

Pistachio Wastes in Iran and the Potential to Recapture them in Value Chain

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Information	Abstract
<p>Article Type: Review Article</p>	<p>Introduction: Evaluation of pistachio wastes is of great importance. In addition to the importance of different organs of various species from edible to medical and industrial points of view, scientists have always been interested in knowing their properties.</p> <p>Materials and Methods: Pistachio wastes are created in different stages of planting, harvesting and post-harvesting, which increase the grower's costs and decrease efficiency. In this study, the amount of waste in the pistachio production chain and the recapturing of wastes in value chain will be discussed.</p> <p>Results: It is proposed that governmental and private sectors codify a new program for using pistachio wastes in the industry by supporting new technology in preparing the processing unit to convert pistachio wastes to valuable materials. Therefore, using this technology, the growers' economy will improve and, of course, the environment would be safe for production of pistachio nuts.</p> <p>Conclusion: Recapturing of pistachio waste can be useful in reprocessing industries, the production of pickles and jams from pistachio hulls, pistachio oil from kernel waste, tar and activated carbon from shell in more economical process, the use of waste as a substrate for production of edible mushrooms and using the pistachio processing waste as food for animals, poultry and fish.</p>
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1- Introduction

Pistachio (*Pistacia vera*) originated from Central Asia. The domestication occurred less than 2000 years ago and traders introduced it throughout the Middle East and the Mediterranean area. Today, the major production areas are located in the Middle East, North America and Europe. Iran is the world's largest pistachio producer and its production accounts for 44% of the whole world production [1].

With an estimated 459000 hectares of pistachio cultivation and an average annual production of about 240000 tons of dried pistachio, pistachio is one of the major horticultural products in Iran. In 2013, Iran produced about 230000 tons of pistachio nuts, valued about 1200 million dollars [1].

Pistachio production plays a central role in the economy of pistachio-producing provinces. In these regions, the income of many Iranian families depends directly or indirectly on pistachio production [1].

Pistachio is also one of the most important agricultural products of Iran. With regard to its cultivation, evaluation of its production wastes would be important. In addition to the importance of different organs of various species from edible to medical and industrial points of view, scientists have always been interested in knowing their properties [2].

Pistachio wastes are produced in different steps of planting, harvesting and post-harvesting, which increase the grower's costs and decrease efficiency. There is an inverse relationship between the amount of wastes with the grower's experiences and the acreage.

Regarding the type and amount of wastes, the greatest amount of waste produced in the orchard is due to climatic factors and pests. The rest of waste is produced during processing and grading as a result of using traditional grading and processing machines, which is the highest percentage of waste in the pistachio production chain.

Of course, other factors such as frost damage and heat stress damage, storage conditions, water stress and type of cultivars are also involved in the amount of pistachio waste during the production chain. Results of studies show that 27.7 percent of pistachio waste is caused by climatic factors, and 24.7 percent is caused by different pests during the pistachio production chain [3].

In this paper, the amount of waste in the pistachio production chain and the recapturing of waste in the value chain will be discussed.

1.1. Nutritional benefits of pistachio

Like many other nuts, pistachio is a highly nutritive fruit with approximately 50% fat, 23% proteins and 13% carbohydrates. Close to 90 percent of the fat is of unsaturated type: oleic acid, a monounsaturated fat, and linoleic acid, which is an essential fatty acid [4, 5].

Pistachio nuts are also an important source of fiber, minerals (copper, manganese, potassium, phosphorus and iron) and vitamins (vitamin B6, thiamin and, in lesser amounts, other B vitamins such as folate, biotin, riboflavin, niacin, and pantothenic acid). They are also rich in phytosterols, or plant sterols, which are believed to block the absorption of cholesterol from food [4, 5].

In recent years, scientists have found that pistachio nuts are rich in antioxidants and can

increase the level of serum antioxidant. This can have positive effects in lowering the oxidized low density lipoprotein (LDL) and reduce the risk of cardiovascular diseases [4, 5]. Other positive effects associated with pistachios are lubrication of the human intestinal tract.

2. Agricultural wastes in Iran

In the years 2012– 2013, almost 75.4 million tons of crops have been harvested from arable land in Iran, from which 22.2 million tons were grain (wheat, barley, corn), 716,000 tons legumes (peas, beans, lentils, etc.), 10.4 million tons industrial products (cotton, tobacco, sugar beets, oilseeds and sugarcane), 15.8 million tons vegetables (potatoes, onions, tomatoes, etc.), about 8.2 million tons melon, watermelon, and cucumber and 17.9 million tons were forage plants group (alfalfa and other forage plants) [6, 7- 8]. According to the available statistics in Iran, almost half of all the agricultural products are destroyed in different stage without being consumed [7,8, 10, 11]. The factors leading to postharvest losses include biological factors(respiration rate and changes in composition, ethylene production rate, mechanical damage, water stress, germination, physiological disorder and pathogen agents), environmental factors (temperature, relative humidity, air speed and the composition of the atmosphere) and economic and social factors (inadequate marketing systems and transportation facilities), the unavailability of equipment and required tools, etc. [2, 12, 13]. Through recycling, re-processing and optimal usage of agricultural wastes, they can be used in an effective way. Most agricultural wastes have

useful applications in building materials, livestock feed, fuel, paper, lumber, chemicals, composting and mulching, pharmaceuticals and soon. For example, some wastes such as rice husks, peanut shells, cotton stalks, vegetable wastes that are burned using a dry method (burning in the presence of high air and complete combustion) could be used as fuel for motors. In other methods, agricultural wastes could be converted to charcoal in the absence of oxygen and using dry heat, which is a common industry in developing countries [2, 13].

2.1. Pistachio waste in Iran

Since pistachio is also one of the most important agricultural products of Iran with regard to its cultivation area, the evaluation of its production wastes is of great importance. In addition to the importance of different organs of various species from edible to medical and industrial points of view, scientists have always been interested in knowing their properties [2].

Pistachio wastes are produced in different stages of planting, harvesting and post-harvesting, which increase the grower's costs and decrease efficiency. The amount of waste has an inverse relationship with the grower's experiences and the acreage. Regarding the type and amount of waste, most of the waste produced in the orchard is due to climatic factors and pests. The rest of the waste is produced during processing and grading as a result of using traditional grading and processing machines, which is the highest percentage of waste in the pistachio production chain. Of course, other factors such as frost damage and heat stress damage, storage conditions, water stress and type of

cultivars are also involved in the amount of pistachio wastes during the production chain. The results of studies show that 27.7 percent of pistachio wastes are caused by climatic factors and 24.7 percent of wastes are caused by different pests during the pistachio production chain [2].

The main pistachio waste materials produced during the peeling (dehulling) stage include hulls (the soft skin of fresh pistachio), clusters and leaves. The collection of these materials is also called the residue of the process of peeling fresh pistachio, pistachio waste or pistachio side products [2].

This material has a corruptible nature in a way that after a few days (sometimes 1-2 days) it gets black, rotten and moldy (Fig 1-5). The influx of annoying insects around them can be seen as a result of extensive environmental pollution pose (Fig 1-5).



Fig. 1- Traditional hulling machine and pistachio waste beside a village



Fig. 2- Traditional hulling machine and pistachio waste beside a street



Fig. 3- contaminated and moldy waste beside a pistachio orchard



Fig. 4- Pistachio waste beside an orchard



Fig. 5- The pistachio waste and other waste in residential areas

In addition, this waste material could serve as a suitable medium for overwintering spores of *Aspergillus sp.*, which increase the distribution of aflatoxin in the pistachio orchard. Unfortunately, some growers use these wastes as fertilizer, which absolutely increases the amount of aflatoxin contamination in the pistachio production chain. Spores of *Aspergillus sp.* easily move through the movement of air (wind), so the accumulation of this material around the pistachio orchards or pistachio processing factories have similar effects of inserting the

material into the orchard. Besides these, it should be noted that, as a result of the costs of taking these materials to and removing them of pistachio processing factories in the present situation, their economic situation is not satisfactory because of notable initial investment in processing units and limited economic performance during the year [2, 14].

Experience has shown that 1 kg of dried nuts will be produced from 3 kg of pistachio nuts which enter the processing units from the orchard, The other 2kg remained in the processing units are pistachio waste. Since almost 75% of these wastes are water, about 660g of pure dry materials could be obtained from this waste. As a result, about 66% of dried pistachio production will be in the form of dried pistachio wastes. Therefore, it can be assumed that, given the annual production of 250 thousand tons of pistachio, 132 to 165 tons of pistachio waste will be produced

annually [2].

2.1.1. Physical and chemical composition of pistachio nut waste

Soft skin (hull) is the dominant component in pistachio wastes in the processing unit and accounts for about 53 to 81% of the total wastes. Pistachio clusters as a component of the roughage and bad food account for about 10 to 30% of waste. The leaves of pistachio usually make up less than 10% of waste. Pistachio Shell and kernel from the lowest amount of pistachio wastes (less than 0.5% and a maximum of 5%) (Table 1).

Measurement of the chemical composition of pistachio wastes showed pistachio hull had not able ash (12 to 14% of dry matter). Pistachio kernel and pistachio shell showed the highest and lowest crude fat, with 48% and 0.3% of dry matter, respectively. Crude protein was the highest in kernel and the lowest in the shell (Table 1).

Table 1- Nutrient composition in different parts of pistachio

Pistachio waste parts	Ash%	Crude fat%	Crude protein%	Total soluble phenolic%	Tannin%	NDF%	ADF% ^{**}
Total pistachio waste (hull, cluster, leaves and etc.)	9.1	8.7	14.2	8.6	4.1	25.5	25.5
Hull	12.7	5.7	16.6	9.6	4.5	25	20
Cluster woody part	5.6	7.1	12.1	10	4.8	ND ^{***}	ND
Leaves	9.2	3.8	12.4	13.9	6.9	ND	ND
Kernel	2.8	48	24.5	1.2	0.3	ND	ND
Shell	0.9	0.3	1.6	1.5	0.5	ND	ND

*Neutral Detergent Fiber

** Acid Detergent Fiber

*** Not Determined

2.1.2. Different kinds of pistachio waste

2.1.2.1. Hull

One of the major pistachio wastes is the hull (a green skin on fresh pistachio which is removed), but much of it remains without any usage. This skin has a fibrous structure and it is made up of water, protein, fat, minerals, vitamins, colorants and terpenes material. Pistachio hull has 32.64% dry matter, 11.24% crude protein, 15.38% crude fiber, 12.13% ash, 5.79% fat, 55.46% nitrogen free extract (NFE), 4425.45 kcal energy, 2.3-4.5% tannin, 1.08% calcium, 0.11% phosphors, 0.31% of magnesium, 4.44% potassium, 660.68ppm Iron, 23.6ppm manganese, 13.23ppm copper and 27.5ppm [15, 16, 17].

2.1.2.1.1. Application

- 1) Essential oil production
- 2) Antioxidant production
- 3) Anti-fungal and anti-microbial products.

2.1.2.2. Essential oil production

Pistachio hulls have essential oil as they contain fragrance. Studies have shown that 11% of pistachio hulls is essential oil. The essential oil includes α -pinene, camphene, β -pinene, 3-carene, p-cymene limonene, Terpinolene, p-cymene-8-ol, α -Terpineol, and Barnyl-acetate. Each component has several considerable properties [18, 19].

2.1.2.3. Antioxidants production

Hull could also be a source of natural antioxidants. Antioxidants could be use as an additive to prevent lipid oxidation. Although synthetic antioxidants are usually used for this purpose, since this type of antioxidant has undesirable effects such as mutagenic and carcinogenic effects in the human body, they are gradually omitted from the list of antioxidants. As a result of this, preparation and production of natural antioxidants as an alternative is necessary. Due to it phenolic

compounds, the hull can be used as a natural antioxidant. In a study, the effect of hull extract on delaying the oxidation of soybean oil was evaluated, and the results showed that the hull extract with a content of 7.8% phenolic component at a concentration of 0.06% had the same effects as synthetic antioxidants. So, different concentrations of phenolic compounds in the pistachio hull can consider ably slowdown oxidation [16, 19].

2.1.2.4. Anti-fungal and anti-microbial material production

Research has shown that pistachio leaves and hull extracts have positive anti-bacterial properties. The antibacterial activity of the hull is more than the leaves. These effects of the leaves and the hull extracts are due to tannins, which are phenolic compounds and a group of anti-microbial substances. Also, due to antioxidant effects, tannins protects plants against insects and fungi. The strong colors of the tannin compounds with iron can be used in the preparation of ink types in commercial quantities, too [19].

The effects of hull on reducing aflatoxin contamination was studied, and the results showed that it partially destroys toxin production and can reduce fungal growth and development. The spores of this fungus cannot grow on pistachio intact hull [19].

2.1.2.5. Using pistachio hull in the preparation of jams and marmalades

Preparation of jams and marmalades from pistachio hull is traditionally done manually at homes with high utility. The production method and procedures can be performed in a completely hygienic and industrial way.

2.1.2.6. Pistachio hull in pickle preparation

Like in making jam, intact and non damage

hull can be sorted after dehulling and be industrially used to produce pickles.

2.1.2.7. Use pistachios hull for dyeing

Today, natural colorants are emerging globally due to the fact that they are safe and environment-friendly and thus the application of natural dyes should be considered as a better alternative to synthetic ones. Using natural dyes contributes to the added value of textiles and also responds to the increasing demand for compatibility with the environment. In a study, pistachio hull was evaluated for wool dyeing, and pistachio hulls were found to have good agronomic potential as a natural dye in Iran. Metal mordants, when used in conjunction with pistachio hulls, were found to enhance the dye ability and its fastness properties. The stepwise process of dyeing with pre-mordanting showed energy and time saving and also high dye retention. Therefore, this natural dye has good scope in the commercial dyeing of wool yarns used as Persian carpet piles [20].

2.1.2.8. The use of pistachio waste (hulls) as the substrate for mushroom production

Hull can be used as a substrate for mushroom production. Studies have indicated good performance of mushroom production using waste as [20].

2.1.2.9. Using pistachio waste (especially hulls) as an animal fee

Using pistachio wastes (especially hulls) as an animal food not only eliminates feed shortage in some countries but also reduces the risk of environmental pollution. Pistachio hulls are potentially suitable for use in ruminant nutrition, and sun-dried hulls have traditionally been fed to ruminant animals

[15, 19]. Their chemical composition, phenolic compounds and digestibility depend not only on the cultivar and kernel maturity but also on the de-hulling and drying processes [15, 19]. However, certain anti-nutritional factors such as phenolic compounds (5.6% to 15.2% DM basis) may reduce their nutrient availability [15, 16, 22]. Animal assays with (dried or ensiled) pistachio waste are limited. It was reported that pistachio by-product silage (PBPS) with or without additives had no effects on dry matter intake (DMI) and nutrient digestibility of dairy cows during a 21-day experiment. The particle size of PBPS is different from that of corn silage because the by-product has about 25% pistachio clusters [19, 22] that are not chopped before ensiling.

Although the storage silos of pistachio residues could be used, they are costly and somewhat impractical due to their limited transferability. Green hulls have high Moisture Content (MC) and the best place and time of drying is at the processing terminals right after hulling [3]. Industrial drying using indirect heating is another practical and economical method. Moreover, developing such drying equipment for pistachio processing byproducts may prevent the spread of aflatoxin and the contamination of pistachio.

2.1.2.10. The use of pistachio wastes (hulls) in oil production

Small pistachios, stained nuts, pest-ridden, the bird-damaged pistachios and pistachios in the sample for aflatoxin testing are considered to be kernel wastes. Just with 200,000 tons of pistachio export, about 240,000 kg of wastes will be used as samples for aflatoxin testing, which has at least 50% of

oil recovery. So, each year at least 120,000 kg of pistachio oil can be obtained. Of course, using proper equipment and industrial units will increase the efficiency of oil extraction.

Side products of oil processing units are called pistachio kernel meal that have a large amount of protein. If process properly, it can be use as a significant part of the livestock of poultry diet for protein and some essential amino acids [19].

2.1.2.11. Using pistachio wastes to produce fertilizer and compost

Considering the highly organic matter and the nutrimental contents, pistachio wastes could be excellent soil additives that will promote C sequestration and nutrient recycling. It is remarkable that nearly 75% of soil in Iran is poor in organic matter content and needs nutrient recycling for agriculture. However, the high content of polyphenols, nitrates, chlorides and sodium of pistachio wastes could cause adverse effects on soil and water and thus restricts their utilization without pretreatment (e.g. composting). The development of specific guidelines that consider other parameters such as soil properties and cultivation needs will promote sustainable management of this type of waste.

Interestingly, pistachio wastes can increase soil cation exchange capacity (CEC). In a study, the effect of pistachio wastes on chemical soil fertility characteristics was evaluated, and it was found that pistachio wastes increased CEC and nitrogen, phosphorus and potassium in the soil [15, 19].

Composts produced by mixing pistachio wastes and other raw materials such as manures and straw are characterized by very good properties as regards their nutritional

status and organic matter content. From this point of view, these materials could be excellent soil additives. However, their very high electrical conductivity and also the sodium concentration set some limitations to their use. The addition of 5% clinoptilolite in the compostable mixture results in the production of a high quality compost with low electrical conductivity (i.e. 2.6 mS/cm).

2.1.2.12. The production of biogas

Limitation of fossil resources, their non-renewability, increasing petroleum fuel prices, emissions from combustion of fossil fuels all cause energy policy makers and planners to focus on structural studies to change the energy carriers, and move towards clean fuels. One of the best options in this regard is using the energy from biomass sources such as biogas. Biogas, as one of the major sources of energy, can be used directly to provide heating and electricity energy and is a good option to be used in internal combustion generators, micro-turbines, fuel cells and other power producing facilities as well. Anaerobic digestion (AD) of organic wastes to produce methane would benefit society by providing a clean fuel from renewable feed stocks. This could substitute fossil fuel-derived energy and reduce environmental impacts, including global warming and acid rain. Some of the advantages of biogas are 1- disposal of a huge amount of organic waste and recovering energy from it, 2- national independence, 3- decreasing the odor problem, 4- economic and social development in rural areas, 5- providing new job opportunities. Biogas contains 50- 70% methane and 30- 50% carbon dioxide, as well as small amounts of other gases and typically has a calorific value of 21- 24 MJ/m³. Studies have shown that an average of 450 m³ of biogas is produced from each ton of waste, so about 61 million m³ of

biogas will be generated from pistachio wastes [24].

2.1.2.13. Furfural production

Agricultural and forest wastes as renewable energy sources can be used in the production of many chemical materials such as furfural, ethanol and acetic acid. Furfural, which is one of the most important and most commonly used organic solvents, is produced from agricultural wastes, and one million tons is produced in the world every year. One of the important uses of furfural is for extraction solvent used as the base of oil production factories. There are a number of oil factories in Iran that are estimated to use about 3,000 tons of furfural, which is currently wholly funded from abroad. Statistical studies show that the primary source of furfural production in Iran is more than needed in all industries. It seems that a good investment will satisfy the needs of the domestic market and provide export and other uses of furfural as well [24].

2.1.3. Shell

The content of some of the pistachio shell components are showed in Table 2:

Table 2: The contents of pistachio shell components

Element	Content
Nitrogen (%)	0.12
Phosphorus (%)	0.0125
Potassium (%)	0.53
Calcium (%)	0.024
Magnesium (%)	0.033
Sodium (%)	0.014
Iron (ppm)	16
Manganese (ppm)	2.15
Zinc (ppm)	5.4
Copper (ppm)	1

2.1.3.1. Application:

2.1.3.1.1. Production of tar

2.1.3.1.2. Production of activated carbon

After the consumption of pistachio, a large amount of shell is produced, which is wasted as garbage in all part of the country. Therefore, it is better to recapture it as a good resource. Instead of burring or disposing, it can be used to perform pyrolysis processing. By designing and constructing industry and refinery units, we can acquire high value material. Pyrolysis is thermo-chemical decomposition of organic material at elevated temperatures in the absence of oxygen (or any halogen). It involves the simultaneous change of chemical composition and physical phase, and is also irreversible. The word of pyrolysis is coined from the Greek-derived elements pyro «fire» and lysis «separating».

Pyrolysis is a type of the rmolysis, and is most commonly observed inorganic materials exposed to high temperatures. It is one of the processes involved in charring wood, starting at 200–300°C (390–570°F). It also occurs in fires where solid fuels are burning or when vegetation comes into contact with lava in volcanic eruptions.

Some advantages of pistachio shell pyrolysing include:

- 1) Prevention of air and environment pollution
- 2) Economic savings for the country by reducing imports
- 3) Replace wood or coal tar preparation
- 4) Using extraction of active ingredients in the pharmaceutical industry, etc.

Some materials which are obtained from pistachio shell pyrolysing:

- 1) Gas, which contains hydrogen, methane, carbon dioxide and small amounts of other gases.

2) Acid (Pyro Ligneous) in liquid form, which contains methanol, acetic acid and acetone.

3) Tar, which is rich in phenolic substances.

4) Charcoal, which contains carbon and mineral ash wood.

2.1.3.1.3. Tar production:

The most important and most valuable product derived from pistachio shell pyrolysis is tar. On average, from every 100 grams of shelled pistachios, about 15-20 ml tar is obtained. Tar is a viscous liquid with a pungent odor, which includes a variety of different chemical compounds which can also be obtained from coal and wood pyrolysis. Due to the high degree of food grade index, pistachio shell tar has a higher price than wood tar from the perspective of economic value. Tar has many uses in the pharmaceutical industry. For example, anthrax tablets with the highest consumption as an anti-flatulence group in humans are derived from coke of hard pistachio shells.

2.1.3.1.4. The production of activated carbon

At the end of pistachio shell pyrolysis, some coal remains which can be used to produce activated carbon. The activated carbon has many critical applications. Many toxic gases can be separated from the air passing through activated carbon. For example, carbon monoxide is one of the gases that can be separated from the air by injecting a series of chemicals (silver, copper and chromium) to the active carbon. In general, it can be said that activated carbon can be used as a filtering agent in oil refining and beverage industries [25].

3. Conclusion

It is proposed that governmental and private sectors codify a new program for using pistachio wastes in the industry by supporting new technology in preparing processing units to convert pistachio waste to valuable materials. Using these technology, growers' economy will improve and, more important than that, the environment would be safe for the production of pistachio nut. The main task of this industry is to do the most effective processing for pistachio wastes and to convert them to more and more valuable goods. For this purpose, firstly it must decrease the moisture content of pistachio wastes to improve the durability and reduce environmental pollution.

The most important investment options can be used to recapture pistachio wastes to valuable products including the following:

- To be used in reprocessing industries.
- The production of pickles and jams from pistachio hulls, pistachio oil from kernel waste, tar and activated carbon from shell in a more economical way, and it is recommended in Kerman province as most of pistachio waste is produced in this province.
- The use of waste as a substrate for the production of edible mushrooms.
- Using the pistachio processing waste as animal, poultry and fish food.

Conflict of interest

The authors declare no conflict of interest.

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