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Review article

Vegetable and Fruit Waste Production Related to Consumption in Turkey and Certain Middle East Countries

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Abstract

Vegetable and fruit wastes (VFW) comprise a large portion of wastes that contribute to pollution in different ways. This is because there is a large demand for such perishable products by all countries. The Turkish economy was mostly depending on agriculture before 40 years ago but due to globalization this has been changed into industrialization. Even though the industrialization dominates, the consumption of fruits and vegetables has been in an increasing trend in Turkey and its environs. The usage of such resources can be regulated by governments and organizations to avoid overusing them. Also, there are many ways for treating such inevitable wastes. To mention a few, extracting pigment, antioxidants, pesticides, producing single-celled proteins, enzymes, biofertilizers, green energy, and many others from the wastes can be done.

Keywords: Agro-Industrial Wastes, Pollution, Global Food Demand.

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INTRODUCTION

Vegetable and fruit wastes (VFW), which comprise a large portion of markets' waste, are one of the pronounced problems for environments as they are easily biodegraded in municipal landfills (Arvanitoyannis & Varzakas, 2002). Wastes from food industries comprise the second largest portion of wastes after household sewage (Gowe, 2015). VFW has increased significantly in the last 25 years as a result of increasing demands for processed and packed foods (Gowe, 2015). Additionally, they are a burden for economic status as the should be transported and disposed of (Bello et al., 2018). Also, they are one of the biggest factors of greenhouse gas emission (Strategies, 2011) (Gupta et al., 2019) and increased leachate discharge in landfills (Edwiges et al., 2018). The waste comprises about 5.6 million tons per year in India, 180 tons per month in Tunisia (Arvanitoyannis & Varzakas, 2002), and 114 billion gallons of fruit and vegetable liquid by-product per year from vegetable and fruit industries (Morrell & Schmidt, 2020). The wastes come from different plants. For example, more than 5 million tons of the wastes are from sugar beet pulp, 3.5 million tons from brewers grain, and half million tons from onion peels each year (Gowe, 2015). These wastes can be converted into valuable products with low-cost processes (Gowe, 2015). VFW contains cellulose, hemicellulose, lignin, sugar, and many other components which are easily degraded in anaerobic conditions rather than aerobic one (Arvanitoyannis & Varzakas, 2002). This is because a large proportion of organic content should be reduced before aerobic degradation (Arvanitoyannis & Varzakas, 2002). Considering such inevitable wastes, VFW should be considered and managed globally.

The most important step toward solving pollution by VFW is reducing over-using plants and their products (Strategies, 2011). Moreover, reusing food wastes for human or animal uses is another important step for reducing the negative effects of VFW on the environment (Strategies, 2011). Another alternative is recycling the wastes in different ways (Strategies, 2011). There are many processes for treatment of VFW, for example, evaporation membrane process, thermal process, anaerobic digestion, combustion, composting (Arvanitoyannis & Varzakas, 2002), biological treatment after coagulation (Federation, 2018), mechanical biological treatment (Strategies, 2011), feeding them to an animal, and many others (Arvanitoyannis & Varzakas, 2002). Some parts of the waste can be recycled and used as raw materials for other processes, while other parts should be degraded (Arvanitoyannis & Varzakas, 2002). For example, VFW can be fermented by solid-state fermentation and its final product used in making many foods as a fruity flavor (Arvanitoyannis & Varzakas, 2002). Another way of recycling VFW is by using ultrafiltration to get sugar from vegetable and fruit liquid wastes (Morrell & Schmidt, 2020). One of these above-mentioned processes or their combination can be used in treating VFW effectively.

Several organisms are used to treat VFW in the biological treatment process. Some examples of fungi are *Trichoderrna viride*, using pilot-scale continuous fermentation, and *Fungi imperfecti* for treating pea and corn wastes, and *Gliocladium deliquescens* for treating soy processing wastes (Federation, 2018). An example of using algae for the same purpose is *Chlorella* culturing on potato starch waste (Federation, 2018).

There are many reasons for processing VFW. First, establishing recycling units would pave a way for employing staff in different fields (Strategies, 2011). Second, VFW can be used as fertilizers (Strategies, 2011). Third, they can be used to generate energy from them (Strategies, 2011). Third, many types of products can be obtained from VFW such as single-cell protein, methane gas, alcohol (Morrell & Schmidt, 2020), potato starch from recycled solid waste of potato, and pigments from peels of certain fruits (Federation, 2018).

One way of treating VFW is using them in making many valuable products such as single-cell protein, single-cell oil, biopesticides, flavor, fragrance, biohydrogen, biogas, enzymes, biopolymers, and many others (Sandeep K. Panda et al., 2018). In this review, detoxifying VFW to some of these products, by microorganisms, is shown.

Biofertilizer

VFW contains a wide range of nutrients that can be reused as a source of nutrients for increasing soil fertility. For example, leave, straw, grass clipping, and kitchen scrap are a good source to be used for promoting other plant growth (Author & Marty, 2012). So, changing VFW to fertilizer is an easy, low-cost, and effective way of waste recycling. Biofertilizer defines everything originated manure basis-plant extract interval. They have viable microorganisms and show colonization in the rhizospheric portion of plants and help ascending the supply or available primary nutrients as well as growth stimulants to the target crop (Bhattacharjee and Dej, 2014).

Beverages

Some microorganisms can ferment VFW to different types of beverages (Sandeep K. Panda et al., 2018). Many microorganisms can bio valorize different plants (Sandeep K. Panda et al., 2018). For instance, *Saccharomyces cerevisiae* can be used in making wine from cashew fruit (Prommajak et al., 2014). Cashew fruit is the false fruit that holds cashew nut. It cannot be used as a fruit because of its short life span (1-2 days). However, it has good nutritional value and can be processed to further products (Sandeep K. Panda et al., 2018). Another example of using plants for making wines is using yeast for fermenting mango peel through repeated batch fermentation (Sandeep K. Panda et al., 2018). Also, some fruits are unutilized, such as sapota and bael, that can be used in the wine industry (S. K. Panda et al., 2014). Moreover, pineapple wastes for making vinegar and sweet potato for manufacturing beer and wine are used (Sandeep K. Panda et al., 2018). Valuable beverages can be obtained from VFW wastes.

There are many advantages to use plant wastes for making fermented beverages. The first one is to get rid of environmental pollutants effectively. Secondly, to manufacture beverages with higher quality such as high pigment contents. Thirdly, it is a cost-effective way of fermentation (Sandeep K. Panda et al., 2018).

Contribution to sensory characteristics

Reusing VFW can end up a better product flavor, fragrance, and color (Sandeep K. Panda et al., 2018). In other words, using synthetic colorants cause many health problems, while colorants from plant wastes and/or microorganisms lack negative health consequences (Gupta et al., 2019). Besides, coloring agents from such sources have anti-cancer and anti-oxidant properties and prevent cancer, heart diseases, and other degenerative diseases (Sandeep K. Panda et al., 2018) and they enhance the immune system, and skin health (Gupta et al., 2019). For instance, *Rhodotorula sp.* is used in fermentation medium containing apple pomace to obtain carotenoid (Sandeep K. Panda et al., 2018). Additionally, *Monascus purpureus* is used for gaining a yellow pigment from the banana peel, using ethanol (Satapa,2013).

Regarding microbial aroma, many countries recycle VFW for microbial growth, resulting in gaining flavor from microorganisms. For example, lactic acid bacteria (LAB) can produce a desirable aroma from amino acids. In this process, the bacteria secret proteolytic enzymes and degrade casein to amino acids. Also, D-limonene, the composition of the orange peel oil, can be converted to a-terpineol by *Penicillium digitatum*, forming a floral odor (Sandeep K. Panda et al., 2018). So, the organoleptic properties of foods can be improved by VFW.

Bioadsorbent

Some extracted pigments from plant wastes have bioadsorbent properties (Gupta et al., 2019). They lack economic and environmental burdens and toxicity issues (Gupta et al., 2019). For example, arsenic adsorbent capacity can be observed by waste extracts of grape, pomegranate, and apple (in succeeded order) (Gupta et al., 2019). Also, VFW can be converted to bio absorbent and used in waste-water treatment (Arvanitoyannis & Varzakas, 2002). Thus, VFW can serve as a chelating agent for removing toxic materials.

Bio-controls in agriculture

VFW can be used as a substrate, in the solid-state fermentation process, for the growth of some fungi and bacteria that can produce biological pesticides (bioherbicide, bioinsecticide, and bio fungicides) (Panda et al., 2018). An example of this scenario is growing the fungus *B. bassiana* that can kill insects in agricultural grounds, on dry cassava bagasse. During the process of biocontrol, the fungal conidia attach to the insect body and germinate there. Afterward, the fungi secret many lytic enzymes, such as protease, chitinase, esterase, and lipase, breaking down the insect's body. At the same time, the fungus grows to the hemolymph system of the insect to disrupt the system (Panda et al., 2018). Products from such organisms have a great impact on agricultural product quantity and quality (Panda et al., 2018). VFW can be used as environmentally-friendly pesticides. The use of compost extracts is steadily increasing, offering an attractive way for plant growth enhancement and disease management replacing chemical pesticides. A study, performed by Zouari et al. (2020) was focused on possible alternative taking place in plant growth promotion and reducing activity against fungal disease, by using a compost extract of poultry manure-olive husk. *Bacillus siamensis* CEBZ11 strain was isolated from this extract and found to be effective against gray mold in tomatoes. Reduction of disinfesting and germicide can together abolish Phytophthora blight, while soil arbuscular mycorrhizal fungi exert biocontrol on soil-borne diseases. But the combination of reductive disinfestation and germicide use e.g., tobacco (*Nicotiana tabacum* L.) waste on pepper-related (*Capsicum annuum* L.) Phytophthora blight and soil arbuscular mycorrhizal fungi are currently unidentified. The co-working of reductive disinfestation (upfront film-mulching with reductive fertilizer) and tobacco waste showed the greatest abolishment of pepper Phytophthora blight, and increased fruit yield and arbuscular mycorrhizal fungi species(Hou et al., 2020).

Plant hormones

VFW can be used as a substrate for growing organisms that produce plant growth regulators, such as indole 3- acetic acid, gibberellins, indole-2-butyric acid, and many others. These hormones have a great role in seed germination, sprouting, shoot and root elongation, flowering, and fruiting. An example of VFW is cassava bagasse for culturing of *B.subtilis*, which in turn the *B.subtilis* produces indole-3-acetic acid for the growth of plants *Dioscora rotundata L.*. Another example of getting plant growth regulators is gibberellic acid from *Gibberella fugikuroi* when it grows on maize cob particles (Panda et al., 2018). Particular phytohormones can be boosted by using certain VFW. Arancon et al.(2005) studied vermicompost which is a mixture of food and paper wastes including the manure of cattles was observed to promote growth and a significant increased yield of peppers; leading to hormonal induction indicated by an increase in leaf area, plant shoot biomass, marketable fruit weight and as well as a decreased yield of non-marketable fruit. Another study by Arancon et al.(2006) pointed out that when used together with a well known hormone, indole acetic acid; the vermicompost promoted the growth of peppers with more fruits and flowers.

Renewable energy

VFW from the agriculture process and food industries is a good source for manufacturing biogas and bioethanol in a trouble-free method (Singh et al., 2012). VFW contains cellulose, hemicellulose, lignin, and many other carbohydrates. These components can be converted to simple sugars, then to biofuels (Singh et al., 2012). For this purpose, the vacuum fermentation technique is used as a replacement for conventional fermentation, producing a 93.6% higher yield (Sandeep K. Panda et al., 2018). For example, *S. cerevisiae* can be used to gain bioethanol from coffee wastes (Sandeep K. Panda et al., 2018). This is because *S.cerevisiae* has an alcohol dehydrogenase gene (ADH) (Ciriacy, 1975). Also, cassava wastes is a good raw material for producing bioethanol (Sandeep K. Panda et al., 2018).

Sometimes pretreatment process should be done to the wastes, such as microwave exposure, hydrothermal treatment, and dilute acid treatment (Sandeep K. Panda et al., 2018).

Also, a mixture of biogases, including methane, carbon monoxide, carbon dioxide, and many other gases can be obtained from the anaerobic digestion of VFW (Edwiges et al., 2018) (Singh et al., 2012). A good example of methanogenic organisms can be found in the *Archaea* domain and *Euryarchaeota* phylum (Sandeep K. Panda et al., 2018). For efficient biogas production, VFW pretreatment is a good choice. This can be done by hydrolyzing the polymeric content of VFW (Sandeep K. Panda et al., 2018).

Another type of renewable energy that can be obtained from VFW is biohydrogen (Singh et al., 2012). Carbohydrate-rich effluent from different food industries is a suitable substrate for microbial growth and biohydrogen production after delignification (Sandeep K. Panda et al., 2018). This process should be done in two main steps, dark fermentation and photo fermentation (Singh et al., 2012). Sweet potato bagasse harbors the resources for *Clostridium* to produce biohydrogen (Sandeep K. Panda et al., 2018).

Moreover, biodiesel is another important oil that can be obtained from VFW containing oils (Singh et al., 2012). Palm, sunflower, soybean, and rapeseed provide good sources for making bio-diesel (Demirbas et al., 2016). This bio-fuel can be a good alternative to fossil fuels in using them for transportation purposes (Demirbas et al., 2016). Using this environmentally friendly fuel fulfills the people's need for fuels, provide higher heat content, and decrease the emission of harmful gases (Demirbas et al., 2016). Thus, VFW provides a green substrate for making various types of green energy.

Genetically engineered microorganisms

All the above-mentioned processes can be accelerated for a better and higher yield either by developing genetically modified strains or by coculturing of certain microbes. The former can be done through different gene manipulation methods, for example, DNA recombinant technology, induced mutation, transformation, transduction, protoplast fusion, and many others (Sandeep K. Panda et al., 2018). Additionally, the latter approach improves the bioproduction capacity of microorganisms (Sandeep K. Panda et al., 2018). For example, the co-culturing of *Kluyveromyces lactis* and *S. cerevisiae* on whey is used in producing single-cell protein (SCP) (Selim et al., 1991). Different products can be obtained purposely from genetically modified microorganisms, using VFW as substrates.

Animal feed

The food industry's by-product can be sold as a nutritionally rich, and cheap animal feeds as they contain a large portion of different kinds of carbohydrates, fibers, proteins, lipids, and minerals (Gowe, 2015). Additionally, using plant wastes for animal feeds decreases environmental burdens (Márquez et al., 2011).

Antioxidant

Different antioxidants from wastes of different plant species, varieties, and tissue can be recycled. These antioxidants include vitamin E and C, carotenoids such as lycopene, phenolic compounds including flavonoids and phenylpropanoids. These phytochemicals can be extracted from different plant wastes, such as peel, seed, stones, and many others. For example, antioxidants occur in high concentration in seeds of avocado, but in low concentration in its pulps (Gowe, 2015). They can fight against free radicals in the body and prevent some degenerative diseases (F. Whayne et al., 2016). Another rich source of polyphenol and vitamin C is peach waste which has antioxidant properties (Plazzotta et al., 2020). Moreover, some plant extracts have an anti-browning capacity. Some antioxidants from plant extract can prevent browning of foods as polyphenol oxidase activity. In this way, the quality of the food can be maintained (Wessels et al., 2014).

Antimicrobial

Bioactive compounds from plant wastes show a variety of antibacterial, antiviral, anti-mutagenic, and cardio-protective activities (Gowe, 2015). Plants produce such compounds as a defense mechanism against phytopathogenic microorganisms (Gupta et al., 2019). These natural compounds have a novel mechanism of action to fight against many infectious microorganisms. They can be targeted for new drug discovery. For example, the extract of seeds and peels of avocado shows antimicrobial activity, with a minimum inhibitory concentration value of 104.2 µg/mL, against *Zygosaccharomyces bailii* and *Salmonella enteriditis*, respectively. Also, Mozzarella cheese can be preserved by the lemon extract. So, antimicrobial compounds (as a form of essential oil) can be obtained from cheap resources and be used as a natural food additive (Gowe, 2015).

Prebiotics

Sometimes low molecular weight carbohydrates can be obtained from some agro-industrial wastes and can be used to enhance the digestion process. They are mono, di, and oligosaccharides which persist digestion in the digestive system until they rich colon. In the colon, they are fermented by some colon-residing bacteria such as lactic acid bacteria. In this way, they show their health-enhancing capacity (Mohd Nor et al., 2017)(Bello et al., 2018). Some examples include pectic oligosaccharides from orange peel wastes(Gomez et al., 2014) increasing the Lactobacillus and Bifidobacterium population; oligosaccharides from the shells of hazelnut as a waste(Sürek, 2017) and pineapple in powdered form in yogurt(Sah et al., 2016).

Dietary fiber

In agribusiness, rich fiber by-products are produced that they should be recycled to Mitigate environmental problems. These dietary fibers occur in plant wastes in combination with some other healthy substances. For example, proteins, colorants, antioxidants, and many other beneficial substances

(Gowe, 2015). Fibers can be used for many purposes such as, in the cosmetic and pharmaceutical area, for a food additive, for increasing swelling capacity and water holding capacity, and for increasing viscosity of certain foods. So, recycling of fibers from plant waste provide beneficial products and increase industrial profitability (Gowe, 2015) (Chantaro et al., 2008).

Protein source

Agricultural wastes, such as seeds, contain a large proportion of protein that they can be targeted for usage in many foods as a source of protein (Gowe, 2015) (Chantaro et al., 2008). For example, during making papaya puree, about 22% of the fruit is discarded as a protein-rich seed. This protein source has a medicinal value as it can be used for the treatment of sickle cell anemia, a renal disorder due to poisoning, and to cure diseases by helminths (Gowe, 2015).

Other uses of VFW as a food additive

Plant tissues contain many bioactive compounds that can be used as nutritionally rich food additives (Gowe, 2015). A good example is carotenoids, which is an excellent free-radical fighter, occur in a large amount in certain plant and they can be extracted as a good food colorant (Goula et al., 2017). Also, some plants have pectin which can be extracted and used as thickening agents (Voragen et al., 2009).

Despite the above-mentioned advantages of plants' wastes content, certain problems should be considered in using them. For example, some plant parts of certain species harbor a large amount of tannin, which negatively affects digestive enzyme and vitamin and minerals utilization by precipitating certain proteins. To tackle this problem, tannin should be inactivated by acid/alkaline hydrolysis during the extraction procedure (Gowe, 2015). The aim of this review is to determine the amount and types of fruits and vegetables that are used in four countries (Iraq, Turkey, Saudi Arabia, and Iran) to get a glimpse of VFW in the four countries and recommend a proper treatment for such a pollution source.

Data about the quality and quantity of vegetables and fruits in four different countries, Iraq, Turkey, Saudi Arabia, and Iran, were obtained on the website of "Our World in Data" and illustrated below.

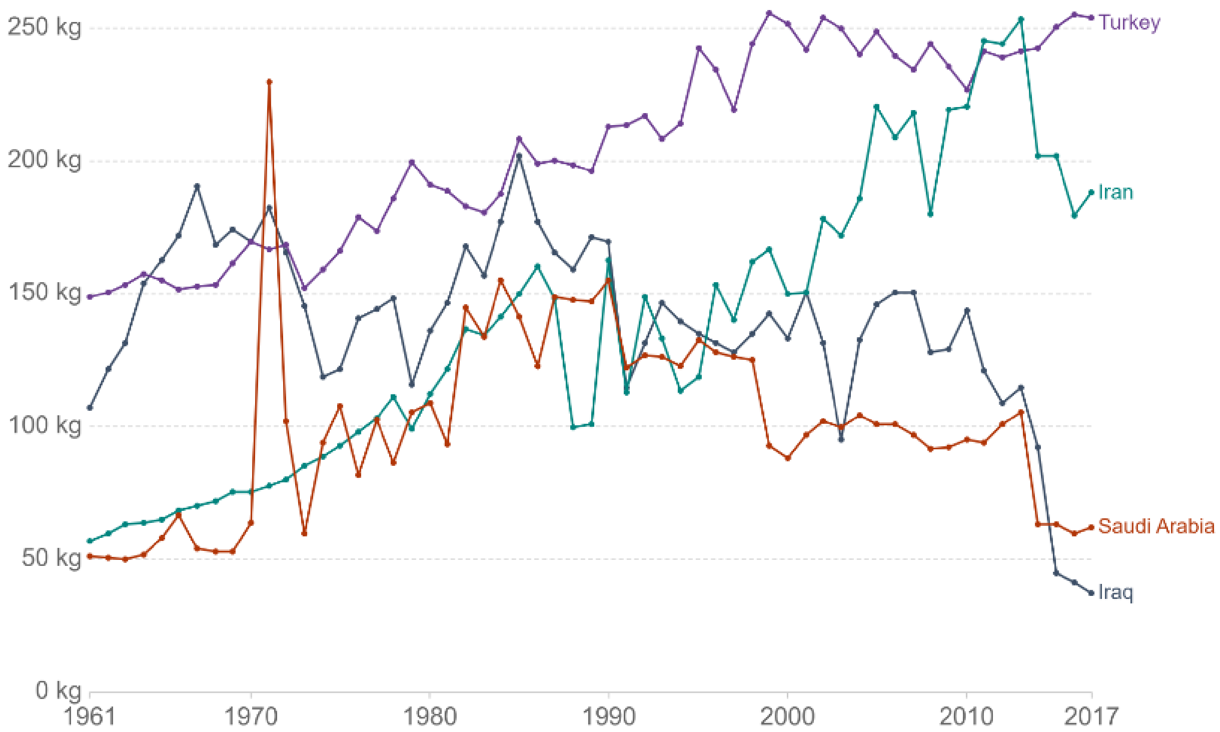

Figure 1. The amount of vegetables, measured in Kilogram per person,that is used in four countries from 1961 to 2017.

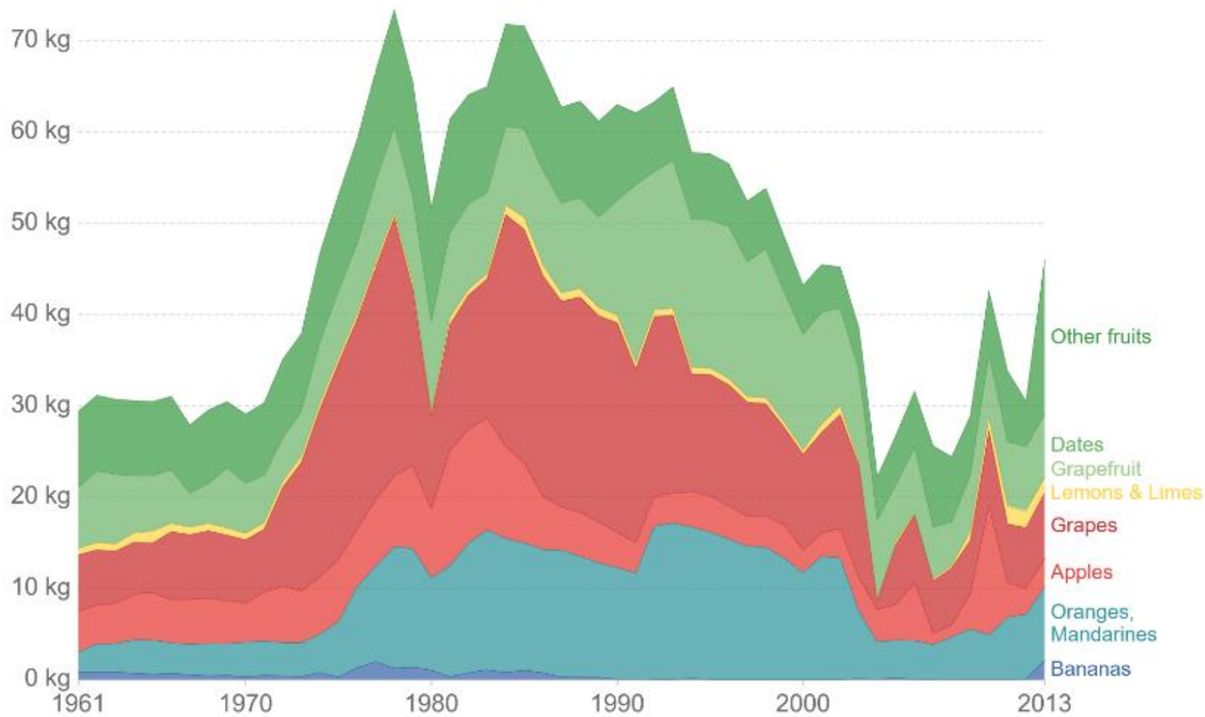

Figure 2. Types and the average amount of fruits that are used by each person in Iraq in Kilograms per year, between 1961 and 2013.

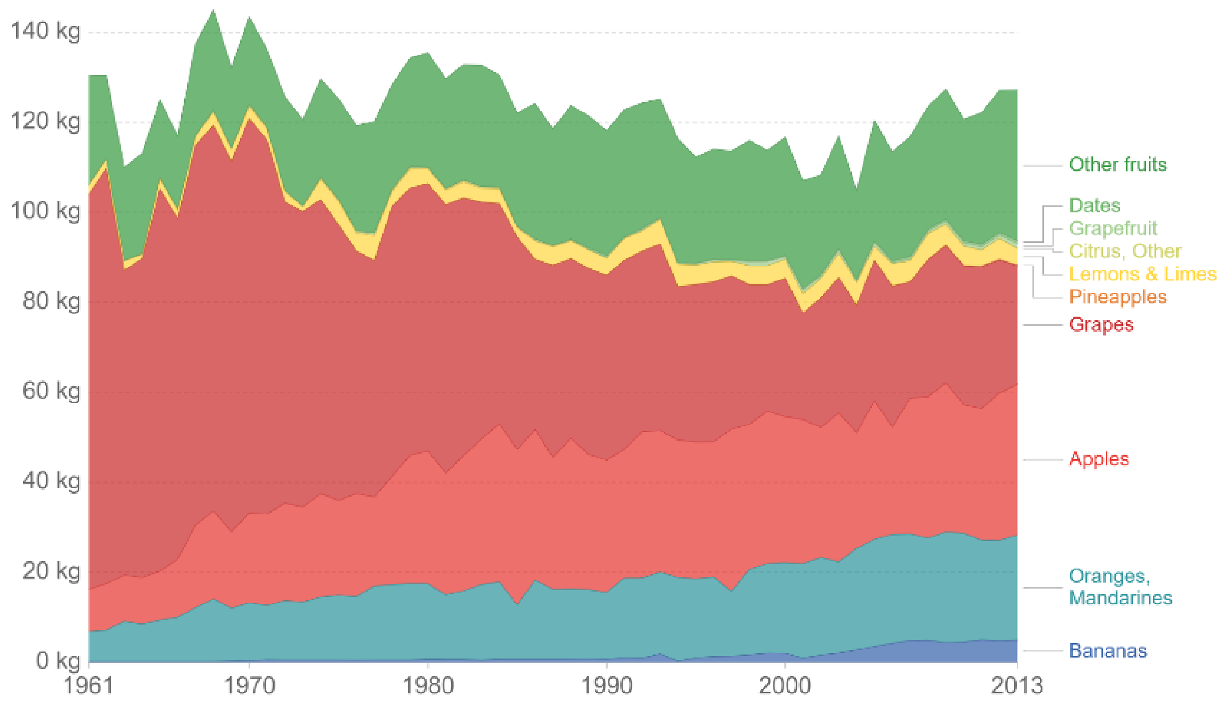

Figure 3. Types and the average amount of fruits that are used by each person in Turkey in Kilograms per year, between 1961 and 2013.

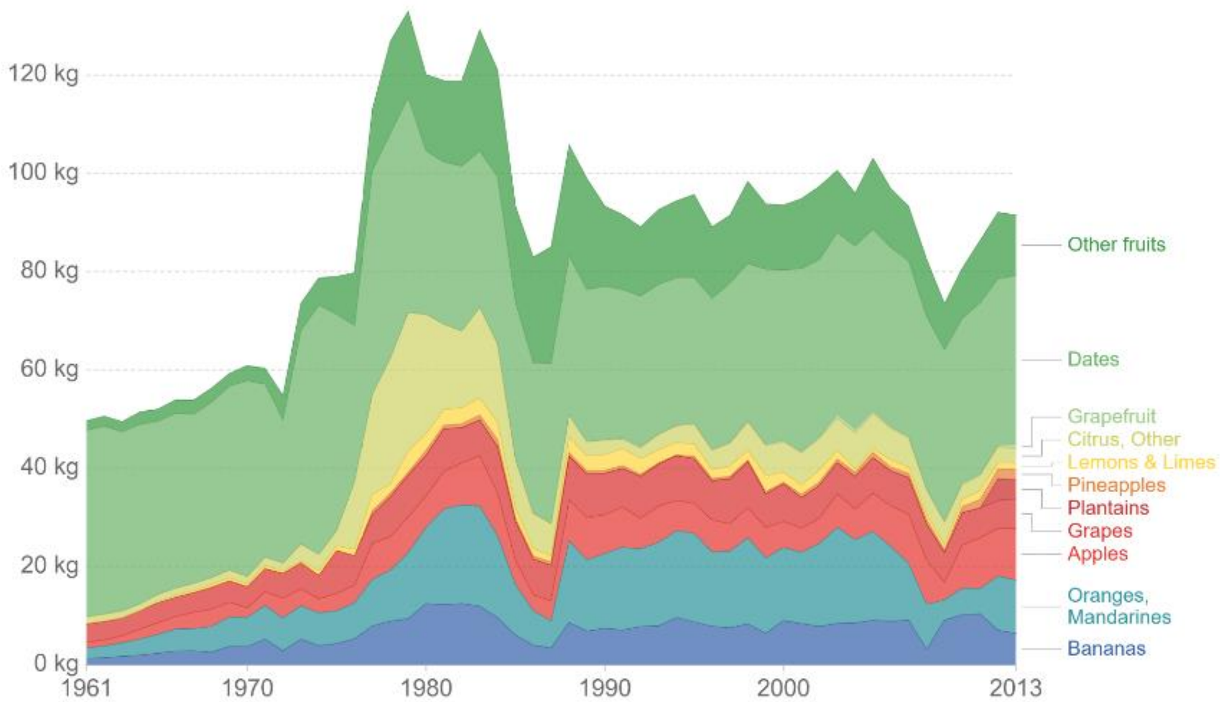

Figure 3. Types and the average amount of fruits that are used by each person in Saudi Arabia in Kilograms per year, between 1961 and 2013.

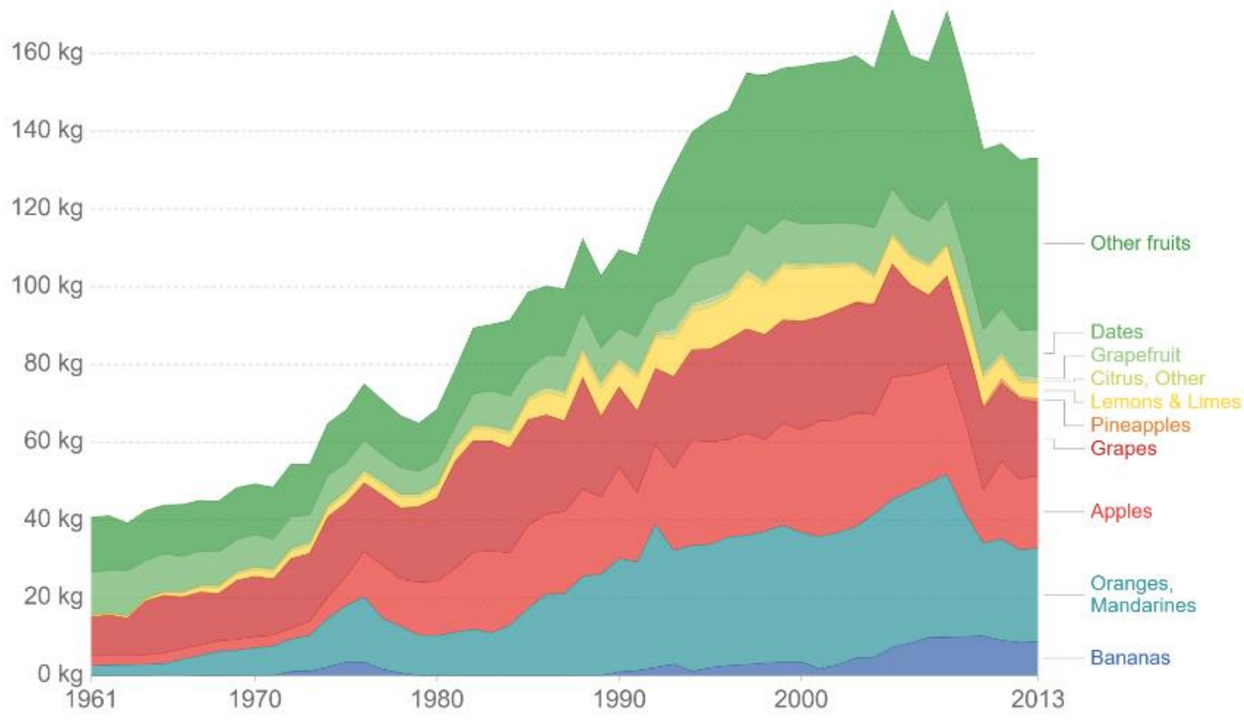

Figure 5. Types and the average amount of fruits that are used by each person in Iran in Kilograms per year, between 1961 and 2013.

Figure 6. The amount of total gas emissions that are emitted from food wastes.

In Figure 1, the amount of vegetables that are consumed in the four countries fluctuated throughout the given period. In Iraq, the greatest amount of vegetables are used in 1985 which accounts for 201.81 Kg, but it decreased to 37.53 Kg in 2017. In Turkey, the amount of vegetable usage has increased in the given period, starting from 148.94Kg to 254.11 Kg. Regarding Saudi Arabia, the amount has highly fluctuated, and the greatest number of utilized vegetables was observed in 1971 which was 229.98 Kg, but the value dropped to 62.31 Kg in 2017. Turning to Iran's situation in consuming vegetables, it was increased until 2013 comprising 253.37 Kg. Later on, the value is lessened to 187.98 Kg in 2017. In general, Turkey used the largest proportion of vegetables in the four countries. According to this data, Turkey should consider the issue of vegetable over-use as a serious problem. This can be done by raising awareness of Turkish people to limit the usage of vegetables, not exceeding their real needs, and improve the recycling sector for vegetable wastes. Also, Iran should focus on reducing vegetable consumption as it increased its usage in recent years.

In Figure 2, the amount and types of used fruits are depicted for Iraq. Dates can be observed as the commonly used fruits in Iraq between 1961 and 2013. In Figure 3, demands on dates, apples, oranges, and mandarins have increased greatly in Turkey in the given period. In figure 3, dates were used commonly in Saudi Arabia from 1961 to 2013 other than other fruits. Also, oranges, mandarins, and banana requests were slightly elevated at the same time. In figure 4, in Iran, all fruits types were utilized greatly and increasingly at the mentioned time. So, Iraq and Saudi Arabia should pave a way for industries to recycle and reuse wastes from dates. Besides, Turkey should consider the treatment of wastes from dates, apples, oranges, and mandarins as they use these fruits mostly. In terms of Iran, they should consider fruit waste treatment as a serious problem, because they use all fruit types increasingly. In these ways, all four countries will be able to reduce pollution by VFW locally.

When we look up to Saudi Arabia in kilogram basis, on average the estimated amount is as follows: the meat, chicken and fish comprises to 87, fruits 97, vegetables and salad 101, cereals and bakery 0.02 and sweets correspond to 0.05. It was not frequently recycled in agriculture up to now(URL 3). In some Arab countries such as Algeria, Egypt, Lebanon, Morocco, and Tunisia, the most excreted food waste is fruits/vegetables (45% of production), then fish/seafood (28%), and roots/tubers (26%). No intensive recycling is available since few agricultural areas are present due to climatic conditions; same is considered to Afghanistan as well(El Bilali and Ben Hassen, 2020).

The most important use of fruits in Turkey is the fruit juice industry. The data reported from Aegean Union of Exporters (EİB) of Turkey includes a total sales record of $220 million of fruit juice between the January-October period in 2019, corresponding to 150 countries worldwide. Only the sales of Turkish fruit juice to the United States increased by 50% and ranged between $50 to $75 million. Netherlands followed the U.S. with $28 million, then came Italy, with a $13 million import of fruit juice from Turkey. The head of the union, Mr. Uçak indicated that Turkey takes an important place among worldwide fruit juice producers. The main export items are apple juice concentrate, grape juice and concentrate and pineapple juice and its concentrate (URL 2).

Regarding greenhouse gas emissions, 26% of the gases come from food production, 6% of the proportion is developed by never eaten foods. So, VFW should be treated wisely for a cleaner environment both locally and globally.

Conclusion

In conclusion, different fruits and vegetables comprise a large portion of global food demand. Based on the light of this fact, a significant amount of VFW is produced in each country differently. Investigating the amount of fruits and vegetables in each country can provide a general picture of the relevant wastes, thus the recommendation for such wastes. Generally, Turkey and Iran should try to find a way for treating wastes from vegetables. Also wastes from dates in Iraq and Saudi Arabia, dates, apples, oranges, and mandarins in Turkey, and all types of fruits in Iran should be used for other purposes to reduce greenhouse gas emissions from such a waste. These can be done by recycling and reusing VFW by one or more methods that have been reviewed in the introduction part based on each countries' wastes, abilities, and economical status.

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