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DECIPHERING FOOD WASTE: EXPLORING CONCEPTS, THEORIES AND MODELS

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I. ABSTRACT

WASTE IS AN INEVITABLE BY-PRODUCT OF GOODS AND SERVICES PRODUCED BY HUMANS, WITH FOOD WASTE BEING A SIGNIFICANT EXAMPLE. FOOD WASTE AND LOSS PRESENT SERIOUS CHALLENGES FOR BOTH ENVIRONMENTAL SUSTAINABILITY AND GLOBAL FOOD SECURITY. FOOD WASTE OCCURS THROUGHOUT THE SUPPLY CHAIN, FROM PRODUCTION TO CONSUMPTION, DUE TO INEFFICIENCIES, OVERPRODUCTION, AND INADEQUATE INFRASTRUCTURE. FOOD LOSS PRIMARILY HAPPENS DURING PRODUCTION AND STORAGE BECAUSE OF PESTS, DISEASES, AND SPOILAGE. ACCORDING TO THE FAO, APPROXIMATELY ONE-THIRD OF ALL FOOD PRODUCED FOR HUMAN CONSUMPTION IS LOST OR WASTED ANNUALLY, AMOUNTING TO ABOUT 1.3 BILLION TONS. THIS WASTE SQUANDERS VALUABLE RESOURCES AND CONTRIBUTES TO ENVIRONMENTAL DEGRADATION, GREENHOUSE GAS EMISSIONS, AND BIODIVERSITY LOSS. IT ALSO EXACERBATES FOOD INSECURITY AND HUNGER, IMPACTING MILLIONS GLOBALLY. ADDRESSING THIS CRISIS REQUIRES ACTION AT MULTIPLE LEVELS, INCLUDING GOVERNMENTS, BUSINESSES, CIVIL SOCIETY, AND INDIVIDUALS. STRATEGIES INCLUDE REDUCING, REUSING, AND RECYCLING FOOD WASTE, IMPROVING SUPPLY CHAIN EFFICIENCY, INVESTING IN INFRASTRUCTURE AND TECHNOLOGY, AND PROMOTING SUSTAINABLE CONSUMPTION PATTERNS. RAISING AWARENESS AND CHANGING CONSUMER BEHAVIOUR ARE ALSO CRUCIAL. EFFORTS TO TACKLE FOOD WASTE AND LOSS ARE ESSENTIAL FOR ACHIEVING SUSTAINABLE DEVELOPMENT GOALS AND ENSURING THE WELL-BEING OF FUTURE GENERATIONS. BY ADDRESSING THESE CHALLENGES, WE CAN CREATE A MORE RESILIENT, EQUITABLE, AND SUSTAINABLE FOOD SYSTEM WHILE MINIMIZING OUR ECOLOGICAL FOOTPRINT.

II.

***Keywords**: waste, food waste, food loss, theories, models*

III. INTRODUCTION

Waste is a man-made byproduct that has no purpose or can no longer fulfill its intended purpose. The concept of waste is relative in two main ways. First, something becomes waste when it loses its primary function for the user, meaning one person's waste output can often become another person's raw material input. Second, the notion of waste is relative to the technological state of the art and the location of its generation, making it a very dynamic concept. **Non-waste**, on the other hand, refers to something that has been assigned a purpose by its current or potential owner, who will either use it for that purpose or modify its state or structure to ensure it can fulfill the assigned purpose. Waste encompasses any material or substance that is discarded, unwanted, or no longer useful. This includes various types of waste, such as solid waste (e.g., garbage, refuse), liquid waste (e.g., wastewater, sewage), and hazardous waste (e.g., chemicals, medical waste). Waste can be generated from numerous sources, including households, businesses, industries, and construction sites. Proper management and disposal of waste is important for protecting the environment and human health. According to the United Nations Environment Programme **(UNEP)**, "*Waste is any substance or object which the holder discards or intends or is required to discard*" **(UNEP, 2021)**. The United States Environmental Protection Agency (EPA) defines waste as "*any material that is discarded, burned, incinerated, or recycled, or is inherently waste-like, or military munitions*" **(EPA, 2022)**. The European Union Waste Framework Directive defines waste as "any substance or object which the holder discards or intends or is required to discard" **(European Union, 2008)**. Waste and its classification are presented in the **Tables 1,2 and 3**.

Table 1 - What is waste? (Webster's and Cassell dictionaries).

Lexical entry	Definition
Waste (verb)	to consume, to spend, to use up unnecessarily carelessly or lavishly; to fail to use to advantage; to wear away gradually; to devastate.
Waste (adjective)	something superfluous, left over as useless or valueless; desolate, desert, unoccupied, uncultivated, devastated, barren; having served or fulfilled a purpose, no longer of use.
Waste (noun)	the act or instance of wasting of throwing away; gradual diminution of substance, strength, value; material, food, etc. rejected as superfluous, useless or valueless; material produced by a process as a useless by-product; an unusable product of metabolism; anything unused, unproductive, or not properly utilised; anything left over as excess material; by-products not in use for the work at hand; that which is of no value; worthless remnants; refuse, damaged, defective, or superfluous material; material rejected during a manufacturing process; an unwanted by-product of a manufacturing process, chemical laboratory, or nuclear reactor; refuse from places of human or animal habitation.

***Source**: Eva, Pongrácz. (2002)*

Table 2 - Concept of Waste

EU	Waste shall mean any substance or object in the categories set out in Annex I, that the holder discards or is required to discard **(European Council, 1991)**.
OECD	Wastes are materials other than radioactive materials intended for disposal, for reasons specified in Table 1 **(OECD, 1994)**.
UNEP	Wastes are substances or objects, which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law **(UNEP, 1989)**.
Lox	Waste is either an output with ('a negative market') 'no economic' value from an industrial system or any substance or object that has 'been used for its intended purpose' (or 'served its intended function') by the consumer and will not be re-used **(Lox, 1994)**.
McKinney	Waste is the unnecessary costs that result from inefficient practices, systems or controls **(McKinney, 1986)**.
Baran	Waste is the difference between the level of output of useful goods and services that would be obtained if all productive factors were allocated to their best and highest uses under rational social order and the level that is actually obtained **(Baran, 1959)**.
Hollander	Waste is something that needs to be expelled so that the system continues to function **(Hollander, 1998)**.
Elwood and Patashik	Waste, like beauty, is in the eye of the beholder **(Elwood and Patashik, 1993)**.
Gourlay	Waste is what we do not want or fail to use **(Gourlay, 1992)**.
Pongrácz	Waste is an unwanted, but not avoided output, whence its creation was not avoided either because it was not possible, or because one failed to avoid it **(Pongrácz, 1998)**.
Pongrácz	Waste is a man-made thing that has no purpose; or is not able to perform to its purpose **(Pongrácz, 2002)**.
Pongrácz	Waste is a man-made thing that is, in the given time and place, in its actual structure and state, not useful to its owner, or an output that has no owner, and no purpose **(Pongrácz, 2002)**.

***Source**: Pongrácz et al. (2004)*

Table 3 - Classes of Waste

Class 1	Non-wanted things are created not intended, or not avoided, with no purpose.	Into this group belong outputs with negative market value, non-useful by-products, emissions, processing and process wastes, cleaning wastes, etc.
Class 2	Things with a finite purpose, are destined to become useless after fulfilling it.	This is the group of single-use products: most packaging, single-use cameras, disposable diapers, etc.
Class 3	Things with not acceptable performance due to a flaw in Structure or State.	Obsolete products, old furniture, discarded household appliances, non-rechargeable batteries, demolition wastes, etc.
Class 4	Things with acceptable performance, but their users fail to use them for their intended purpose.	Spoiled products, products used in excess, products that go beyond their target, or simply products that the owners do not wish to own anymore. They could be perfectly useful, but they are wasted solely due to the holder's wrongful action and often are non-retrievable. This class embodies the essence of wastefulness.

***Source**: Pongrácz et al. (2004)*

Figure 1 - Waste Hierarchy

Waste Hierarchy is a systematic approach to ranking waste management options based on their environmental impact *(Figure 1)*. It ranks waste management options according to what has the best outcome for the environment. The five stages of the waste hierarchy are: ***Prevention***: giving top priority to preventing waste in the first place; ***Reuse***: preparing waste for re-use; ***Recycle***: recycling waste; ***Recovery***: recovering waste; and ***Disposal***: disposing of waste, e.g. landfill, as a last resort. The "waste hierarchy" ranks waste management options according to what is best for the environment. It gives top priority to preventing waste in the first place. When waste is created, it gives priority to preparing it for re-use, then recycling, then recovery, and last of all disposal *(e.g. landfill)*.

IV. CONCEPTS IN FOOD LOSS AND FOOD WASTE (FLW)

Food waste (FW) poses a significant global challenge, steadily escalating and raising concerns not only for human well-being but also for ecosystem health. Approximately 20% of the world's total food supply is estimated to end up in waste bins at homes, food establishments, and retail outlets. In recent years, FW has garnered considerable attention as a pressing ethical issue on the international stage. Wasting food equates to squandering the time, money, and energy invested in its production, as well as natural resources. Moreover, FW significantly impacts the environment through greenhouse gas emissions. Urgent action is required to mitigate these economic, social, and environmental consequences. Various practices and methodologies are being implemented globally to manage food waste effectively. Decreasing food loss and waste is crucial for achieving a Zero Hunger world. FW is influenced by personal, cultural, political, geographic, and economic factors. Awareness of FW prevention and recovery is growing worldwide. This chapter explores the underlying reasons for FW and discusses innovative measures to reduce and prevent it, alongside an overview of global FW management. Anaerobic digestion and FW composting are recognized as viable and sustainable methods for extracting biofuel and bioproducts from FW.

Food: Any substance — whether processed, semi-processed, or raw — that is intended for human consumption. "Food" includes drink and any substance that has been used in the manufacture, preparation, or treatment of food. "Food" also includes material that has spoiled and is therefore no longer fit for human consumption. It does not include cosmetics, tobacco, or substances used only as drugs. It does not include processing agents used along the food supply chain, for example, water to clean or cook raw materials in factories or at home. In other words, food is biological material subject to degradation and different food stuffs have different nutritional values.

Food Systems fundamentally shape lives, well-being and human and planetary health and they are in control to tackle some of the most pressing challenges of our time. Food Systems are a major contribution to environmental degradation, but they can also protect and restore environmental outcomes if managed properly. Food systems are expected to deliver several essential services, which can be summarised as the "triple challenge" of providing food security and nutrition for a growing population, providing livelihoods to those working along food supply chains, and ensuring environmental sustainability **(OECD, 2021)**. Food systems account for a significant share of global environmental pressures such as greenhouse gas emissions, water pollution, and biodiversity loss. Addressing these pressures will require action not only by agricultural producers, but also by other supply chain actors, consumers, and policy makers. Informing these decisions requires evidence of environmental impacts along food supply chains. Food systems account for a significant share of global environmental pressures such as greenhouse gas (GHG) emissions, water pollution, and biodiversity loss **(IPCC, 2019; IPBES, 2019; Poore and Nemecek, 2018)**. It is now widely recognised that addressing these environmental pressures will require action not only by agricultural producers, but also by other supply chain actors, consumers, and policy makers **(Poore and Nemecek, 2018; Hodson et al., 2021)**. The food system includes all the elements, such as the environment, people, inputs, processes, infrastructures, institutions, markets, and activities, that are related to producing, processing, distributing, retailing, and consuming food, and their effects, including socioeconomic, health-related and environmental outcomes **(OECD, 2021).** Food System gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes.

Food Crisis: A food crisis occurs when rates of acute food insecurity and malnutrition rise sharply at local or national levels, raising the need for emergency food assistance. A food crisis is defined as 'major' if more than 1 million people or more than 20 per cent of a total area, region or country population is estimated to be facing IPC/CH Phase 3 or above or equivalent, or if at least one area is classified in Emergency (IPC/CH Phase 4) or worse, or if the country is included in the IASC humanitarian systemwide emergency response-level 3.

Sustainable Food System (SFS) is a food system that ensures food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised.

Food Crisis occurs when levels of acute food insecurity and malnutrition rise sharply at local or national levels, raising the need for emergency food assistance. One or more of the pillars of food security are: food availability, food access, food utilization and food stability. Food crises are more likely among populations already suffering from prolonged food insecurity and malnutrition, and in areas where structural factors increase their vulnerability to shocks.

Food System Resilience as the ability of different individual and institutional food system actors to maintain, protect or quickly recover the key functions of that system despite the impacts of disturbances.

Food Security: "The availability of an adequate global food supply of vital commodities at all times to ensure a constant increase of food consumption and to compensate for changes in production and price" **(Burchi and Muro, 2016; Bhat et al. 2021).** Future Food security can be seen as contingent upon sustainability. Access to food is contingent on factors such as the local climate, the state of the environment, and the availability of natural resources. According to the Committee on **World Food Security (2012),** food and nutrition security is built on four pillars viz. ***Food availability*** (the availability of ample amounts of food regularly); ***Food access:*** acquiring enough food for a healthy diet. ***Food utilization*** (built on food safety, nutritional and social value, and appropriate use of food); ***Stability*** (food availability, accessibility, and consumption. Food security is commonly defined (following the 1996 World Food Summit) as a situation where "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." In line with this definition, food security is often conceptualised in terms of availability (physical supply of food), access (the ability of relevant groups to have access to available food, e.g. in terms of household income and affordability), and utilisation (which relates to consuming a safe and nutritious diet); complete food security then requires stability across these three dimensions. Food security is most commonly

defined as '… when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life **(FAO, 1996)**.

Acute food insecurity: Acute food insecurity is any manifestation of food insecurity at a specific point in time that is of a severity that threatens lives, livelihoods or both, regardless of the causes, context or duration.

Chronic food insecurity: Chronic food insecurity refers to food insecurity that persists over time, largely due to structural causes. The definition includes seasonal food insecurity that occurs during periods with non-exceptional conditions.

Food insecurity: Food insecurity refers to the lack of secure access to sufficient amounts of safe and nutritious food for normal human growth and development and an active and healthy life. For people to be food secure, food must be both consistently available and accessible in sufficient quantities and diversity, and households must be able to utilize (store, cook, prepare and share) the food in a way that has a positive nutritional impact.

A food value chain is the system of organizations, people, and activities involved in moving food from its producer (usually the farmer) to the consumer. The present work also comprises the consumption phase itself and losses that occur at the end consumer. Five system boundaries were distinguished in the food supply chains (FSC) of vegetable and animal commodities. Food loss/ waste was estimated for each of these segments of the FSC. The following aspects were considered:

Food System Transformation as a future where all people have access to healthy diets, produced in sustainable resilient ways that restore nature and deliver just and equitable livelihoods.

Food Safety incidents are relatively common occurrences. These include pathogen outbreaks (e.g. salmonella) and contamination of food products with allergens, heavy metals, or other harmful substances.

Vegetable commodities and products: Agricultural production involves losses due to mechanical damage and spillage during harvest operations (e.g., threshing or fruit picking) and crops sorted out post-harvest. Post-harvest handling and storage losses occur due to spillage and degradation during handling, storage, and transportation between the farm and distribution points. Processing losses include spillage and degradation during industrial or domestic processing, such as juice production, canning, and bread baking. These losses can happen when crops are sorted out as unsuitable for processing or during washing, peeling, slicing, boiling, process interruptions, and accidental spillage. Distribution losses and waste occur within the market system, including wholesale markets, supermarkets, retailers, and wet markets. Lastly, consumption losses and waste occur at the household level during food consumption.

Animal commodities and products: *Agricultural production*: For bovine, pork, and poultry meat, losses refer to animal deaths during breeding. For fish, losses refer to discards during fishing. For milk, losses refer to decreased milk production due to dairy cow sickness (mastitis). *Post-harvest handling and storage*: For bovine, pork, and poultry meat, losses occur due to death during transport to slaughter and condemnation at the slaughterhouse. For fish, losses include spillage and degradation during icing, packaging, storage, and transportation after landing. For milk, losses involve spillage and degradation during transportation between the farm and distribution points. *Processing*: For bovine, pork, and poultry meat, losses occur due to trimming spillage during slaughtering and additional industrial processing, such as sausage production. For fish, losses refer to industrial processing such as canning or smoking. For milk, losses involve spillage during industrial milk treatment (e.g., pasteurization) and milk processing (e.g., cheese and yogurt production). *Distribution*: Losses and waste occur within the market system, including wholesale markets, supermarkets, retailers, and wet markets. *Consumption*: Losses and waste occur at the household level during consumption.

Food spoilage is any change that makes food unfit for consumption, caused by factors such as microorganism contamination, insect infestation, or degradation by naturally occurring enzymes. Physical and chemical changes, like tissue damage or oxidation, also contribute. Foods from plant or animal sources begin to spoil soon after harvest or slaughter due to the release of enzymes from damaged cells, leading to quality degradation, off-flavors, texture deterioration, and nutrient loss. Common spoilage microorganisms include bacteria (e.g., Lactobacillus), yeasts (e.g., Saccharomyces), and molds (e.g., Rhizopus).

Food preservation is any of many methods by which food is kept from spoilage after harvest or slaughter. Such practices date to prehistoric times. Among the oldest methods of preservation are drying, refrigeration, and fermentation. Modern methods include canning, pasteurization, freezing, irradiation, and the addition of chemicals. Advances in packaging materials have played an important role in modern food preservation.

Municipal Solid Waste (MSW) includes waste originating from households, commerce, trade, small businesses, office buildings and institutions (schools, hospitals, and government buildings). It also includes bulky waste *(e.g., old furniture, mattresses)* and waste from selected municipal services, e.g., waste from park and garden maintenance, waste from street cleaning services (street sweepings, the content of litter containers, market cleansing waste), if managed as waste. $MSW\ generated$ is total municipal solid waste generated in a given year (as calculated for Indicator 11.6.1) $Share\ of\ food\ wastet$ is the proportion of total MSW made up of food waste in the year, which can be estimated from waste composition studies The food waste index for the year is then calculated using the simplified estimate of food waste per capita in the same formula as above: $Food\ Waste\ Indextsimp = Food\ waste\ per\ capitatsimp\ Food\ waste\ per\ capitat0simp \times 100$.

Waste management refers to the collection, transport, recovery and disposal of waste, including the supervision of such operations and after-care of disposal sites **(European Council, 1991)**. Waste Management also entails strategic planning, prescribing options, prevention of the contamination of the environment and conservation of resources, and minimizing the amount and toxicity of waste creation. choosing the best treatment option, taking into consideration legislation, assessing effects and consequences and decision-making **(Pongrácz, 2002)**.

Bio-waste: Defined by the European Commission in the green paper on the management of bio-waste as "biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. It does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood. It also excludes those by-products of food production that never become waste."

Mismanaged waste: Collected waste that has been released or deposited in a place from where it can move into the natural environment (intentionally or otherwise). This includes dumpsites and unmanaged landfills. Uncollected waste is categorised as unmanaged.

Food waste includes food and associated inedible parts removed from the human food supply chain in sectors such as retail, food service (restaurants, schools, hospitals, etc.), and households. "Removed from the human food supply chain" refers to disposal methods like landfill, controlled combustion, sewer, litter, co/anaerobic digestion, composting, or land application. It comprises raw or cooked food discarded before, during, or after preparation in manufacturing, distribution, retail, or food service activities, including items like vegetable peelings, meat trimmings, and spoiled or excess ingredients. Food waste can be both edible and inedible.

According to the **U.N. (2019),** FLW as "food (including inedible parts) lost or discarded along the food supply chain, comprising pre-harvest losses, and excluding food diverted to animal feed, seed or to other non-food material uses such as bio-based products". A wide range of FWL definitions can be found in the scientific literature. For instance, **FAO (2011)** defines FWL as "the masses of food lost or wasted in the part of food chains leading to edible products going to human consumption" **(FAO, 2011)**. This definition includes only food intended for human consumption, but that ends up wasted, even if it is used later for other purposes, such as feed, composting, or other possible routes. Instead, in the **FUSION report (2014)** the definition of food waste, in addition to the edible food parts, also includes the inedible parts removed from the FSC to be recovered or disposed of (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill, or discarded to sea) excluding the part revalorized for feed or bio-based material and biochemical processing (**Gustavsson et al. 2014)**. According to **Gustavsson et al. (2011)**, ***Food waste*** is often used for ***Food losses*** occurring at the end of the food value chain (retail and final consumption), where most losses are caused by wasteful behaviour. Nevertheless, in this paper, both terms are used synonymously and refer to all ***Food losses*** because a distinction between wasteful behaviour and other reasons for ***Food losses*** was difficult to perform. **Food losses** can be qualitative, such as reduced nutrient value and undesirable changes to taste, texture, or colour, or quantitative as measured by decreased weight or volume. Here, *food loss* is a subset of *post-harvest losses* (or post-production) and represents the edible amount of food available for human consumption but is not consumed. *Food waste* is a subset of food loss. Food loss occurs for many reasons, including natural shrinkage (e.g., moisture loss), mould, pests, inadequate climate control, and food waste. Food safety concerns can also trigger short-term spikes in food waste of implicated foods.

Food Loss takes place in the supply chain after harvesting (post-harvesting stages like handling, transport, storage, and distribution), and before reaching the consumer, it is specifically the reduction in the quantity of food **(Kour et al. 2023)** while the term "food waste" refers to the loss of items meant for consumption by humans that are later deteriorated, eventually lost, and discharged as landfill **(Rather et al. 2022; Pandey et al. 2021)**. Different notions of FWL are generally used for the different stages of the Food Supply Chain. For instance, "food loss" is attributed to the losses occurring in the early stages of the FSC (agriculture and postharvest stages), whereas "food waste" refers to the losses in the downstream stages of the FSC (retail, household, and hospitality). The Food and Agriculture Organization of the United Nations (FAO) considers a distinction between **food loss** (i.e. a decrease of quantity or quality in edible food mass, intended for human consumption, that occurs in the primary stages of the supply chain – production, postharvest and processing stages) and **food waste** (i.e. food losses occurring at the end of the food chain – retail and final consumption – related to retailers' and consumers' behaviour) **(FAO, 2011)**. A further classification of food waste refers to **avoidable, possibly avoidable, and unavoidable** food waste.

Avoidable food waste includes food that is edible by the majority of consumers but ends up thrown away because it exceeded its expiration date or is not wanted anymore. Possibly avoidable food waste is food thrown away due to personal preferences, while unavoidable food waste is food unwanted by the major part of consumers *(e.g., eggshells, bones, orange peels, etc.)* **(Parfitt et al. 2010; WRAP, 2013)**. According to **Quested and Johnson (2009)**, food waste can be classified into three categories: avoidable, potentially avoidable and unavoidable food waste. The emergence of unavoidable food waste cannot be affected, but the quantities of the other two categories in total food waste can be significantly reduced **(Salhofer et al., 2008, Bernstad Saraiva Schott and Cánovas, 2015)**. One of the suggested definitions of food waste was proposed by **FUSIONS (2014)** – an EU project to establish the monitoring, tracking and reporting on food waste for EU Member States according to this unique methodology. "Food waste is any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed of (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded at sea)". When quantifying food waste, it is important to understand that it cannot be avoided completely because some parts are inedible. **Food loss** refers to a decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption. These losses are mainly caused by inefficiencies in the food supply chains, such as poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors, and lack of access to markets. In addition, natural disasters play a role. **Food waste** refers to food appropriate for human consumption being discarded, whether or not it is kept beyond its expiry date or left to spoil. Often this is because food has spoiled but it can be for other reasons such as oversupply due to markets, or individual consumer shopping/eating habits. **Food wastage** refers to any food lost by deterioration or waste. Thus, the term "wastage" encompasses both food loss and food waste. **Food losses** can be qualitative such as reduced nutrient value and undesirable changes to taste, texture or colour or quantitative as measured by

decreased weight or volume **(Buzby and Hyman, 2012)**. **Food losses** are grouped into three categories, based on the definitions in **Quested and Johnson (2009):** ***Avoidable losses*** refer to food and drink thrown away because they are no longer wanted, e.g. because they perished or exceeded their date of expiry. Most avoidable losses are composed of material that was, at some point before disposal, edible, even though a proportion is not edible at the time of disposal due to deterioration *(e.g. rotting, decomposition)*. ***Possibly avoidable losses***, in contrast, refer to food and drink that some people eat and others do not *(e.g. apple peels)*, or that can be eaten when prepared in one way but not in another *(e.g. potato or pumpkin skins)*, or that is sorted out due to specific quality criteria *(e.g. bent carrots)*. ***Unavoidable losses*** comprise waste arising from food and drink preparation that is not and has not been, edible under normal circumstances. This includes apple cores, banana skin, tea leaves, coffee grounds, and inedible slaughter waste. Additionally, harvesting, storage, transportation, and processing losses that are not avoidable with the best available technologies and reasonable extra costs are also classified as unavoidable. Food losses (FL) refers to a decrease, at all stages of the food chain before the consumer level, in mass, of food that was originally intended for human consumption, regardless of the cause. Food waste (FW) refers to food appropriate for human consumption being discarded or left to spoil at the consumer level – regardless of the cause. Food loss refers to a decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption. These losses are mainly caused by inefficiencies in the food supply chains, such as poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors, and lack of access to markets. In addition, natural disasters play a role. Food waste refers to food appropriate for human consumption being discarded, whether or not it is kept beyond its expiry date or left to spoil. Often this is because food has spoiled but it can be for other reasons such as oversupply due to markets, or individual consumer shopping/eating habits. Food wastage refers to any food lost by deterioration or waste. Thus, the term "wastage" encompasses both food loss and food waste. Food Loss and Waste refer to the decrease in mass (quantitative) or nutritional value (qualitative) of food - edible parts - throughout the supply chain that was intended for human consumption. Food that was originally meant for human consumption but which gets out of the human food chain is considered as food loss or waste, even if it is then directed to a non-food use (feed, bioenergy). Food Loss refers to food that during its process in the food supply chain gets spilled, spoilt or otherwise lost, or incurs reduction of quality and value before it reaches its final product stage. Food loss typically takes place at the production, postharvest, processing and distribution stages in the food supply chain. Food Waste refers to food that completes the food supply chain up to a final product, of good quality and fit for consumption, but still does not get consumed because it is discarded, whether or not after it is left to spoil. Food waste typically (but not exclusively) takes place at retail and consumption stages in the food supply chain."

European Commission (2014), have been classified into three categories: "(i) food losses: food products lost during the production phase; (ii) unavoidable food waste: referring to food products lost during the consumption phase (banana peels, fruit cores, etc); (iii) avoidable food waste: products that could have been eaten, but were lost during the consumption phase." **Gustavsson et al. (2011)** separated FW into five generation sources: agricultural production, post-harvest handling and storage, processing, distribution and consumption. **Parfitt et al. (2010)** as "food losses occurring at the end of the food chain (retail and final consumption), which relates to retailers' and consumers' behaviour," or by **Brian et al. (2013)** as: "food that is of good quality and fit for human consumption but that does not get consumed because it is discarded either before or after it spoils. Some more definitions of food waste and food loss are given in **Table 4**.

Table 4 – Definitions of Food Waste and Food Loss

Institution	Definitions
Food Waste (by High-Level Panel of Experts)	Food appropriate for human consumption being discarded or left to spoil at the consumer level regardless of the cause
Food Waste (by FUSIONS EU)	Any food and its inedible parts, removed from the FSC to be disposed of (including composted, crops ploughed in or not harvested, anaerobic digestion, bio-energy production, co- generation, incineration, disposal to sewer, landfill or discarded to sea) or recovered
Food Loss (by High-Level Panel of Experts)	A decrease, at all stages of the FSC before the consumer level, in the mass of food that was originally intended for human consumption, regardless of the cause
Food Loss and Waste (by United States Department of Agriculture)	FW is a subcomponent of FL and occurs when an edible food goes unconsumed. The food which is still edible at the time of discard is considered as food waste
Food Loss (by FAO)	Decrease in weight (dry matter) or quality (nutritional value) of food that was originally produced for human consumption
Food Waste (by FAO)	Food appropriate for human consumption being discarded, whether after it is left to spoil or kept beyond its expiry date
Avoidable food waste	Food that is thrown away that was, at some point before disposal, edible (e.g. slices of bread, apples, meat)
Unavoidable food waste	Waste arising from food preparation that is not, or has not been, edible under normal circumstances (e.g. bones, egg shells, pineapple skins)

***Source**: WRAP (2009) Household Food and Drink Waste in the United Kingdom. **Note**: FAO: Food and Agriculture Organization; FUSIONS EU: Food Use for Social Innovation by Optimising Waste Prevention Strategies EU; EU: European Union; FSC: food supply chain; FW: Food Waste; FL: food loss.*

Inedible (or non-edible) parts: Components associated with a food that, in a particular food supply chain, are not intended to be consumed by humans. Examples of inedible parts associated with food could include bones, rinds, and pits/stones. "Inedible parts" do not include packaging. What is considered inedible varies among users (e.g., chicken feet are consumed in some food supply chains but not others), changes over time, and is influenced by a range of variables including culture, socio-economic factors, availability, price, technological advances, international trade, and geography.

Food access: Food access refers to access by households/individuals to adequate resources for acquiring appropriate foods for a nutritious diet.

Food availability: Food availability refers to the availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports.

Food Balance Sheet: It gives the total amount of food available for human consumption in a country/region during one year.

Food Quality Loss or Waste (FQLW) refers to the decrease of a quality attribute of food (nutrition, aspect, etc.), linked to the degradation of the product, at all stages of the food chain from harvest to consumption.

Food Waste Index: It is calculated according to the following approach: $Food\ waste\ per\ capita_t = Total\ food wastet\ Annual\ Average\ Population_t$ where: t = year Total food waste is the sum of waste in three sectors in a given year as per the formula below: $Total\ food\ wastet = FWHouseholdst + FWFood\ service\ t + FWRetailt$ The Food Waste Index for the year in question is then calculated as food waste per capita in that year divided by food waste per capita in a baseline year (t0) multiplied by 100 to express the result as a percentage: $Food\ Waste\ Indext = Food\ waste\ per\ capita_t\ Food\ waste\ per\ capita_0 \times 100$ In countries where it is not possible to obtain the detailed data necessary to estimate total food waste using the formula above, a simplified approach to calculating food waste per capita may be taken: $Food\ waste\ per\ capitatsimp = MSW\ generatedt \times Share\ of\ food\ wastet\ Annual\ Average\ Populationt$ where: t = year

Food Supply Chain (FSC) is defined as a succession of actions and movements between different actors, going from farmers producing food, passing by manufacturers then distributing to retailers to reach the final consumers *(eg. Household/hospitality level)*. FSC referring to the processes describing how food from a farm ends up on our tables, is not exempt from these disruptions. Food wastage is the result of food loss and food waste.

Recycling is not always the best waste management solution due to limitations by the Second Law of Thermodynamics and diminishing returns. Other options, like prevention, reuse, and energy recovery, can sometimes offer better ecological or economic benefits. Therefore, growing the recycling industry is not always a desirable policy target. Recycling only occurs when the secondary material is converted into a new product or used in another way.

Reusable: Products and packaging, including plastic bags, that are conceived and designed to accomplish within their life cycle a minimum number of uses for the same purpose for which they were conceived. In terms of "minimum number of uses", the PR3 Reuse Standards (PR3 2024) suggest that reusable (containers) should be designed to withstand at least 10 reuse cycles.

Reuse: Use of a product more than once in its original form.

Carbon Footprint: It measures the total amount of greenhouse gases (GHGs), primarily carbon dioxide (CO2), emitted directly or indirectly as a result of human activities. In the context of food wastage, it evaluates the emissions associated with the production, distribution, consumption, and disposal of food that is ultimately wasted. Food wastage contributes to carbon emissions through various stages of the food supply chain, including agricultural activities *(e.g., cultivation, harvesting, and transportation)*, processing, packaging, storage, retail, and waste management *(e.g., decomposition in landfills)*. Assessing the carbon footprint of food wastage helps quantify its contribution to climate change and identifies opportunities for mitigation strategies, such as reducing food loss and waste, improving resource efficiency, and implementing sustainable practices throughout the supply chain.

Water Footprint: It measures the total volume of freshwater used directly or indirectly in the production process of goods and services. It includes both blue water (surface and groundwater) and green water (rainwater stored in the soil and used by plants). In the context of food wastage, the water footprint assesses the volume of water wasted throughout the food supply chain, including irrigation, processing, cleaning, and cooking, as well as losses during transportation and storage. Food wastage exacerbates water scarcity and environmental degradation by inefficiently utilizing freshwater resources. Assessing the water footprint of food wastage helps identify areas where water resources are being mismanaged and support the development of water-saving measures and sustainable water management practices.

Land Occupation/Degradation Impact: It assesses land use change, habitat destruction, soil erosion, and degradation from food production and waste. Food wastage leads to land degradation and biodiversity loss through deforestation, habitat conversion, and intensive farming. Evaluating the land impact of food waste helps quantify its ecological footprint and identifies areas for improved land management to minimize environmental harm and preserve ecosystems and biodiversity.

Potential Biodiversity Impact: The potential biodiversity impact evaluates the effects of food wastage on biodiversity, including species loss, habitat destruction, and ecosystem disruption. Food wastage harms biodiversity by causing habitat destruction, pollution, and loss of genetic diversity in agriculture. It also disrupts essential ecological processes like pollination and nutrient cycling. Assessing this impact raises awareness of food wastage's ecological consequences and supports conservation strategies, sustainable land use, and biodiversity-friendly agricultural practices.

Economic Quantification Component: The economic quantification component examines the financial costs of food wastage, covering production, distribution, retail losses, and waste management expenses. Food wastage places substantial economic burdens on individuals, businesses, and society, resulting in lost revenue, higher production costs, and waste disposal expenses. Assessing the economic impact of food wastage quantifies its financial implications, offering valuable insights for decision-makers,

policymakers, and stakeholders. This information helps prioritize interventions, invest in waste reduction initiatives, and implement cost-effective solutions to mitigate food loss and waste.

Portion Control: It is a critical aspect of reducing food waste. Many individuals tend to serve themselves larger portions than they conserve, resulting in leftover food that often ends up being thrown away. By educating consumers about portion control and encouraging them to serve smaller portions, we can minimise the waste at the source.

Food Surplus is often caused by buying more than what is needed due to discounted sales, promotions, offers and also impulsive shopping.

Sustainable Consumption and Production (SCP) refers to "The use of services and related products, which responds to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as the emission of waste and pollutants over the life cycle of the service or product so as not jeopardize the needs of future generations". SCP is a holistic approach and is about systematic change. It is built around three main objectives viz., decoupling environmental degradation from economic growth, applying life cycle thinking; and sizing opportunities for developing countries and leap frogging lead to more resource efficient environmentally sound and competitive technologies.

Sustainable Public Procurement is a "process, whereby public organisations meet their needs for goods and services works and utilities in a way that achieves value for money on a whole life cycle basis in terms of generating benefits not only to the organisations but also to society and the economy whilst significantly reducing negative impacts on the environment.

Bennett's law observes that as incomes rise, people eat relatively fewer calorie-dense starchy staple foods and relatively more nutrient-dense meats, oils, sweeteners, fruits, and vegetables. Bennett's law is related to Engel's law, which considers the relationship between rising household incomes and total food spending.

Engel's law is an economic relationship proposed by the statistician Ernst Engel in 1857. It suggests that as family income increases, the percentage spent on food decreases, even though the total amount of food expenditure increases. Expenditure on housing and clothing remains proportionally the same, and that spent on education, health and recreation rises. Even though Engel's law was proposed roughly 160 years ago, it holds relevance today in the context of poverty, especially the reduction of poverty. For instance, the lines and rates for national poverty are often determined by the food share of household expenditure. A quotation from Engel himself reveals the same relationship between income and the percentage of income spent on food, but also indicates the application of Engel's Law in measuring the standard of living: The poorer a family, the greater the proportion of the total outgo [family expenditures] which must be used for food. ...The proportion of the outgo used for food, other things being equal is the best measure of the material standard of living of a population.

Resilience denotes "the ability to prepare and plan for, absorb, recover from, and more successfully adapt and transform in response to adverse events" **(OECD, 2020)**.

Three pillars of sustainability: **(a)** Economic ramifications, which can be either positive (economic benefit obtained from management of the waste) or negative (economic cost to dispose of the waste); **(b)** Environmental impacts, which are usually negative *(e.g. greenhouse gas emissions)*, but can also be positive *(e.g. use of waste for the removal of pollutants in wastewater)*; and **(c)** Social considerations, which can be either positive *(e.g. food redistributed to people in need)* or negative (e.g. increased taxes).

Controlled waste: It is Collected, and then either recycled or disposed of in a controlled facility.

Uncontrolled waste is either: Not collected, and so by necessity dumped or burned in the open by the waste generator, or Collected and then dumped or burned at its final destination.

Lifecycle: The life cycle of a product comprises any steps in a "cradle to grave" approach: the extraction of the necessary raw materials, the manufacturing of the product (comprising material manufacturing and assembly), its distribution to the user, its use and its end-of-life (including collection and treatment: reuse, recycling, incineration with or without recovery, landfilling and so on).

Malnutrition: It refers to deficiencies or excesses in nutrient intake, imbalance of essential nutrients or impaired nutrient utilization. The double burden of malnutrition consists of both undernutrition and overweight and obesity, as well as diet-related noncommunicable diseases. Undernutrition manifests in four broad forms: wasting, stunting, underweight, and micronutrient deficiencies. **(WHO, 2024)**

Over-nutrition: It is defined as the gap between the energy value of food consumed per capita and the energy value of food needed per capita.

Obesity: It is an increasing health problem and not only in industrial countries, the consideration of over-eating concerning food wastage leads to considerable practical implementation problems. First of all, obesity may have medical causes rather than the intake of too many calories. The incidence of obesity has been on the rise for the past 25 years, reaching over 2 billion people throughout the world. **(Alberca et al., 2021)**

Circular economy: One of the current sustainable economic models, in which products and materials are designed in such a way that they can be reused, remanufactured, recycled or recovered and thus maintained in the economy for as long as possible,

along with the resources of which they are made, and the generation of waste, especially hazardous waste, is avoided or minimized, and greenhouse gas emissions are prevented or reduced, can contribute significantly to sustainable consumption and production.

Externality: An economic term used to describe an indirect cost or benefit experienced by an unrelated third party, arising as an effect of another party's activity. For example, pollution caused by mismanaging waste is an externality.

Incineration: Destruction and transformation of material to energy by combustion

Open burning: Waste that is combusted without emissions cleaning.

Food safety shocks: Food safety incidents are relatively common occurrences. These include pathogen outbreaks (e.g. salmonella) and contamination of food products with allergens, heavy metals, or other harmful substances.

Life Cycle Assessment (LCA) is a commonly used methodology for assessing the environmental impact of a product over its entire life cycle. The basic principles for conducting an LCA are defined in the ISO 14040 and ISO 14044 standards, which identify four main phases of an LCA: the definition of the goal and scope of the assessment; the Life Cycle Inventory (LCI) analysis; the Life Cycle Impact Assessment (LCIA); and the interpretation of results.

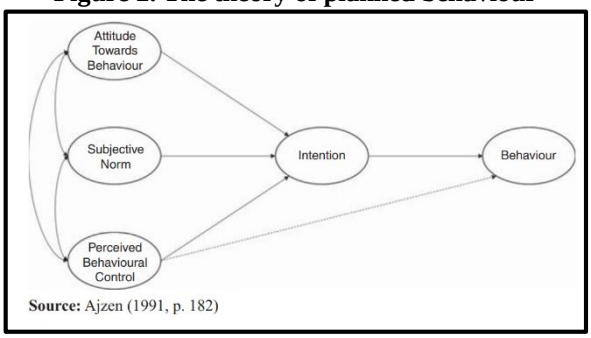
The System of Environmental-Economic Accounting (SEEA): It covers "environmental assets" (water resources, energy resources, forests, fisheries, etc.), their economic use, and returns to the environment (waste, air and water emissions).

Theories of Waste Management

Theory of Planned Behaviour (TPB): The TPB suggests that people's intentions to perform a behaviour are influenced by their attitudes, subjective norms, and perceived behavioural control. In the context of food waste, this theory posits that individuals' intentions to waste food are shaped by their beliefs about the consequences of wasting food, social norms related to food disposal, and their perceived ability to control food waste. For example, if someone believes that throwing away food has minimal negative consequences (attitude), perceives that others around them also waste food (subjective norm), and feels they have control over their food waste behaviour (perceived behavioural control), they are more likely to waste food.

When it comes to understanding consumer behaviour, the Theory of Planned Behaviour (TPB) **(Ajzen, 1991)** has been widely applied in various contexts and has provided predictive power of attitudes, norms, perceived control and intentions on the behaviour. According to the TPB, attitudes represent positive or negative evaluations of self-performance of a specific behaviour; subjective norms represent the perception of social pressures or relevant others' belief that one should or should not behave in a specific way; perceived behavioural control indicates the perceived ease or difficulty of behaving in a specific way; intentions represent the willingness to behave in a specific way; and finally the behaviour is the observable action taken, ranging from simple strategy choices in games to actions of appreciable personal or social significance. The well-established TPB is shown in **Figure 2**.

Figure 2. The theory of planned behaviour



Theory of Reasoned Action (TRA): The TRA is similar to the TPB but focuses on attitudes and subjective norms. According to the TRA, an individual's intention to engage in a behaviour (such as wasting food) is influenced by their attitude toward that behaviour and the subjective norms associated with it. In the context of food waste, TRA suggests that if someone has a positive attitude toward discarding food *(e.g., they don't see it as a problem)* and perceives that others around them also waste food, they are more likely to engage in food wastage.

Social Practice Theories: These theories emphasize that behaviours are embedded in social practices (repetitive activities with shared meanings). Food waste is not just an individual action; it is part of broader practices related to food consumption, storage, and disposal. By examining the interconnections between different activities (such as grocery shopping, cooking, and throwing away leftovers), social practice theories help explain patterns of food waste. For instance, cultural norms around portion sizes, meal planning, and food storage impact how much food ends up being wasted.

Anthropological Perspective: Anthropology teaches us that food waste is not universally perceived the same way across societies. While some cultures consider wasting food as normal *(e.g., during feasts or celebrations)*, others view it as a danger or taboo. Anthropologists study how cultural beliefs, rituals, and social contexts shape food practices, including waste. For most people, food waste is considered normal only in situations of poverty or social exclusion.

Table 5 presents the major tenets of important organizational theories and how they can be interpreted in the context of food waste reduction in circular FSCs.

Table 5 - Elements of various organizational theories for managing food waste in circular food supply chains.

Theory	Element	Links to Food Waste
Stakeholder Theory	Multiple stakeholders	• Regulatory stakeholder (HACCP directive) • Top management commitment • Employees • Supply chain partners
Institutional Theory	Regulative, normative, and cultural–cognitive pillars	• Firm belief in reducing food waste • Preference for donating to food charities than sending to landfill • Explicit association with established food charities • Prioritizing survival to innovation during COVID-19 lockdowns • Associating with the green image • Voluntary initiatives on reducing food waste and sustainable food practices • General lack of trust in IT projects
Resource-based Theory and the Natural resource-based Theory	VRIN (valuable, rare, inimitable, and non-substitutable) resources and competitive advantage	• Wasted food is a waste of valuable imputed natural resources (energy, labour, soil, fertilizers, water, and more) • Inimitable knowledge on reducing, recycling, and reusing waste, and valorising food waste is a source of competitive advantage • Efficient operations management for reducing raw material consumption for competitive advantage • Waste prevention vs. waste control in CE organizations • Efficient quality control for competitive advantage
Paradox Theory	Learning, organizational, and belonging paradoxes	• Soft means *(e.g., behavioural changes)* vs. relatively hard means *(e.g., using technological support)* for reducing food waste • Supply chain collaboration vs. maintaining individual identities of partners • Comparing costs of technological investments in reducing food waste with the resources imputed to the saved food
Resource Dependence Theory and Natural Resource Dependence Theory	Supply chain dependency	• Dependence on data from other supply chain partners for making prompt business decisions • Data sharing and security issues • The use of modern technologies exacerbates these dependencies

Institutional Entrepreneurship	Breaking away from dominant ways of doing things	• Entrepreneurs and enterprises do not consider profit as their single motive anymore. Other considerations including social and environmental impacts are increasingly being employed in entrepreneurial decision-making.

***Source**: Ramanathan et al. (2024)*

Schanes et al. (2018) emphasize two ontological approaches to explain the phenomenon of food waste: the psychological related approach and the social practice theory. The psychological approach identifies the cognitive and individual factors underlying food waste behaviours. The most used theoretical model is the planned behaviour theory **(Ajzen, 1991)** in which attitude, social norm, controllability and additional predictors such as environmental concern, habits, and situational predictors (household size, age) are considered as the determinants of the behaviour. The social practice theory **(Evans, 2011; Ganglbauer et al., 2013; Lazell, 2016; Leray et al., 2016)** adopts a holistic view of food waste practices in which food waste is integrated into many other practices such as planning, shopping, storing, cooking, eating and managing leftovers.

Theory of Waste Management: This theory provides an in-depth account of the domain and includes conceptual analyses of waste, the activity of waste, and a holistic view of the goals of waste management. It is founded on the expectation that waste management aims to prevent waste from causing harm to human health and the environment.

Socio-Psychological Model Perspective: This theory focuses on understanding human behaviour and attitudes toward waste management. It considers social, psychological, and cultural factors that influence waste generation, disposal, and recycling behaviours.

Urban Ecology Theory (for solid waste management): This theory emphasizes the relationship between urban ecosystems and waste management. It considers waste as part of the urban environment and explores ways to integrate waste management into sustainable urban development.

Policy-Making Approach (for solid waste management): This theory focuses on developing and implementing policies, regulations, and guidelines to manage waste effectively. It considers economic, environmental, and social aspects of waste management.

Eco-Innovations Theory (for solid waste management): This theory encourages the development and adoption of innovative technologies and practices to reduce waste generation and improve recycling rates.

Triple-Bottom Line Theory (for solid waste management): This theory evaluates waste management based on three dimensions: economic, environmental, and social. It aims to achieve a balance between these three aspects.

Sustainability Theory (for solid waste management): This theory promotes waste management practices that meet present needs without compromising the ability of future generations to meet their own needs. It emphasizes long-term environmental and social sustainability.

Actor-Network Theory (for sustainable waste management programs): Applied to analyse key elements for sustainable waste management in universities and cities. Considers the interactions between various actors (e.g., policymakers, waste collectors, citizens) and their influence on waste management outcomes.

The Theory of Waste Management emphasizes the prevention of waste causing harm to human health and the environment and highlights the importance of defining waste accurately to construct a sustainable waste management agenda.

The socio-psychological model perspective focuses on understanding the factors that influence public waste separation behaviour, which is crucial for the successful implementation of recycling and waste separation at source.

Models on Food Waste Management

A Methodology for Sustainable Management of Food Waste: This research paper takes a holistic approach to understanding different types of food waste and supports informed decisions for more sustainable management. It reviews existing food waste categorizations and analyses their usefulness. The paper proposes a systematic methodology to identify types of food waste through a nine-stage categorization, along with a version of the waste hierarchy applied to food products. For each type of food waste characterized, it suggests waste management alternatives to minimize environmental impacts and maximize social and economic benefits.

Modelling Approaches to Food Waste: Researchers have explored various modelling techniques to address food waste, including **Discrete Event Simulation**: Which simulates food waste events over time. **Machine Learning**: Utilizes algorithms to predict food waste patterns. **Bayesian Networks**: Probabilistic models for analysing food waste factors. **Agent-Based Modelling**: Simulates interactions between agents *(e.g., consumers, retailers)* in food systems. **Mass Balance Estimation**: Quantifies food waste by tracking inputs and outputs. These models help understand food waste dynamics and inform strategies for reduction.

Business Models for Food Waste Prevention: Entrepreneurs and businesses play a crucial role in addressing food waste. A study analyzed over 400 businesses to identify common approaches and business models for tackling food waste. These models include food surplus redistribution, innovative packaging, waste-to-energy conversion, and technology-driven solutions.

Framework for Managing Food Waste: **Närvänen, Mesiranta, Mattila, and Heikkinen (2020)** present a framework for managing food waste, covering food surplus, food loss, and food waste. The framework highlights food waste as unstructured, cross-cutting, and relentless. It emphasizes the need for coordinated efforts across sectors to combat this global challenge.

Models on Food Loss Management

Food Loss Index (FLI): The Food and Agriculture Organization (FAO) has developed a methodology for measuring and monitoring food losses along production and supply chains, excluding the retail stage. The FLI covers losses occurring from harvest up to but excluding the retail stage. It measures changes in losses over time and compares them to a base year, allowing monitoring of trends and targeted interventions[1].

IFPRI Food Losses Methodology: The International Food Policy Research Institute (IFPRI) has developed a comprehensive methodology to improve the measurement of food losses across the value chain. This approach not only quantifies the quantities of food lost but also considers deterioration in quality, leading to economic losses. The objectives of this methodology are to: Gauge the extent of food losses across various commodities in developing countries; Measure both quantitative and qualitative economic losses; Identify nodes where losses are more prevalent and pinpoint specific production processes during which losses occur.

Energy Balance Models: These models have been successfully used to: Improve dietary adherence; Estimate the magnitude of food waste; Predict dropout from clinical weight loss trials; and Generate hypotheses in nutrition experiments.

Robust Statistical Techniques for Estimation: Researchers propose improvements to the modelling approach used by the FAO in estimating annual food losses by country and commodity. Combining robust statistical techniques with adherence to official statistical rules enhances accuracy in assessing food losses[3].

Summary

Concepts, theories, and models play pivotal roles in shaping and defining research problems across various fields. Researchers accumulate knowledge of concepts and introduce them to their chosen research areas, facilitating a deeper understanding. Similarly, theories developed by renowned researchers aid in comprehending the subject matter and relating it to the research topic, ultimately refining research problems and guiding investigations in the chosen field. Models, whether theoretical, mathematical, or econometric, serve as frameworks that guide researchers in developing models tailored to their specific research areas. In this paper, the authors summarize pertinent concepts, theories, and models relevant to food loss and food waste management. Understanding these concepts fosters knowledge development and stimulates new insights in the field of food loss and waste management.

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