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CASE STUDY

The impact of fruit and vegetable waste on economic loss estimation

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ABSTRACT

BACKGROUND AND OBJECTIVES: Receiving nutrients from fruits and vegetables are essential for public health. However, a large amount of waste is produced during producing, supplying, and consuming these fruits and vegetables. Water, fertilizers and pesticides used for the production of agricultural products can affect the soil and their cultivation environment and finally lead to environmental pollution. Therefore, this study aimed to investigate the amount of fruit and vegetable waste caused by corruption and evaluate its economic loss and health damage.

METHODS: The data were collected using the observation technique aided by observation tools and weighing tests to physically analyze and determine the quantity and quality of waste from Tehran's fruit and vegetable distribution centers. In each center, the waste obtained from fruits and vegetables was stored in special waste tanks at the end of the day, and the waste was transported to outside the center by special waste disposal vehicles. The economic loss of unusable fruits and vegetables was calculated according to the weight of their waste in the fields of agricultural product supply. The data were analyzed using statistical software SPSS, ANOVA statistical test, and Excel software.

FINDINGS: The results revealed that the amounts of fruit and vegetable wastes were 12 percent and 24 percent, respectively, accounting for a total loss of 54,891,539 USD. The highest quantity of fruit waste (15 percent) was observed in summer, and the economic loss due to fruit waste was higher in this season. Also, the amounts of vegetable waste in summer and spring were equal to 28 percent and 24 percent, respectively, indicating the higher economic loss due to vegetable in these seasons.

CONCLUSION: The results showed that the economic loss due to vegetable waste was greater than the economic loss due to fruit waste. The amount of vegetable waste was 24 percent, representing a high economic loss. The generation and disposal of these wastes caused a great economic loss and health problems due to their unpleasant odor, release of leachate into the environment, and landfill pollution. Therefore, it was recommended to follow appropriate production principles and supply operations. Moreover, a comprehensive waste disposal management, as a practical measure, should be used to prevent and control these problems. The use of modern technology in harvesting, transporting and supplying fruits and vegetables could reduce their lesion, and subsequently reduce the economic loss.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
46	4	7

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INTRODUCTION

Food safety is one of the most important issues in human life (Ahmadi *et al*., 2020). One-third of the food is wasted worldwide, while 1 billion people are malnourished, and this food disposal can feed 1.9 billion people (Shafiee-Jood and Cai, 2016; Joardder and Masud, 2019; Elik *et al.*, 2019). The consumption of agricultural products is growing each year (Sosalagere *et al*., 2022), and the continuous increase in population, despite technological advancements, has led to an imbalance in supply, demand, and consequently increased food waste globally (Ashokkumar *et al.,* 2022; Ganesh *et al*., 2022). The Food and Agriculture Organization (FAO) of the United Nations declared that food waste included all things that could change accessibility, edibility, health, and safe or quality of a product and prevent the consumer from consuming it (Girotto *et al*., 2015). There is a limitation for natural resources of agricultural products, and the required range for these resources to produce agricultural products is related to the increase of population (Gholifar *et al*., 2010; Tien *et al*., 2019). On the other hand, fruits and vegetables are major sources of nutrients and minerals. More than 42 percent (%) of the food waste is made up of fruits and vegetables, as the most consumed food, in the world (Pushparaj *et al.,* 2022; Ganesh *et al*., 2022.; Coman *et al*., 2020). They have the highest amount of waste among food products, which can be due to high sensitivity to spoilage. FAO estimated that 40-50% of fruits and vegetables were wasted throughout the food supply chain worldwide (Gustavsson *et al*., 2011). In other words, more than one-third of the fruits and vegetables produced worldwide are destroyed before reaching the consumer (Yavari *et al.,* 2022; Plazzotta *et al*., 2020). This amount is equivalent to 28 million tons of waste (Abadi *et al.,* 2021). Fruits and vegetable waste include withered, shriveled, rotten, and decayed food products that have been provided with suitable conditions for spoilage in the stages of handling, transportation, packaging, storage, sale, and consumption (Gholifar *et al*., 2010; Kitinoja and Kader, 2015; Shafiee-Jood and Cai, 2016; Ganesh *et al*., 2022). The average fruit and vegetable wastes in developed and developing countries have been reported to be in the range of 2%-20% and 24%-40%, respectively (Golshan Tafti *et al*., 2017). The amount of waste from the agricultural sector in Iran is 35%, equal to 28 million tonnes (t) of waste (Abadi *et al*., 2021). It has been reported that about 25%-30% of Iran's garden products are lost only because of the lack of maintenance and storage equipment (Taghizadeh-Alisaraei *et al*., 2017). The survey conducted on the components of fresh urban solid waste in one of the waste disposal centers of Tehran (Kahrizak) revealed that more than 60% of waste is made up of food waste, fruits, vegetables, and organic materials (Shariatmadari *et al*., 2015). In Iran, about 90% of the raw materials are supplied from the agricultural sector, and increase of agricultural waste has negative effects on social and environmental issues such as production of a large amount of methane gas (MG) (Hawkins, 2013), large amounts of loss of water, soil, fertilizer, seeds, and labor (Ganesh *et al*., 2022). Fruits and vegetables, as one of the most consumed foods in the world, account for more than 42% of food waste (Ganish et al., 2022; Kuman *et al*., 2020). They have the highest amount of waste among food products, which can be due to their high sensitivity to corruption. Large quantities of organic waste are produced daily in fruit and vegetable fields in big cities such as Tehran. To the best of the authors' knowledge, no comprehensive study has been performed regarding fruit and vegetable wastes in the Tehran Municipality so far. In mega cities of Iran, vegetables are sold in the centers named "vegetable squares"· Unsuitable transportation service, inadequate process, and bad storage space are responsible for 35% of fruit and vegetable waste produced, which is a significant amount (Omrani *et al*., 2008; Nawab Akbar, 2014). According to national reports, more than 51,000 tons of fruit and vegetable waste is being produced in fruit and vegetable fields and subsidiaries of Tehran, the value of which is estimated to be over 14,000 USD per year. In Iran, fruits and vegetables are collected from the farm in bulk and are transferred to sales centers inappropriately. Considering the sensitivity of fruits and vegetables to corruption in the farm, inappropriate transportation conditions, unsuitable maintenance conditions, and improper supply conditions in sales centers, wastes of fruit and vegetable are higher compared to other foods. Specifying the amount of fruit and vegetable waste and identifying its damage in Tehran can be extended to other cities of Iran. This study aimed to investigate the amount of fruit and vegetable waste caused by corruption and wastage in Tehran and evaluate its economic loss and health damage. The study has been carried out in Tehran, Iran in 2021.

MATERIALS AND METHODS

This descriptive-analytical study was performed in a cross-sectional design in Tehran in 2021. Investigations were first conducted in a library and then in the field using the observation technique with the help of observation tools, tests, and checklists. Finally, the obtained data were analyzed using the statistical software and tests. Product input data to all fruit and vegetable distribution centers of Tehran Municipality (250 centers) during 2022 were collected to physically determine the quantity and quality of waste. Likewise, they were analyzed and evaluated using software and statistical tests while registering in the computer system. All the stages and required information are recorded by hundreds of people in the field of health and exploitation of the Tehran Municipality Fruit and Vegetable Organization.

The organization of fruit and vegetable fields

Tehran, as the capital of Iran, is one of the largest and most populous cities with 22 municipal districts (Fig. 1). The Fruit and Vegetable Fields of Tehran Municipality (FVFTM) were established according to the resolution of Tehran Municipality in 1979. Food supply centers, including 22 fields and 228 fixed and neighborhood markets (a total of 250 centers) under the Tehran Municipality's direct management, provide citizens with services such as distributing and supplying all the necessary food and agricultural products. The organization of FVFTM is the largest supply network of agricultural and food products in Iran, providing the daily food needs of more than 2 million people. In these markets, other food groups, including eggs, poultry meat, red meat, and meat products, milk and dairy products, fish and aquatic products, commercial products, basic goods, nuts and dried fruits, bakery, and confectionery products, and summer foods are also sold. In other words, all products of food and agricultural fruits and vegetables needed are offered in these centers.

Data collection

Data related to the amount of arrival, sale, and waste of fresh agricultural products of various types of

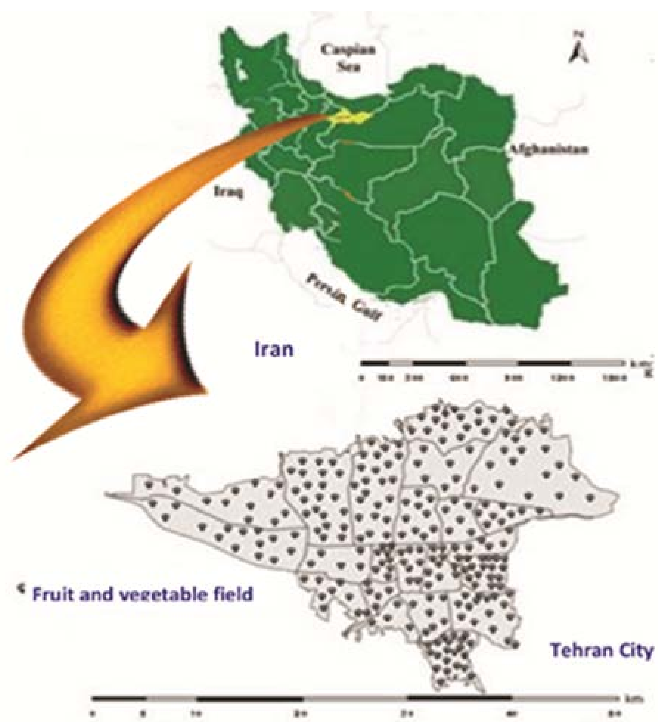

Fig. 1: Geographic location of the study area and spatial distribution of fruit and vegetable fields in Tehran, Iran

vegetables (such as tomato, carrot, cabbage, potato, onion, garlic, radish, eggplant, cucumber, pepper, pumpkin, lettuce, turnip, green bean, bean, beet, celery, other types of bean), green vegetables for table, stew and soup (including parsley, chive, spring onion, garden cress, cilantro, spinach, dill, tarragon, savory, horseradish, mint, and basil), and fruits (including apple, orange, grape, peach, tangerine, banana, pear, pomegranate, persimmon, fig, watermelon, melon, cantaloupe, apricot, cherry, strawberry, sour cherry, kiwi, dew melon, sweet lemon, rose apple, nectarine and other types of fruit) in 250 existing centers (fields and markets) located in Tehran were collected daily during the year for four seasons of spring, summer, autumn, and winter. Usually, fresh fruit and vegetable products are separately transported by trucks and weighed via digital scales, and their details are recorded in all the FVFTMs. The consignment is unloaded from the trucks and transferred to storage. The information and input data of products (amount and type of products) are recorded and stored by each center's head of administrative affairs in the administrative system and the comprehensive management system of fruit and vegetable fields (tonnage system). While the agricultural products are ready for sale, the price approved by the organization and the weight of the sold product are recorded and stored in the scale's memory. In addition to the product weight, the purchase slip provided to the customer includes the price, date of purchase, and the name or number of the stall or market. At the end of the working day, all the sales information stored on the digital scales is transferred and recorded by the person in charge of administrative affairs of the field or market in the comprehensive management system of the fruit and vegetable fields (tonnage system). Furthermore, to maintain this information in the system of each center, all the information and tonnage of sales in the fields are printed daily and preserved physically. The information and data registered in the comprehensive management system or the tonnage system of the fields of Tehran Municipality are checked, summarized, and stored by the tonnage officials as the organization's deputy of the fields and tonnage. The price list of the products offered in fruit and vegetable markets available in the comprehensive management system of the agricultural products markets is updated daily by the officials of the commercial department of the organization of FVFTM. Since the price of each product is recorded by the officials of the fields and markets, the product is always offered based on the approved price.

Recording the amount of the produced waste

At the end of each day, the amount of fruit and vegetable waste is separately weighed by a digital scale and recorded, and the waste tonnage is automatically sent to the Department of Health, Safety, and Environment (DHSE) and health department of FVFTM. In each center, the waste from fruits and vegetables is held in special waste tanks, and at the end of the day it is transported to outside the center by special waste disposal vehicles.

Estimation of economic loss

All the data related to the entry and sale of fruit and vegetable products of each center registered in the comprehensive management system of the fields were analyzed separately. The acceptance price of the fruit and vegetable products was obtained from the commercial vice-chancellor of the FVFTM. In 2021, the new price lists were approved 63 times (20 times in spring, 16 times in summer, 13 times in autumn, and 14 times in winter). The average selling price of the product was considered in the price list for each season. Furthermore, the number of Kilogram (KG) of waste of each product was multiplied by its price to get the amount of loss caused by the produced waste. The economic loss of unusable fruits and vegetables was calculated according to the weight of the fruit and vegetable waste in the fields of agricultural product supply. It is worth mentioning that the total amount of costs was considered based on the exchange of the Iranian currency (Rial) to the American dollar (USD).

Statistical analysis

The results were analyzed using statistical software SPSS, analysis of variance (ANOVA), and Excel software. The abundance of production waste was calculated as the amount of fruits and vegetables that could not be consumed (expressed as a percentage of the total amount of the fruits and vegetables entered into the market). The economic importance of the problem was analyzed based on the information obtained from the market and calculated annually in each season.

RESULTS AND DISCUSSION

The FVFTM has a completely traditional structure, and the method of sending products by manufacturers to these centers causes the production of large amounts of waste before they reach the consumer, as they are thrown away as fruit and vegetable waste.

Findings related to fruits

In spring, out of 68,605 t of fruit sold in the FVFTM, 7,258 t of waste (12%) was produced, and its economic value was 5,338,558 USD. According to Fig. 2, the amount of waste for apple, orange, grape, peach, and tangerine was 15%; and for apricot, cherry, sour cherry, kiwi, and nectarine was 12%. Likewise, among the fruits of this season, lemon and banana had the highest and the lowest amounts of waste of 18% and 5%, respectively.

In summer, out of the 82,343 t of fruit sold in the FVFTM, 12,244 t of waste (15%) was produced, and its economic value was 819,948 USD. According to Table 1, the amount of waste for pear, cantaloupe, and watermelon was 10%. In summer, the highest amount of waste was related to grape, peach, rose apple, and sweet lemon (20%) , and the lowest amount of waste was related to banana (8%) and melon (9%).

In the autumn, out of the 3296128 t of fruit sold in the FVFTM, 6,422 t of waste (10%) was produced, and its economic value was 3,605,404 USD. As can be seen in Table 2, peach and grape had the highest amount of waste (15%). Moreover, melon and banana have the lowest amount of waste (5%) in this season.

In winter, out of the 59,848 t of fruit sold in the FVFTM, 5,828 t of waste (10%) was produced,

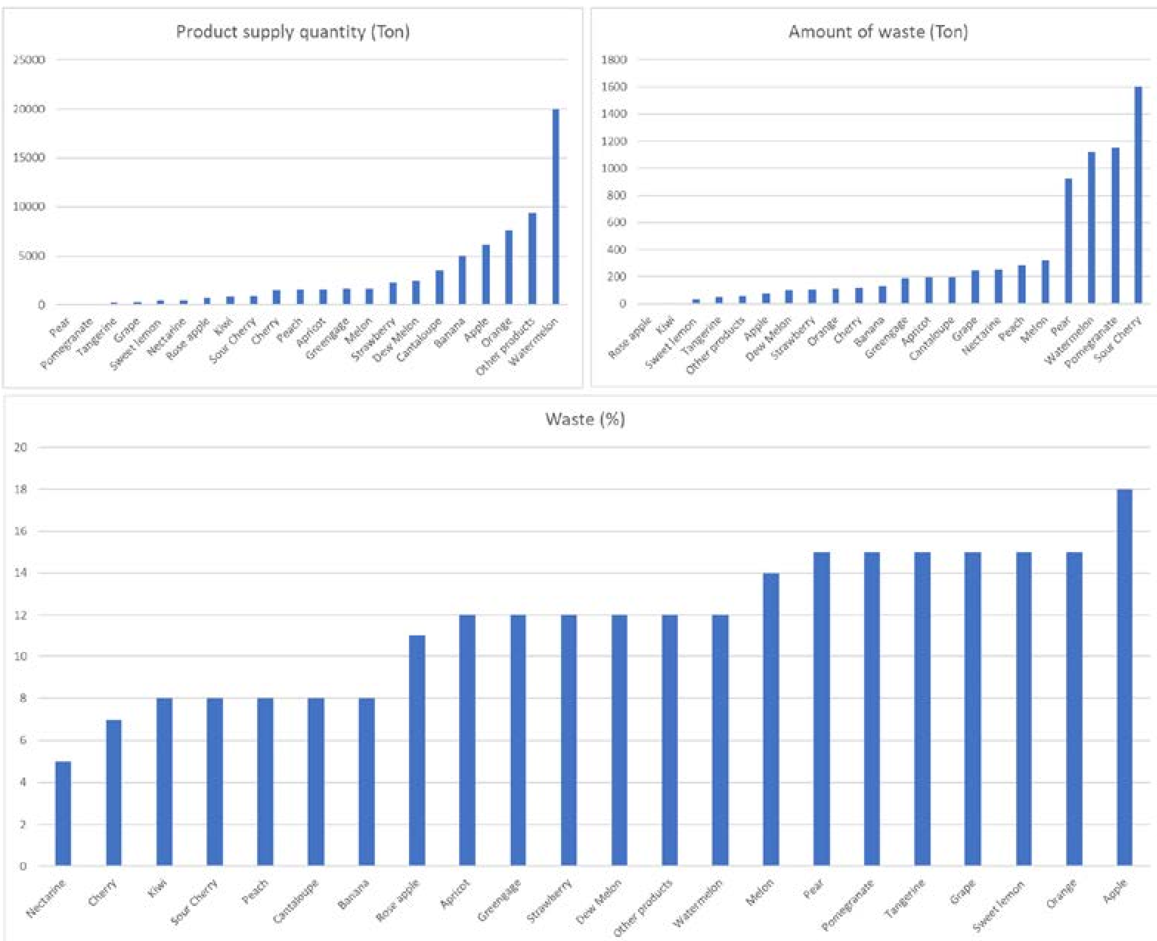

Fig. 2: Fruit waste in spring in the fruit and vegetable fields organization of Tehran Municipality

Table 1: Fruit waste in summer in the fruit and vegetable fields organization of Tehran Municipality

Product	Product supply quantity (Ton)	Amount of waste (Ton)	Waste (%)	Loss value (USD)
Apple	3998	600	15	258318
Orange	40	6	15	1846
Grape	6422	1284	20	864600
Peach	7095	1419	20	1047917
Tangerine	2	0.328	16	137
Banana	5624	450	8	401476
Pear	1402	140	10	126204
Pomegranate	335	40	12	20056
Fig	1345	202	15	162919
Watermelon	17431	2743	10	527520
Melon	6832	615	9	201014
Cantaloupe	4921	492	10	160852
Apricot	1036	155	15	217054
Cherry	1252	188	15	250601
Strawberry	106	16	15	17396
Sour cherry	1113	167	15	141262
Kiwi	0.588	0.086	15	41
Greengage	29	4	15	5767
Sweet lemon	874	175	20	58974
Rose apple	3506	701	20	372157
Nectarine	5773	866	15	666117
Other products	13207	1981	15	2590710
Total	82343	12244	15	8119948

Table 2: Fruit waste in autumn in the fruit and vegetable fields organization of Tehran Municipality

Product	Product supply quantity (Ton)	Amount of waste (Ton)	Waste (%)	loss value (USD)
Apple	9470	947	10	385948
Orange	6421	642	10	216176
Grape	3665	550	15	379875
Peach	1626	244	15	167664
Tangerine	9909	991	10	400322
Banana	5766	289	5	262588
Pear	671	67	10	59448
Pomegranate	6871	687	10	365252
Persimmon	1968	236	12	149822
Fig	251	30	12	21358
Watermelon	2313	162	7	27540
Melon	706	36	5	10009
Cantaloupe	319	22	7	7046
Strawberry	0.217	0.017	8	13
Kiwi	790	63	8	28002
Sweet Lemon	4194	419	10	227423
Nectarine	202	24	12	8601
Other products	8445	1013	12	915849
Total	63589	6422	10	3605404

and its economic value was 7,072,040 USD. Based on the data presented in Table 3, grape and melon had the highest and the lowest amounts of waste of 15% and 4%, respectively.

Despite the long storage life and average shelf life of citrus fruits (Terry *et al.*, 2011), the waste of these fruits was low in autumn, due to their harvest in this season, and high in spring, due to the long storage time or improper storage conditions. Banana has low waste due to having a relatively constant demand pattern

Table 3: Fruit waste in winter in the fruit and vegetable fields organization of Tehran Municipality

Product	Product supply quantity (Ton)	Amount of waste (Ton)	Waste (%)	Loss value (USD)
Apple	12731	1273	10	621029
Orange	18537	1854	10	980732
Grape	745	112	15	61613
Tangerine	5290	529	10	301718
Banana	5727	286	5	281529
Pear	264	26	10	24793
Pomegranate	2981	298	10	159956
Persimmon	183	22	12	18120
Watermelon	354	18	5	3315196
Melon	3	0.121	4	31
Strawberry	305	30	10	49294
Kiwi	2535	203	8	109569
Sweet lemon	13	1	8	292
Dew melon	2289	229	10	168335
Other products	7891	947	12	1261354
Total	59848	5828	10	7072040

throughout the year (Terry *et al*., 2011). The high perishability of rose apple is influenced by its thin and dehydrated skin (Techakanon and Sirimuangmoon, 2020). Since grape, as a perishable fruit, mainly suffers from decline of quality after harvesting, its waste was significant in all seasons. The waste of grape can be reduced by the prevention of the factors that reduce its quality, mainly driven by the gray mold fungus *Botrytis cinerea* (Shen and Yang, 2017). It is not far from the idea that peach, as a highly perishable fruit with a short shelf life, has a higher loss under environmental conditions, and after harvesting, its nutritional and organoleptic quality decreases rapidly (Mahajan *et al*., 2015). High shelf life (Pech *et al*., 2008) and hard skin (rind) are the factors that reduce the waste volume of melon as a non-climacteric fruit.

Findings related to vegetables

In spring, out of 89,577 t of vegetables sold in the FVFTM, 21,171 t of waste (24%) was produced, and its economic value was 6,705,072 USD. Table 4 shows that the waste is 30% for potato and 25% for onion and garlic. In this season, the highest and the lowest amounts of waste were related to lettuce (50%) and radish (5%), respectively.

In summer, out of 97,340 t of vegetables sold in the FVFTM, 26,994 t of waste (28%) was produced, and its economic value was 9,178,741 USD. According to Table 5, the amounts of waste for celery, potato, and onion were 40%, 35% and 30%, respectively. In this season, the highest and the lowest amounts of waste were related to lettuce (55%) and radish (6%), respectively.

In autumn, out of 104668 t of vegetables sold in the FVFTM, 27,783 t of waste (22%) was produced, and its economic value was 7,101,533 USD. According to Table 6, the amount of waste was 30% for celery and 25% for potato and tomato products. In this season, the highest and the lowest amounts of waste were related to lettuce (50%) and radish (5%), respectively.

In winter, out of 99,956 t of vegetables sold in the FVFTM, 23,834 t of waste (23%) was produced, and its economic value was 9,178,741 USD. According to Table 7, the amount of waste was 30% for celery and 25% for potato and tomato. Moreover, in this season, the highest and the lowest amounts of waste were related to lettuce (50%) and radish (5%), respectively.

Although potato and onion are semi-perishable (Terry *et al*., 2011, Tyovenda *et al*., 2022), their storage (Saha *et al*., 2014) can spoil them, especially under air heat (Maroušek et al., 2020, Asif et al., 2022). In addition, spring onion, like garlic, is highly perishable (Kłebukowska *et al*., 2015). Since there are no suitable conditions for maintaining the quality of agricultural products in the FVFTMs, the observed amounts of waste are expected, not only for tomato but also for other perishable products. In addition to the fact that most of the lettuce waste is produced at the end of the distribution chain (Terry *et al*., 2011), its waste volume is high due to its specific volume, high humidity, and lack of packaging (Lopez *et*

Table 4: Vegetable waste in spring in the fruit and vegetable fields organization of Tehran Municipality

Product	Product supply quantity (Ton)	Amount of waste (Ton)	Waste (%)	Loss value (USD)
Green vegetables (table, stew, and soup)	6076	1215	20	374045
Tomato	12117	2666	22	1160411
Carrot	5561	1112	20	337417
Cabbage	2152	387	18	105622
Potato	15107	4532	30	1175779
Onion	11739	2935	25	554878
Garlic	747	187	25	135431
Black radish	3	0.157	5	33
Eggplant	3687	479	13	101172
Cucumber	9507	1426	15	426397
Pepper	1590	207	13	95410
Courgette	1763	247	14	69445
Lettuce	6886	3443	50	1090036
Turnip	6	0.680	11	95
Green beans	978	98	10	55460
Broad bean	3323	499	15	131524
Beetroot	14	2	14	308
Celery	721	216	30	56142
Other products	7600	1520	20	835458
Total	89577	21171	24	6705072

Table 5: Vegetable waste in summer in the fruit and vegetable fields organization of Tehran Municipality

Product	Product supply quantity (Ton)	Amount of waste (Ton)	Waste (%)	Loss value (USD)
Green vegetables (table, stew, and soup)	5352	1338	25	427174
Tomato	15158	3941	26	1728087
Carrot	4101	1026	25	485079
Cabbage	1967	433	22	139789
Potato	18494	6473	35	1518686
Onion	14100	4230	30	764683
Garlic	361	90	25	69488
Black radish	12	0.007	6	113
Eggplant	4355	697	16	150077
Cucumber	9754	1658	17	529372
Pepper	1774	266	15	106449
Courgette	2194	351	16	99915
Lettuce	5129	2821	55	Turnip
Turnip	12	2	17	406
Green beans	1387	208	15	103231
Broad bean	60	9	15	2319
Beetroot	10	1	10	365
Celery	1133	453	40	95900
Other products	11987	2997	25	1959430
Total	97340	26994	28	9178741

al., 2000). Black radish had little waste in all seasons. Radish skin is a protective barrier for this product (Yücetepe *et al.*, 2021). The large volume of celery waste can be reduced by packaging and providing suitable temperature conditions (0 to 0.6 °C) and the required amount of relative humidity (RH)

Table 6: Vegetable waste in autumn in the fruit and vegetable fields organization of Tehran municipality

Product	Product supply quantity (Ton)	Amount of waste (Ton)	Waste (%)	Loss value (USD)
Green vegetables (table, stew, soup)	6077	1094	18	348876
Tomato	12472	3118	25	1259686
Carrot	5839	1051	18	361294
Cabbage	5035	856	17	269966
Potato	16001	4000	25	1389321
Onion	14063	3094	22	581100
Garlic	193	19	10	16098
Black radish	283	14	5	2605
Eggplant	4134	496	12	94935
Cucumber	9849	1379	14	390915
Pepper	1540	185	12	75302
Courgette	3534	424	12	130755
Lettuce	8804	3902	50	1064778
Turnip	2591	337	13	70421
Green beans	1031	103	10	46772
Beetroot	2206	309	14	65663
Celery	1990	597	30	126942
Other products	9026	1805	20	806096
Total	104668	22783	22	7101533

Table 7: Vegetable waste in winter in the fruit and vegetable fields organization of Tehran Municipality

Product	Product supply quantity (Ton)	Amount of waste (Ton)	Waste (%)	Loss value (USD)
Green vegetables (table, stew, and soup)	6395	1151	18	475133
Tomato	13047	3262	25	1701195
Carrot	5923	1066	18	228034
Cabbage	4014	682	17	215107
Potato	17183	4296	25	1740828
Onion	12921	2843	22	618632
Garlic	190	19	10	15257
Black radish	423	21	5	3491
Eggplant	3218	386	12	85495
Cucumber	9437	1321	14	495759
Pepper	1523	183	12	67872
Courgette	2156	259	12	101918
Lettuce	9122	4561	50	941294
Turnip	1573	204	13	70617
Green beans	424	51	12	26909
Broad bean	67	10	15	2977
Beetroot	1724	241	14	62504
Celery	1547	464	30	80114
Other products	9069	1814	20	837096
Total	99956	22834	23	7770243

(92%-95%) (Rizzo and Muratore, 2009). Undoubtedly, the amount of waste would be reduced by controlling the diseases that reduce the quality of vegetables after their harvesting (Soleimani *et al.*, 2021). According to Fig. 3, the amount of fruit waste in the FVFTM during 2021 was 12%, which led to an economic loss of 24,135,950 USD. The highest amount of fruit waste (15%) was observed in summer, in which the economic loss was higher compared to other seasons. Considering that fruit ripening is affected by high temperatures, the softness of ripe fruit reduces the transportability and shelf life of the product (Mulholland *et al.*, 2003) and leads to an increase in waste in this season. It is suggested

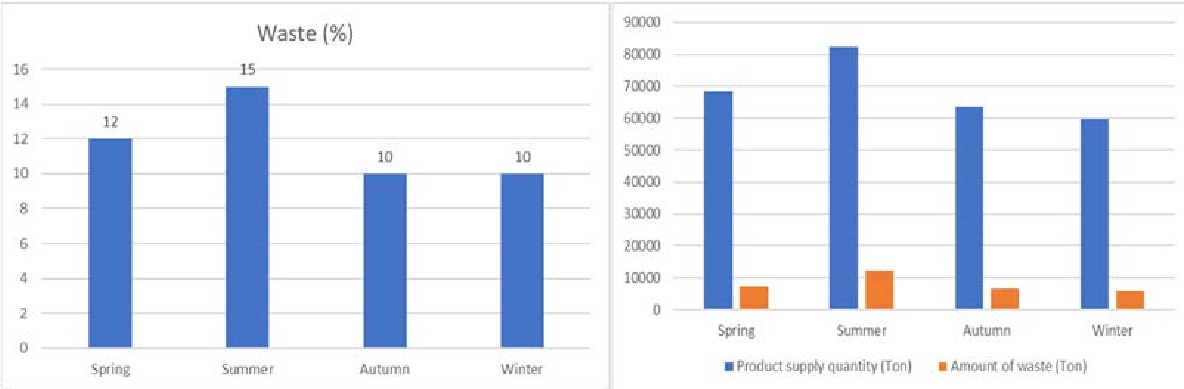

Fig. 3: Fruit waste in fruit and vegetable fields organization of Tehran Municipality

Fig. 4: Vegetable waste in fruit and vegetable fields organization of Tehran Municipality

to pack the summer fruits which do not have proper packaging using suitable technologies such as vacuum cooling and ethylene control.

According to the values reported in Fig. 4, the amount of vegetable waste in the FVFTM in 2021 was 24%, causing a high economic loss of 30,755,589 USD. Vegetable wastes in summer and spring were 28% and 24%, respectively, resulting in a higher economic loss compared to other seasons.

The economic loss due to fruit and vegetable waste was estimated as 54,891,539 USD in a year. Indeed, the costs associated with seeds, pesticides, staffing, transportation, and the amount of water wasted to produce these products are added to this economic loss (Liu *et al*., 2013, Joardder and Masud, 2019). The results of this study showed that the economic loss caused by vegetable waste was greater than that of fruit waste, while vegetables have a major contribution to the health of the people in the world (Kalia and Singh, 2018). Since the decrease of moisture content in agricultural products has a significant role in their quality loss (Al-Tayyar *et al*., 2020), it is possible to control the moisture content of these products by providing favorable conditions in terms of temperature and humidity and by suitable packaging (Rizzo and Muratore, 2009). Even though the main priority is to prevent the food waste production (Abadi *et al*., 2021), inventing the useful methods to separate and transform food waste into a valuable substances (Gustavsson *et al*., 2011) is important to reduce the economic loss and environmental issues (Liu *et al*., 2013). Food waste and bulking materials may contain trace amounts of contaminants and pathogens. These contaminants have long half-lives and are easily move within soil and plants. They can accumulate within the food supply chain and cause moderate to high toxicity levels (O'Connor *et al*., 2022). According to the findings of the present study, a large amount of waste is produced daily in Tehran. This waste is mixed with urban waste and transported from different areas of the city to landfill centers by garbage trucks with high fees. The accumulation of such wet organic materials has resulted in adverse environmental effects including leachate leakage, attracting insects, stench (Neff *et al*., 2015), and producing harmful greenhouse gases (Joardder and Masud, 2019). They also cause a considerable economic loss which needs to be prevented. In this sense, a proper waste disposal management system seems to be vital (Neff *et al*., 2015). Since fruit and vegetable wastes contain organic and protein substances, they can be used to prepare organic fertilizers; biofuels for electricity generation, cooking, and heating (Kuwahara *et al*., 1999); biopolymers (Girotto *et al*., 2015); pectin (Khoshnevisan *et al*., 2020); and to produce hydrogen and volatile fatty acids (Scotto di Perta *et al*., 2022). The results indicated that the economic losses caused by fruit and vegetable wastes in the fruit and vegetable fields organization of Tehran Municipality were 24,135,950 USD and 30,755,589 USD, respectively, totally amounting to 54,891,539 USD in 2021.

CONCLUSION

Fruit and vegetable wastes can be a fundamental problem due to the continuous increase of population in cities. The FVFTM plays a vital role in producing fruit and vegetable waste, and reducing this waste is important due to food safety and environmental issues. The high amount of waste from the supply and sale of fruits and vegetables in the FVFTM differs from season to season, and causes a huge economic loss each year. The present study revealed the increment of fruit and vegetable waste in sale fields and economic loss in hot seasons of the year. The amounts of waste from some fruits and vegetables in the FVFTM reached over 20% and 50% in summer, respectively. Since fruit ripening is affected by high temperatures, the softness of ripe fruits reduces their transportability and shelf life and leads to increase of fruit waste in this season. The amount of vegetable waste in the FVFTM was 24%, representing a high economic loss. Vegetable wastes in summer and spring were 28% and 24%, respectively, and therefore their economic loss was higher in these seasons. The total economic loss caused by fruit and vegetable wastes was estimated as 55 million USD in a year. Indeed, the costs associated with seeds, pesticides, staffing, transportation, and the water wasted to produce fruits and vegetables would add to their economic loss. The economic loss caused by vegetable waste was greater than that of fruit waste. The increase of fruit and vegetable waste imposes serious threats such as environmental pollution, health risks, need for more transportation equipment, and lack of burial grounds. Therefore, there is an urgent need to reduce the amount of fruit and vegetable waste and minimize their economic loss by adopting standard management practices and executing different approaches in food waste management. Proper methods for collecting and disposing the food waste can be effective in reducing economic and environmental losses. It is also suggested to apply appropriate policies for good agricultural and post-harvest practices, such as the use of ethylene synthesis inhibitors or absorbents to reduce the ripening speed in fruits or the use of packaging for reducing fruit and vegetable wastes in the storage, distribution and supply stages. In addition, to prevent the environmental problems, it is necessary to implement more accurate management principles for waste disposal.

AUTHOR CONTRIBUTIONS

B. Parsafar performed the data gathering, data analysis and preparing the manuscript. M. Ahmadi supervised the design of the study, its reviewing and editing. Gh.J. Jahed Khahiki, the corresponding author, contributed by supervising the design of the study and the original draft, rendered data analysis, interpreted the results, performed writing, reviewing and editing of the manuscript. N. Shariatifar participated in the design of the study, reviewing and editing. A. Rahimi Foroushani contributed to the methodology, and software and data analysis.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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PUBLISHER'S NOTE

ABBREVIATIONS

%	Percent
ANOVA	Analysis of variance
°C	Degree Celsius
*DHS*E	Department of health, safety, and environment
FAO	Food and Agriculture Organization
Fig.	Figure
FVFTM	Fruit and Vegetable Fields of Tehran Municipality
KG	Kilogram
MG	*Methane gas*
RH	Relative humidity
SPSS	Statistical package for the social sciences
t	Ton
USD	United States Dollar

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