Design of a wind tunnel for separating flower parts of saffron

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ABSTRACT

The separation possibility of stigma from the other parts of saffron flower using its aerodynamic properties was studied and a vertical wind tunnel was designed on the basis of the obtained results. Terminal velocities of three parts of saffron flower, including petal, stigma and anther within four days after harvest were investigated. Significant difference between terminal velocity of stigma (2.4-2.8 m/s) and the other parts (1-2 m/s) of flower on the first day after harvesting, revealed that accurate separation using air stream is possible. Equal friction method was applied for design. A vertical wind tunnel applying a fan with a flow rate of 1700 m^3/h and a static pressure of 0.82 cm was designed for stigma separation of saffron flower from the other parts. The duct of introduced wind tunnel was sized equal to 40.6 × 40.6 cm for main, 40.6 × 33 and 40.6 × 18 cm for lateral branches.

KEY WORDS: *Aerodynamic properties, wind tunnel, saffron*

INTRODUCTION

Saffron (*Crocus Sativus*) is one of the most expensive edible flowers of the world. With a production of about 170 tones of dried saffron, which is approximately 81% of the world's production of saffron, Iran is considered to be the main producer of dried saffron all over the world (Ebrahimzadeh, 2006). Spain is the second producer with about only 12% of the world's saffron production. A farm of saffron needs daily and manually harvesting because every plant of saffron produces only three flowers in different height and days. There are 2170 flowers in each kilo of harvested fresh flower, and processing every 78 kilos of fresh flowers results in one kilo of dried saffron. This final product is actually the stigma part of flower (Fig. 1). The stigma, as the only economic part of flower has eatable and medicinal applications. The stigma has three branches which are connected together at the bottom. Harvest and post-harvest operations should be conducted warily to avoid any harmful effect on taste, color, and odor of stigma. The manual harvesting, including cutting and picking up the whole flower should be carried out daily before sunrise. It reduces the quality of flower in addition to moisture content which it seems that it has a significant effect on flower processing. A post-harvest operation includes stigma separation from the other parts of flower in the shortest period of time before drying up the harvested flowers. All operations are currently carried out manually.

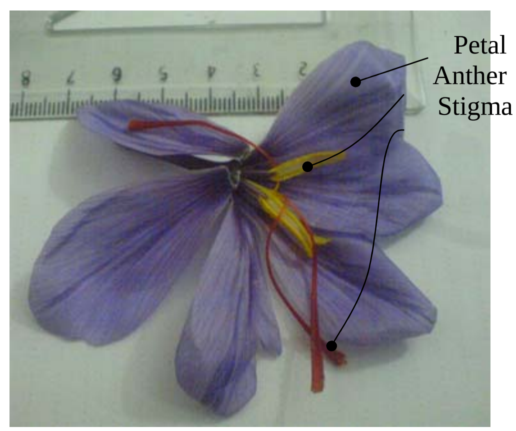

Figure 1: The image of saffron flower and its main parts

Operation mechanization of harvest and post-harvest of saffron flower

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is economically important due to time limitation, daily harvesting, and possible contamination due to manual operations. The stigma separation is one of the most laborious and expensive operations. Particle separation using aerodynamic properties have been introduced by industry in addition to many researches such as El-Sayed, Yahaya, Wacker, Kutzbach (2001). Separation is usually carried out using terminal velocity of aimed particles which is supposed to be separate from the rest of the mixture with different terminal velocities. The applied apparatus is named a vertical wind tunnel.

In the current study, the possibility of design and fabrication of a vertical wind tunnel on the basis of aerodynamic properties of saffron flower was investigated. The aim of the study was separating stigma from the other parts of flower to increase the level of mechanization and efficiency of post-harvest operations. Saffron flower was divided to the three main parts, including petal, anther and stigma.
Aerodynamic properties involving terminal velocity of different parts of flower was identified. The properties were investigated on different days after harvest because the properties of agricultural produce are moisture content dependant (Ozguven, Vursavus, 2005; Aydin, 2002; Demir, Akinci, 2004). The results showed that the separation of stigma from the other parts is definitely possible due to a significant difference of their terminal properties, especially on the first day of harvesting. Therefore, a vertical wind tunnel on the basis of obtained results was designed.

MATERIALS AND METHODS

Preparing flower parts

Saffron flowers were provided from farms around Mashhad in Khorasan Razavi province, Iran. Flowers were taken directly to the lab in the shortest period of time. They were kept in a dark store with environmental temperature and humidity during four days after harvest. The flowers were taken out daily from the store and each flower was cut from the receptacle point and divided to three parts; namely, stigma, petal and anther. The values of moisture content of flower parts in different days are shown in Table 1.

Table1. Moisture content (%) of three parts of saffron during four days from harvesting (wet basis)

	First day	Second day	Third day	Forth day
Stigma	85.2	72.6	42.1	26.6
Anther	68.6	16.6	12.6	7.4
Petal	79.1	46	17.6	11.6

Determination of aerodynamic properties

The terminal velocity of each part was experimentally measured using the floating method. This method provides blowing air in a vertical duct for produce particles to be floated. The air speed at the time of floating is measured by a digital hot wire anemometer and it is called terminal velocity. At the time of floating, the weight of particles is equal to the drag force (Mohsenin, 1986). A vertical air duct (Fig. 2) which was designed and fabricated in the Agricultural Research Center of Mashhad (Iran) was used for measuring terminal velocity of saffron flower parts. The duct can provide variable air stream with changing the frequency of electric motor supplier. A hot wire anemometer with an accuracy of 0.1 m/s was applied for experiments. The environmental temperature was 15 ºC and experiments were repeatedly conducted during four days from harvesting (four level of moisture content shown in Table 1). The experiments were carried out for three parts of saffron flower, including stigma, anther and petal and each was repeated 5 times.

Figure 2: The vertical air duct which used for measurement of terminal velocity

Wind tunnel design

Equal friction method was selected compared with the other two existing methods, including static regain and total pressure. None of these methods will automatically lead to an economical design unless a careful evaluation and balancing of all cost variables are considered. The basis of the equal friction method is to maintain the pressure loss in the entire system in order to keep it the same in all parts. The value of friction loss with knowing the velocity and flow rate in the main duct can be determined. Then the same friction loss value is used for determination of all other wind tunnel specifications throughout the design.

RESULTS AND DISCUSSIONS

The results of terminal velocity measurement for different parts of saffron flower throughout four days after harvest are shown in Fig.3. There was a significance difference among the values of terminal velocity for different parts and moisture contents. The maximum difference was on the first day of harvesting. The terminal velocity ranged from 2.4 to 2.8 m/s and between 1 and 2 m/s for stigma and other parts respectively. The results support the idea of the possibility for separating stigma from the other parts of the flower using terminal velocity. The possibility is high, especially on the first day of harvesting. It puts emphasis on the belief of traditional farmers that the first day of harvesting is the best day for stigma separation.

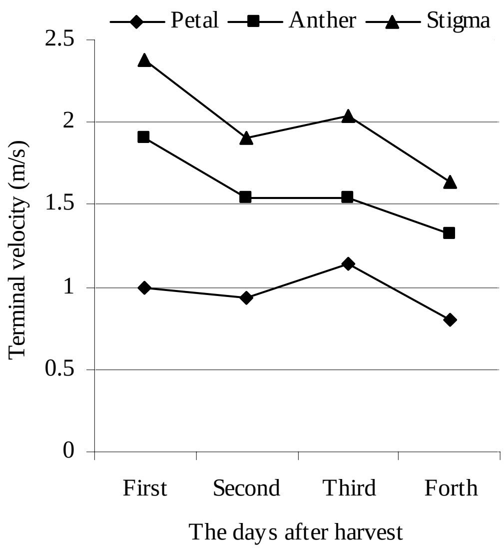

Figure 3: The terminal velocity of flower parts during four days after harvest

The design layout of the wind tunnel is shown in Fig.4. The air velocity in section A was selected 3 m/s to prevent the stigma from falling on the fan. The section B is considered for outgoing stigma with the velocity of 2.7 m/s. The other parts of the flower are planned to leave the wind tunnel from section C with the velocity of 2.1 m/s.

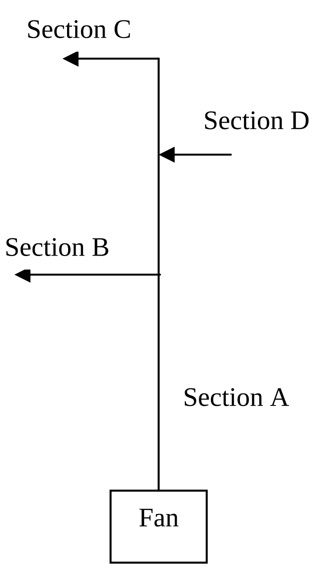

Figure 4: The layout of vertical wind tunnel

The choice of air velocities was on the basis of the results of the terminal velocity measurement to ensure that any part of flower leaves the wind tunnel in the proper way. The section D is planned for feeding flower parts to the wind tunnel with a sealed feeder. With assuming the total air flow as 1700 m^3/h and the value of air velocity in section A, the friction pressure loss was determined equal to 0.07 meter of water per 0.3 meter of pipe with a diameter of 44.7 cm (ASHRAE, 1972). The rectangular equivalents were selected to be 40.6 × 40.6 cm with the objective of having the same depth for all sections to facilitate fabrication of the wind tunnel (Table 2). Along the above friction pressure loss, all of the wind tunnel was sized and specified. The results are shown in Table 3.

Table 2. The results of tunnel sizing

Section	Flow Rate m^3/h	Velocity m/s	Duct Dia. cm	Rectangular Duct Size cm
A	1700	3	44.7	40.6 × 40.6
B	1224	2.7	40	40.6 × 33
C	476	2.1	28	40.6 × 18

Table 3. The results of friction pressure losses

Section	Friction per 0.3 m cm H_2o	Loss per Section cm H_2o
A	0.07	0.25
B	0.07	0.25
A+B+ elbow	0.07	0.80
A	0.07	0.25
C	0.07	0.35
A+C+ elbow	0.07	0.82

It is designed to fabricate the elbow in both outlets with the ratio of 1.5 (R/W) where R is the radius and W is width. The equivalent length of the elbows was also added to the total run of wind tunnel. The model of designed duct is shown in Fig.5.

The run to section C has the highest apparent resistance and it was used to calculate the static pressure of the fan. The required static pressure of the fan was obtained equal to 0.82 cm. Checking the difference of friction pressure loss between sections B and C showed that the existing difference (0.02) is within the acceptable limit of 0.05 (ASHRAE, 1972). The low difference also revealed there is no need to balance the wind tunnel using a damper.

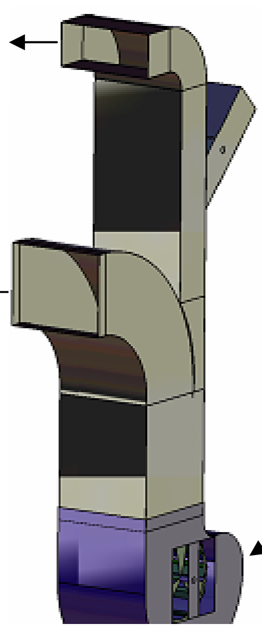

Figure 5: The model of designed vertical wind tunnel for separation stigma from the other parts of flower, inlet and outlets of materials are shown

CONCLUSIONS

A vertical wind tunnel aimed to use for processing of saffron flower was designed. The investigation result on terminal velocity measurement of three main parts of the flower showed that separation stigma from the other parts of flower is possible. The value of the terminal velocity of stigma compared with petal and anther was ranged from 2.4 to 2.8 and 1 to 2 m/s respectively on the first day of harvesting. Equal friction method with a fixed friction loss of 0.07 cm H_2o per 0.3 m was applied for design of a vertical wind tunnel. The flow rate and static pressure of fan were determined to be 1700 m3/h and 0.82 cm, respectively. The duct sized to 40.6 × 40.6 cm in main, 40.6 × 33 and 40.6 × 18 cm in lateral branches.

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