 60% by 2050. Minimizing food losses and waste can assist in meeting this rising demand while also reducing the strain on food production (Halloran *et al.*, 2014).

Food waste reduction is linked to the United Nations' Sustainable Development Goals 2nd and 12th - "Zero Hunger" and "Responsible Consumption and Production." The European Union is likewise committed to halving food loss by 2030, and as part of that policy, it launched the EU Platform on Food Losses and Food Waste in 2016, which allows preventative measures to be designed, best practices to be shared, and progress to be tracked over time. Throughout the food chain, waste is produced (Chinie, 2020).

The primary goal of this study is to identify the biggest roadblocks to sustainable food waste management in the food industry. The second goal is to propose an approach for analyzing these problems in order to gain a better knowledge and management of Food Waste Management activities in the food supply chain. We employ the Best Worst Method (BWM) to investigate these issues (Mangla *et al.*, 2021).

In this study, we give a rigorous, transparent, and reproducible literature evaluation of the existing scientific conversation on consumer food waste. We examine and analyze research on the factors that prevent or encourage consumer food waste, and we address the contributions of psychology-oriented methods and social practice theory based on this analysis. Following that, we offer insights into policy and corporate choices for addressing the concerns revealed by such findings, as well as recommendations for further study (Schanes, Dobernig, and Gözet, 2018).

2. LITERATURE REVIEW

2.1. Supply Chain Sustainability

Sustainability has three goals known as the triple bottom line. They are- people, planet and profit. If a company can effect these three areas positively, it is considered more sustainable.

Supply chain sustainability is a view of supply chain processes that affect the environmental, social, economic and other aspects of a supply chain's components (Seuring, 2013).

Sustainable supply chain includes identifying the source of raw materials, ensuring good conditions for workers and reducing the carbon footprint. It also includes environmental impact as an imperative, consideration of all stages across the entire value chain for each product and a multi-disciplinary perspective, encompassing the entire product life cycle (Gupta and Palsule-Desai, 2011). Energy usage reduction, CO_2 emission reduction, proper waste disposal, water usage reduction can help in sustainability in supply chain. Thus, sustainable development ensures meeting the needs of the present without compromising the future (Seuring and Müller, 2008).

Sustainability has a great impact on food industry. For instance, there is a belief that organic product is better for the environment. Therefore, more sustainable food industries try to use more organic resources for procurement. In recent times, it is seen that the consumers are increasingly showing interest in sustainable and ethically sourced food and drink products (Food ingredients Global, 2011). There is no doubt that the popularity of plant-based foods is increasing day-by-day, but it doesn’t mean that everyone is going to become vegan. For example, the ‘Natural Burger’ from Sodexo uses a 75-25 blend of beef and mushroom which balances nutrition and taste. This example reflects the blended foods that are plant-based with a little amount of meat resulting in fewer calories, cholesterol, sodium and a reduced carbon footprint.

2.2. Food waste Management:

The collection, transportation, treatment, and disposal of human waste is commonly referred to as waste management. Waste management is a broad term that describes a wide range of topics. Biohazardous waste, chemical waste, and organic waste are only a few of the types of wastes. Different types of waste need different ways of treatment and disposal.

Now, in regards to our objective, Food waste refers to food that has been purchased but not consumed and has ended up as waste. Food waste defined by the UN Food and Agriculture Organization (FAO) as any healthy or edible item that is wasted, lost, contaminated, or devoured by parasites at any stage of the food supply chain, rather than being meant for human use.
The Global Initiative on Food Loss and Waste Reduction of the United Nations Food and Agriculture Organization (FAO) provides a framework for classifying food loss and waste, from which we establish working definitions (Waste *et al.*, 2018).

Also, from a study indicating the worldwide acceptance for food and waste management implies that, items eliminated from the food supply chain throughout the pre- and post-consumer periods are not consistently defined by several standards, implying the need for internationally accepted food loss and waste standards (Waste *et al.*, 2018).

(Gustavsson et al. (2011) reported data on FW generation from various regions of the world, revealing that FW generation is of equal scale in both developed and developing countries (DCs). Nonetheless, there are significant differences between developed and underdeveloped countries. Over than 40% of food wastage occur at the post - harvesting and manufacturing stages in the latter, whereas around 40% of food wastage happens at the retail stage and consumer lever in the former, thus on a per-capita basis, significantly more food is lost in the industrialized world than in the developing world (Girotto, Alibardi and Cossu, 2015).

The causes of food loss and waste in middle- and high-income countries are mostly concerned about customer behavior as well as a lack of cooperation among members of the supply chain. Agricultural produce waste might result from commercial transactions between farmers and consumers. Food products that do not meet the acceptable form or aesthetic may be discarded, resulting in food waste. Inadequate planning and the expiration of "best before" dates, along with customers' often cavalier attitude, result in enormous volumes of waste on a consumer level. Food waste in developed regions can be minimized if the food industry, merchants, and consumers are made more aware of the problem. This entails the waste of vast quantities of resources needed in production of food, as well as a rise in GHG emissions as a result (Girotto, Alibardi and Cossu, 2015).

3. METHODOLOGY

3.1. Workflow

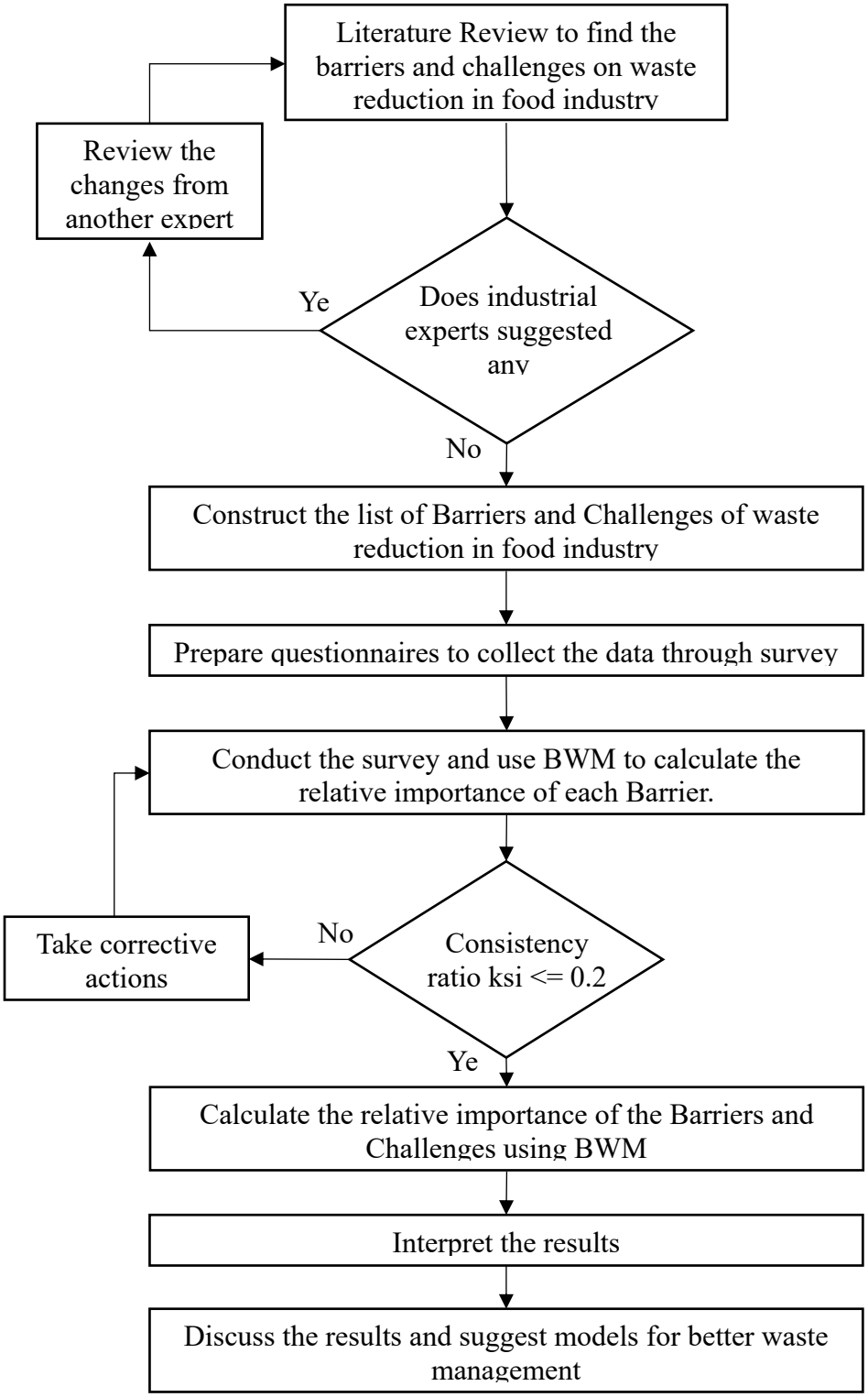

Figure 03: *Flow chart representing the flow of work.*

3.2. Survey and Data collection

This study has a major research implication. We made a survey on 100 professionals and 25 of them response. This study used Best Worst method to identify the basic reason behind food waste. In this model, the study find out the drivers of food waste in supply chains and organize them in order from best to worst in worldwide scenario. This study has conducted by the professional supply chain manager who closely work with food chain and Certified Supply Chain Analysts. Through BWM calculations, we obtained the relative and final weighted averages (arithmetic mean) for different criteria. The KSI value greater than 0.2 was rejected. Food Waste management has a great economic value in any country especially in developing country like Bangladesh. Minimizing foo waste has become a basic problem over the world. The results of the present study can create great value on this regard (Suhi *et al.*, 2019).

3.3. Multi Criteria Decision Making (MCDM):

Decision analysis is a significant technique in problem resolution when there are several players, criteria, and objectives. MCDM challenges are often composed of five components: the aim, the decision maker's preferences, options, criteria, and results.

Sustainable food waste management has a multi-criteria aspect to its challenges and barriers. This makes it harder for decision-makers to identify comparability among the parameters. MCDM can be a helpful method for this case.

MCDM research is intertwined with other areas such as Multi-Attribute Decision Making (MADM), Multi-Attribute Utility Theory (MAUT), Multi-Objective Decision Making (MODM), and Public Choice Theory (PCT). To establish the MCDM techniques within a wider quantitative framework, we may distinguish three categories of work that characterize formal numerical approaches.

(1) Models that make use of inferential or descriptive statistics.

(2) Systems analysis or mathematical programming models.

(3) Data base management and information system-based models.

3.4. Best Worst Method (BWM)

Here is the step-by-step process we used to analyze BWM method for this research.

Step 1: Identification of decision-making criteria:

A set of decision-making criteria (c_1, c_2, c_3, …, c_n) was identified by the suggestions of experts.

Step 2: Identifying the best and the worst criteria from the set of criteria found in step 1:

In this step, the experts, consulted for this research, identify the most important (best) and the least important (worst) criteria.

Step 3: Comparing the best criterion with the other criteria:

'Best-to-others vector' is generated in this step with a scale of 1 to 9. Here, 1 means criterion A(best) is equally important as criterion B(other) and 9 means criterion A is way more important than criterion B. This vector can be expressed as,

$$V_B = (v_{B1}, v_{B2}, v_{B3}, \ldots, v_{Bn}) \quad (1)$$

Where, v_{Bi} indicates the relative preference value of the most important criterion, *B* over criterion *i*. So, v_{BB} must be 1 always.

Step 4: Comparing the other criteria with the worst criterion:

Like step 3, 'others-to-worst vector' is generated in this step. A scale of 1 to 9 is also used here. 1 means criterion A (other) is equally important as criterion B (worst) and 9 means criterion A (other) is way more important than criterion B (worst). This vector can be expressed as,

$$V_W = (v_{1W}, v_{2W}, v_{3W}, \ldots, v_{nW}) \qquad (2)$$

Where, v_{iW} indicates the relative preference value of criterion *i* over the worst criterion, W. So, v_{WW} must be 1 always.

Step 5: Computing the optimal weights $(w_1^*, w_2^*, w_3^*, \ldots, w_n^*)$

By computing the optimal weights of the decision-making criteria, the maximum absolute differences for all *i* are minimized over the set,

$$\{ |w_B - v_{Bi}w_i|, |w_i - v_{iw}w_w| \}.$$

And a min-max model can be formed like this,

$$\text{min-max}_i \{ |w_B - v_{Bi}w_i|, |w_i - v_{iw}w_w| \}$$

with subject to,

$$\Sigma_i w_i = 1, \text{ where, } w_i \geq 0 \text{ for all } i \qquad (3)$$

Eq^n (3) can be transformed into a linear programming model,

$$\min \beta^L$$

With subject to,

$$|w_B - v_{Bi}w_i| \leq \beta^L \text{ for all } i,$$

$$|w_i - v_{iw}w_w| \leq \beta^L \text{ for all } i,$$

$$\Sigma_i w_i = 1, \text{ where, } w_i \geq 0 \text{ for all } i \qquad (4)$$

By solving eq^n (4), the optimal weights $(w_1^*, w_2^*, w_3^*, \ldots, w_n^*)$ and the consistency ratio, β^L were obtained. β^L indicates the consistency level of the decision makers. A lower value of β^L ensures higher consistency of the decision makers and a higher value of β^L indicates that there is something wrong in prediction and it should be re-examined.

Challenge to reduce waste in food industry	Code	Importance Rating
No demand from customers or stakeholders	C1	0.097
Lack of incentives	C2	0.091
Lack of awareness	C3	0.140
Over production due to incorrect forecasting	C4	0.150
Frequent operational mistakes	C5	0.092
Improper packaging	C6	0.117
Bad transportation facility	C7	0.084
Lack of cold storage	C8	0.103
Behavioral issues of consumers	C9	0.127

4. ANALYSIS OF FINDINGS

Table 01: *Selected Sustainable Challenges, respective codes and relative importance ratings.*

From the result of survey, we came to learn that the most important challenge to reduce waste in food industry is C4 (15%) and the least one is C7 (8.4%). In addition, C3 (14%) and C9 (12.7%) also seem to be more important than the

others. However, this survey was conducted with the help of supply chain experts from Bangladesh, a developing country. So, this result can't be said to be perfect from all perspectives.

For example, for a developed country, bad transportation facilities shouldn't be a mentionable challenge in this case. On the contrary, for an under-developed country, lack of incentives from the government and lack of cold storage should have a higher percentage of importance. But a developing country like Bangladesh has the mixed importance of all these 9 stated challenges. That's why we don't find any of them too much high or low in percentage.

Future researchers will be able to evaluate challenges to reducing food waste in food industries in developing countries like Bangladesh, according to the findings of this study. The highest percentage is observed in the "Overproduction due to incorrect forecasting" which can be the main concern. So, the reasons that lead to this problem should be analyzed. One main reason for the incorrect forecast is –in most cases it is done on the basis of pure assumptions and not valid data. For example-During Ramadan the demand for Beverages increases rapidly. With the increasing demand, production and supply are also increased. If the previous year's statistical data including supply and demand is analyzed then proper forecasting can be made which will help reduce wastage.

Lack of awareness is also an important concern for countries like Bangladesh. According to the latest Wasted Food Study, young individuals aged 18 to 24 waste more food than any other age group due to a lack of understanding about the impact of food waste. A lot of people don't know about the bad impacts of food waste. So, public awareness and campaigns are necessary to let people know about the bad impacts of food waste on the economy as well as the environment.

Behavioral issues of consumers also play a role in this case. Most people feel no moral obligation in reducing the wastage of food. In Bangladesh, food waste mainly occurs at wedding ceremonies and restaurants. This is due to a lack of concern and behavioral issues. There are no certain rules and regulations regarding improper food waste management. Public awareness can also play an important role in this case.

5. SUGGESTED STRATEGIES

The solution for food waste management is many. And many of them are already existing and work in parallel in the daily supply chain. Among those some of them are mentioned below:

1. Giving Proper Expiration Guidelines
2. Ensuring less food waste
3. Biofuel and Bioenergy Production
4. For improved forecasting ensuring appropriate planning
5. Increasing shelf life
6. Resisting ourselves from overproduction
7. Minimizing errors in industrial processing and keeping up with food safety policies
8. Overcoming managerial, financial, and technical constraints
9. Limiting over-merchandising and over-ordering in supermarkets and grocery stores
10. Consumer behavior
11. Save and use leftovers

Now, if we talk about our research outcomes, our top three most important challenges were:

1. C4 Overproduction due to incorrect forecasting (C4)
2. C3 (lack of awareness (C3)
3. Behavioral issues (C9)

5.1. Overproduction due to incorrect forecasting.

The first and the most frequent challenge we found is overproduction due to incorrect forecasting**.** Some crucial steps must be taken regarding forecasting in order to reduce overproduction caused by erroneous forecasting.

This problem can be solved by two different teams of the company.

- Supply chain management team
- Manufacturing team

5.1.1. Supply chain management team's task

First and foremost, the supply chain management team must recognize the market size and potential, as well as seasonal variations in market size. For example, the pace of product consumption can fluctuate depending on the festive season or the time of year. As a result, supply chain managers should thoroughly identify the market, utilizing data from prior years' sales. It should also be taken into account the product's increasing consumption rate every year. Marketing or branding effects on sales must also need to be examined.

5.1.2. Manufacturing team's job

After supply chain management has completed its predictions, the manufacturing unit takes action. Manufacturing should be controlled by the manufacturing unit based on predictions of supply chain management. In this case, the production must be extremely responsive and adapt swiftly to the changing demands. In addition, better warehousing is required. Their major goal must be to meet the demand while still being prepared for unexpected production due to market fluctuations.

5.2. Lack of awareness

Now, moving towards our second challenge which is **lack of awareness.** We can say that a lack of food waste awareness is a frequent problem among customers, management teams, and retailers. One of the main reasons for this is a lack of understanding about expiration dates.

First of all, mass awareness must be created among individuals both consumers and retailers regarding reducing food waste, by introducing them to many sorts of dates of food that are commonly seen on the packaging. Those dates are:

1. Sell by date: The date can be used to determine how long an item should be on display for sale before its quality degrades. After this date, items are typically safe to eat, although their flavor and appearance may begin to deteriorate.
2. Best if used by (or before) date: The date "Best if used by" indicate when the food item will be at its best quality.
3. Guaranteed fresh date: This date is frequently used in baked goods that are consumable. Freshness is no longer guaranteed beyond this date, though it may still be edible.
4. Pack date: This is the date when the item was packed, and it is most commonly found on canned and boxed goods. It usually takes the shape of a code that is difficult to comprehend. YYMMDD or MMDDYY are examples of month (M), day (D), and year (Y) codes.
5. Use by date: Canned products, dry goods, sauces, and other shelf-stable commodities sometimes have "use-by" dates.
6. Expires on date: The date after which a product should not be offered because its quality or efficacy is predicted to deteriorate.

Regular customers, retailers, and local consumers must be aware of these expiration dates in order to get the most out of the product. As a result, a customer can be more truthful and be recognized when a product is best to buy and when it is best to buy guaranteed fresh. Also, retailers will be more sincere about a product when it is most ideal to sell it before it spoils. As a result, social awareness about minimizing waste might be raised, and higher food waste could be avoided.

Furthermore, a company's all-sector workers and management team should always compile an annual report based on the amount of lost revenue each year due to food waste, which will help them push toward reduced food waste and keep an eye on food waste.

5.3. Customer behavioral issues

Our third challenge is customer behavioral issues. This is a typical yet significant challenge in the food waste management process. Because, as the global population is increasing, people generate more and more food waste every day. It can be performed by doing more shopping than necessary or by serving more food during the festive season or at any social occasion. Again, many consumers do not want to utilize leftovers or do not have the necessary skills to do so. Moreover, it is a frequent tendency among people to produce more food waste when going for eating outside. Insufficient awareness of expiration dates can lead to food waste.

From (Attiq *et al*., 2021) we get the fact that there is a huge amount of lacking of knowledge among young consumers about the effects of food waste, the habit of wasting, a lack of regret about lost food, and a lack of worrying about spending the money while wasting food.

Some basic efforts must be made in order to solve all of these client behavioral concerns. For example,

1. Engaging with local government
2. Telling legislators that food waste is an important issue
3. The government should run more and more campaigns against food waste and the economic loss that the country suffers as a result.
4. Various training programs must be ensured about on how to properly treat leftovers and how to reuse them.
5. Support businesses with better food waste treatment
6. Food waste events must be organized frequently.

The main focus of these campaigns and events must be to get people familiar with food waste and the number of economic losses the nation faces due to food loss. Also, consumer engagement with the 4'Rs always needed to be appreciated. The 4'Rs are,

1. Refuse
2. Reduce
3. Reuse
4. Recycle

Consumers must be made aware of the situation of the advantages of less food waste. They should place a greater emphasis on the financial benefits of reducing food waste. However, altering people's behavior is usually a difficult undertaking, thus eliminating this problem will take a lot of effort.

5.4. Biofuel and bioenergy production

Though our focus was on identifying barriers to food waste management and giving some solutions related to it. We can reduce food waste to a great margin through some steps yet there will be at least a little amount of waste present. For 100% of reduction of food waste is almost next to impossible. Thus, treating these wastes is also necessary. One great way is the production of biofuel and bioenergy. Let's take a look at this.

As the globe grapples with climate change, demand for bioenergy and sustainable food supplies will rise. Bioenergy can also be created in an environmentally friendly manner. In many countries, such as Southeast Asia, Latin America, and Sub-Saharan Africa, the potential for producing biomass for energy in a sustainable manner is still untapped, and it has the ability to generate considerable amounts of renewable energy with minimum changes in land cover.

Food waste can be converted into biofuels or energy by means of the following processes:

1. Biodiesel is produced via the transesterification of oils and lipids.
2. Fermenting carbohydrates to generate bioethanol or bio-butanol.
3. Biogas (methane-rich gas) is produced via anaerobic digestion.
4. Dark fermentation for producing hydrogen.
5. Pyrolysis and gasification.
6. Hydrothermal carbonization.
7. Incineration.

Thus, various biofuel and bioenergy can be produced as well as they can be implemented in various sectors (Girotto, Alibardi and Cossu, 2015)

6. CONCLUSIONS, LIMITATIONS, AND SCOPE FOR FUTURE WORKS

The goal of the present study was to establish a model that would direct the pathway to minimize food waste in the food economy. Food waste is a common and major problem all over the world which leads to an economical loss in the industries. This research would provide some information about how to reduce food waste. We suggest that future researchers on food waste would use sensitivity analysis to improve the result. This study suggested sustainability. Any industry that can follow this process to lead a sustainable food chain management with the least waste.

The present study has some limitations. Factors like financial attitudes, GDP, religion, and consumer psychology in the specific region have not been considered has not been considered in recent studies. Furthermore, recommend that future studies focus on the fact that family education plays an important role in not wasting food. Besides, this study is generalized. But the drivers of food management can vary from region to religion and country to country.

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