Strawberry post-harvest energy losses in Iran

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Abstract: The aim of this study was to estimate the amount of energy losses caused by post-harvest strawberry losses in the Kurdistan province of Iran. Preserving the shelf life and quality of fresh fruits and vegetables, necessitates reducing respiration rates and protecting these fresh produce items from postharvest infection by moulds and microorganisms. This can be accomplished in most cases through storage at reduced temperatures and through modified atmosphere storage. The most common decay of strawberry is *Botrytis* rot, also called Gray Mold, caused by *Botrytis cinerea*. The disease can begin pre-harvest, remaining as latent infections, or begin postharvest. The total strawberry production was about 22,679 ton in Kurdistan province. The average strawberry post-harvest losses were found to be 28% in the study area, thus the total post-harvest strawberry losses were estimated as 6350.12 ton. The total energy losses of strawberry production in Kurdistan province were evaluated to be 12.065 TJ. This amount of losses is equal to 1971.4 BOE (Barrel of Oil Equivalent). Also the total post-harvest strawberry losses were equal to 7,809,200 $. The amount of losses could be reduced by using controlled atmosphere storage technology and by improving the quality of inputs, cultural practices, harvest operation methods, packing and packaging, sorting, transport, and storage. Also the amount of post-harvest losses could be reduced by using the breeding varieties instead of landrace variety, because the landrace variety has a very soft tissue and it is tremendously sensitive to mechanical injury. Biological control of post-harvest disease might be effective. Perhaps the antagonists could be used at harvest to prolong the shipping and marketing periods. The *Botrytis* responsible for pre-harvest and post-harvest rotting of strawberries could be reduced by spraying with *Trichoderma* species. Additional studies are needed in this context to survey the biological control. [Researcher 2010;2(4):67-73]. (ISSN: 1553-9865).

Keywords: *Botrytis cinerea*; energy losses; Kurdistan; Iran; Post-harvest losses; *Rhizopus stolonifer*; Strawberry

1. Introduction

Post-harvest diseases of fruits and vegetables are a major expense in food production. Losses are difficult to estimate reliably, but according to a 1965 U.S. Department of Agriculture survey, post-harvest losses in fruits, nuts, and vegetables amounted to about 23% of the harvested crop. Losses in developing countries run even higher because of poor Storage and food-handling technologies. Post-harvest losses in tropical Africa and in India have been put at 30% (Wilson and Pusey, 1985). Estimates of post-harvest crop losses worldwide have also been given as 10-20% but 25-40% for the tropics by other researchers (Ogunleye and Adefemi, 2007). Some estimates suggest that about 30-40% of fruit and vegetables are lost or abandoned after leaving the farm gate. Obviously, post-harvest management determines food quality and safety, competitiveness in the market, and the profits earned by producers. The post-harvest management of fruit and vegetables in most developing countries in the region is, however, far from satisfactory. The major constraints include inefficient handling and transportation; poor technologies for storage, processing, and packaging; involvement of too many diverse actors; and poor infrastructure (Rosa, 2006).

Small-scale farmers in developing countries are faced with many problems and constraints. Pre- and post-harvest crop losses due to insects, diseases, weeds, and droughts result in low and fluctuating yields, as well as risks and fluctuations in incomes and food availability (Tonukari and Omotor, 2010).

Strawberries are highly perishable fruits due to their extreme tenderness, vulnerability to mechanical damage, high level of respiration and their susceptibility to fungal spoilage (Maxie et al, 1959; Dennis, 1978). Fresh strawberries, therefore, have a very limited post-harvest life and cannot be stored except briefly (Dennis and Mountford, 1975).

Post-harvest losses are typically more severe, especially when conditions are favorable for disease development; in some cases 80-85% of a crop may be lost (Hong *et al*. 1998; Larena *et al.* 2005). Grey mould, caused by *Botrytis cinerea* Pers. (ex Fr.), is the most severe post-harvest disease of strawberries. An important role in the development of the disease playing the infections contracted during flowering, that remain quiescent and then develop at harvest and during storage (Bristow *et al.*, 1986); furthermore, consideration must be given to infections caused by lesions incurred during harvesting and due to external contamination with pathogens such as *Rhizopus stolonifer*. Figure 1 shows the examples of infected strawberries to *Botrytis cinerea*.

Figure 1. The examples of infected strawberries caused by *Botrytis cinerea*

Disease is the greatest cause of post-harvest loss. The most common decay is *Botrytis* rot, also called Gray Mold, caused by *Botrytis cinerea* (Ceponis *et al.*, 1987). The disease can begin pre-harvest, remaining as latent infections, or begin post-harvest. This fungus continues to grow at 0 °C (32 °F). However, growth is slow at this temperature. Rhizopus rot caused by *Rhizopus stolonifer* is another important disease of strawberry. This fungus cannot grow at temperatures below 5 °C (41 °F). Post-harvest fungicides are not used on strawberries; therefore, prompt cooling, storage at 0 °C (32 °F), preventing injury, and shipment at 0 °C (32 °F) under high CO_2 are the best methods for disease control. Damaged fruit should be eliminated from baskets to prevent spread of disease to healthy berries (nesting) (Sommer *et al.*, 1973).

The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio‐energy. At present productivity and profitability of agriculture depend on energy consumption (Salami *et al.*, 2010).

In developing countries like Iran, agricultural growth is essential for fostering the economic development and meeting the ever-higher demands of the growing population. Energy in agriculture is important in terms of crop production and agro processing for value adding (Salami *et al.*, 2009).

A high quality strawberry fruit will be uniformly red in color, firm, flavorful, and free of defects and disease. Sugar content does not increase after harvest; therefore, harvest fully-ripe for best flavor (Kader, 1999).

The amount of energy used in agricultural production, processing, and distribution is significantly high. Sufficient supply of the right amount of energy and its effective and efficient use are necessary for an improved agricultural production (Mohammadi and Omid, 2010).

Life is a continuous process of energy conversion and transformation. The accomplishment of civilization has largely been accomplished due to the increasing efficient and extensive harnessing of various forms of energy to extend human capabilities and ingenuity. Energy is thus one of the indispensable factors for continuous development and economic growth (Mohamed *et al.*, 2006).

The aim of this research was to evaluate the amount of energy losses caused by post-harvest strawberry losses in the Kurdistan province of Iran.

2. Materials and methods

The amounts of strawberry losses were calculated per kilogram and then, these data were multiplied with the coefficient of energy equivalent. Energy equivalent of strawberry is equal to 1.9 MJ kg^{-1} (Singh and Mittal, 1992).

Post-harvest losses are caused by both external and internal factors (Rosa, 2006). In this study all kind of the post-harvest losses has been considered. They are mentioned below.

External Factors Which Lead to Post-harvest Losses

Mechanical Injury: Fresh fruits and vegetables are highly susceptible to mechanical injury owing to their tender texture and high moisture content. Poor handling, unsuitable packaging and improper packing during transportation are the cause of bruising, cutting, breaking, impact wounding, and other forms of injury in fresh fruits and vegetables.

Parasitic Diseases: The invasion of fruits and vegetables by fungi, bacteria, insects and other organisms, is a major cause of post-harvest losses in fruits and vegetables. Microorganisms readily attack fresh produce and spread rapidly, owing to the lack of natural defense mechanisms in the tissues of fresh produce, and the abundance of nutrients and moisture which supports their growth. Control of post-harvest decay is increasingly becoming a difficult task, since the number of pesticides available is rapidly declining as consumer concern for food safety is increasing.

Internal Factors

Physiological Deterioration: Fruit and vegetable tissues are still alive after harvest, and continue their physiological activity. Physiological disorders occur as a result of mineral deficiency, low or high temperature injury, or undesirable environmental conditions, such as high humidity. Physiological deterioration can also occur spontaneously owing to enzymatic activity, leading to overripeness and senescence, a simple aging phenomenon.

Location of the study: This study was conducted in Kurdistan province of Iran. The province is located in the west of Iran, within 34° 44´–36° 30´ north latitude and 45° 31´–48° 16´ east longitude. The total area of the Kurdistan province is 2,820,300 ha. The average rainfall of the province is 450 millimeters (Salami *et al.*, 2009)

Strawberry Production Statistics: The total land area cultivated for strawberry crop was 3800 ha in Iran and this amount was 2500 ha in Kurdistan province in 2007. In this year, the total production of strawberry was 38,500 tones, while this amount was 30,951 tones in Kurdistan province, thus about 80% of total strawberry production in Iran was obtained from Kurdistan province (FAO, 2007; Ministry of Jihad-e-Agriculture of Iran, 2007).

3. Results and discussion

The average strawberry post-harvest losses were found to be 28% in the study area. The average annual yield of strawberry farms was 9071.6 kg ha^{-1} in this study. As the total land area cultivated for strawberry crop was 2500 ha in Kurdistan province, so the total strawberry production is about 22,679 ton; thus the total post-harvest strawberry losses in Kurdistan province are evaluated as 6350.12 ton. The energy equivalent of strawberry is equal to 1.9 MJ kg^{-1}, thus the total energy losses of strawberry production in Kurdistan province are estimated to be 12.065 TJ. This amount of losses is equal to 1971.4 BOE (Barrel of Oil Equivalent). Also the total post-harvest strawberry losses are equal to 7,809,200 $.

Rosa surveyed the post-harvest losses in the Asia-Pacific Region. She notified the amount of the post-harvest losses in India, Indonesia, Iran, Korea, Philippines, Sri Lanka, Thailand, and Vietnam as 40%, 20-50%, >35%, 20-50%, 27-42%, 16-41%, 17-35%, and 20-25%, respectively (Rosa, 2006).

Gell *et al.* determined the relationship between the incidence of latent infection of fruit and that of post-harvest fruit rot. Under the conditions of that study, a 5 – 10% average incidence of latent infection during the blossom to pre-harvest periods may lead to more than 16 – 33% of post-harvest brown rot. This is not an acceptable level for post-harvest disease incidence in commercial peaches. The results demonstrate that latent infection should be taken into consideration in disease management programs in Spain. Although brown rot may not be severe at harvest, it could develop later because of the high incidence of latent infection (Gell *et al.*, 2008). Post-harvest yield losses amounted on average 1.5–2.0% in apple caused by *Monilinia fructigena* (Van Leeuwen *et al.*, 2000).

Haydu and Legard evaluated the effect of pre-harvest fungicide applications to control post-harvest *Botrytis* fruit rot in annual strawberries in Florida. They mentioned that fungicide treatments reduced the incidence of pre-harvest *Botrytis* fruit rot and increased marketable yield. Marketable yield data were then used to extrapolate production into net economic returns per hectare. The study concluded that, at roughly $1000 per season, fungicide treatments represent a minor proportion of total costs, yet have large impacts on strawberry production profits (Haydu and Legard, 2003).

The post-harvest losses of strawberry are much more than pre-harvest losses. As it illustrated, some researchers have studied that the latent rot could develop after harvest and cause severe damage to the crop, thus preventive methods should be applied to control the losses.

Poor quality production and high levels of post-harvest losses occur primarily due to the use of poor quality inputs, poor cultural practices at the production level, lack of knowledge and skill in harvesting, postharvest handling, packing and packaging, inadequacies in basic and postharvest specific infrastructure in terms of pre-cooling facilities, transport, storage and marketing, lack of processing facilities, high transportation costs, poor integration of activities along the chain and complex marketing channels. The situation is further aggravated by the warm humid climates (Rosa, 2006).

Fruits and vegetable were generally transported using vans, and trucks. Mechanical injury during transportation often leads to considerable quality loss. Transportation is a major bottleneck in the marketing chain for fruits and vegetables.

Since strawberries are very perishable fruit, the presence of cooling facilities in wholesale, retail and consumer markets are highly recommended for keeping quality and reducing the remarkable post-harvest losses in such delicate fruit.

The amount of post-harvest losses could be reduced by observing these instances: Improving the quality of inputs, cultural practices, harvest operation methods, packing and packaging, sorting, transport, and storage. Also the amount of post-harvest losses could be reduced by using the breeding varieties instead of landrace variety, because the landrace variety has a very soft tissue and it is tremendously sensitive to mechanical injury. Mechanical injury expands the fungi infection and provides a suitable environment for fungi expansion, thus to reduce strawberry post-harvest losses due to mechanical injury, it's better to cultivate the breeding varieties.

Strawberries are extremely perishable, and it is important to begin cooling within 1 h of harvest to avoid loss of quality and reduction in amount of marketable fruit (Maxie *et al.*, 1959). Temperature management is the single most important factor in minimizing strawberry deterioration and maximizing postharvest life. Forced-air cooling is highly recommended, although room-cooling is used in some cases (Mitchell *et al.*, 1996).

Perhaps because of rapid marketing and very short storage, few physiological disorders occur after harvest. CO_2 injury, particularly when > 15% CO_2 is used, is manifested as a bluing of the skin (Ke *et al.*, 1991), whitening of inner fruit tissues (Gil *et al.*, 1997), and fermentative off-flavors. Shipment with 10 to 15% CO_2 reduces growth of *Botrytis cinerea* (Wells and Uota, 1970) and reduces respiration rate (Li and Kader, 1989), thereby extending postharvest life.

Almenar *et al.* studied controlled atmosphere storage technology to extend the shelf life of wild strawberry fruit (*Fragaria vesca* L.). The effect of gas composition on soluble solids content, titrable acidity, pH, off-flavor, aroma volatiles, and consumer preference was monitored. Their results showed that the 10% CO_2/11% O_2 combination can efficiently prolong the shelf life of wild strawberries by maintaining the quality parameters within acceptable values, through inhibiting the development of *Botrytis cinerea*, without significantly modifying consumer acceptance (Almenar *et al.*, 2006).

In another study for determining the modified atmosphere storage technology, Riad and Brecht mentioned the following results: Strawberries are extremely perishable due to their susceptibility to decay, softening, and water loss. Rapid establishment of a modified atmosphere (MA) with elevated CO_2 is considered to be critical for long distance strawberry shipments in order to inhibit these negative changes, especially decay. After 10 days in air or MA, the strawberries appeared normal, but after an additional 12 hours at room temperature there was significant microbial growth on the air-stored fruit, which may have been due to latent infections that couldn't be expressed at 2 °C. These results indicate that 5% O_2 plus 15% CO_2, although commonly used for domestic strawberry shipments, may not be appropriate for transit times longer than 7 days. It appears that about 9 to 10% O_2 plus 10 to 11% CO_2 may be a better gas composition for transit times greater than 7 days since the strawberry respiration rate was at a minimum in that atmosphere range(Riad and Brecht, 2005).

The effect of ultraviolet-C light (U.V.-C) at low doses on postharvest decay of strawberries caused by *Botrytis cinerea* and other pathogens was investigated by Nigro *et al.* in Southern Italy. The overall results from these investigations indicated that treatment with low U.V.-C doses produced a reduction in postharvest decay of strawberries related to induced resistance mechanisms. Moreover, a germicidal effect of reducing external contaminating pathogens could not be excluded (Nigro *et al*., 2000).

Tronsmo and Dennis reduced the *Botrytis* responsible for pre-harvest and post-harvest rotting of strawberries by spraying with *Trichoderma* species. The sprays were applied at the early flower stage, then at 14-day intervals, with the final spray 14 days after the first harvest. The antagonist performed as well as dichlofluanid applied according to the same schedule. Isolates of *Trichoderma* adapted to grow at low temperatures appeared to be more effective. Perhaps the antagonists could be used at harvest to prolong the shipping and marketing periods (Tronsmo and Dennis, 1983).

4. Conclusions

In this study the amount of energy losses caused by post-harvest strawberry losses in the Kurdistan province of Iran was surveyed. The average annual yield of strawberry farms was 9071.6 kg ha^{-1} in the study area. The total land area cultivated for strawberry crop was 2500 ha in Kurdistan province, thus the total strawberry production was about 22,679 ton. The average strawberry post-harvest losses were found to be 28% in the study area, thus the total post-harvest strawberry losses were found to be 6350.12 ton in Kurdistan province. The energy equivalent of strawberry is equal to 1.9 MJ kg^{-1}, thus the total energy losses of strawberry production in Kurdistan province were found to be 12.065 TJ. This amount of losses is equal to 1971.4 BOE (Barrel of Oil Equivalent). Also the total post-harvest strawberry losses were equal to 7,809,200 $.

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