Design and Development of Saffron Harvesting Machine

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Abstract: Iran is ranked as the first saffron producer with annual production of 170*10^3 kg. Some problems involved in saffron harvesting are driving force behind of design and development of saffron harvesting machine. For this purpose, a prototype of the machine was designed and constructed that harvests the saffron flower from the stalk. This machine comprises a main farm, power transmission system, and pick up head. In the pick up part, several flexible polymer knives have been used to simulate the pick up task as human hand does it. The latter practice is satisfactorily performed with combination of turning and pulling operations similar to human hand. The height of the head can be set within 3-5 cm from land level. This machine has some advantages such as high performance and low losses in saffron harvesting as well as simple and cost-effective construction.

Key words: saffron, harvesting machine, head, design, knife

INTRODUCTION

Saffron scientific name is Crocus L. A plant from Irlacea group among Crocus. It’s distribution is a wide range in the world from Marakesh and portadual in west of Spain to Sin-Kiang in China. Saffron grow up in dry and hot conditions. Iran is ranked as the first Saffron producer. Picking of saffron flowers takes place at dawn, for about 20-25 days, from the end of October until November. This is one of the different phases of the cultivation of this very precious spice, which has got different active principles used in medicine. The price of one kg saffron, according to its quality and pureness, is about 16.000 euros. If the mechanization of this production’s harvest could be possible, it’s quality would have been exceeded and it’s productin would be easy. But it is very difficult and it is because of saffron’s morphology which lead to very high worker costs about 230 worker/hectar. Since Saffron is a strategic and expensive product, then design and manufacturing of an special machine for harvesting of Saffron is nessesary. In this study a plan is investigated which can:

- Operate nearly to the ground
- Led to minimum injury to product
- Cutting of saffron’s flower and accumulating of them in a bin.
- Could be operated in wide range of fields
- Simple and compact

As mentioned, it is nessesary that Iranian farmers use an special mechanism to harvesting of saffron. Now a Days some mechanisms such as Penumatic blower, Flower pick up grips, stripper, Rotary cones, Endless belt with eccentric pulleys, Plastic vane-Idle roller design, Pressurized rollers, three sided pick up, ... are manufactured for this purpose and figures 1-9 show these mechanisms[1].
Figure 1. Flower pick up grips

Pneumatic method is impossible because the flowers are near the ground surface. The pick up grips work very slowly and their life would be little [1].

Figure 2. Flower stripper

The stripper stripes flowers because of their diameter’s difference with other parts of plant. In the use of this mechanism following problems prevent optimum harvest [1].
1-the difference between flower diameter and other parts diameter is low.
2-the flowers group in the field with different heights.

Figure 3. Rotary cones

In rotary cones two cones rotate opposite each other and flower layer between them. Forward moving of machine pushed plants to bottom of cones where their rotation separate flower from other parts. Because of the following reasons this mechanism is not suitable for Iranian saffron harvest:
1-The field must be planted in direct rows which is not conventional in Iran.
2- Driving mechanism would be very difficult as it works nearly the ground surface.
3- The flower may be separate from every point of stem [1].

Figure 4. Endless belt with eccentric pulleys

In the other mechanism endless belt with eccentric pulleys were used. Pulleys are parallel the forward direct. When the pulleys rotate belts close or away from each other and when they closed to each other the flower trapped between them and picked up with forward moving of machine. The following problems occurred with this system:
1-Larg stresses found in belts
2-Driving mechanism would not be easy.
3-Leaves picked up with flowers too.
4-Pulley's cams may be contact with ground surface [1].

Figure 5. Plastic vane-Idle roller design.
Plastic vane-Idle roller design is the other mechanism which introduced in saffron harvesting. In this mechanism the flower trapped between vane and roller and with participating of forward speed and van-roller act is picked up. The height of flower is the most critical parameter. This system is better than the other mechanisms which introduced but the difference between flower’s heights make its work so hard [1].

**Figure 6. Pressurized rollers**

In early mechanisms the flower subject to crushing which damage the product. In order to prevent this, pressurized rollers were used to harvesting of flowers which its side view is shown in figure 7. As picture shows the first two rollers pick up small flowers the second one for the medium flowers and third rollers picking tall flowers. This mechanism has complex plan and manufacturing of it is very difficult [1].

**Figure 7. Side view of pressurized rollers**

The last machine has cutter bar and conveyor mechanism. In this machine upper conveyor pussed flower toward cutter bar and after cutting away it from cutting mechanism and deliver it on lower conveyor which transport flowers to bin.

**Figure 8. Three sided pick up**

Three sided pick up is mechanism like pressurized rollers but in replace of pressurized rollers, a Three sided pick up and a pneumatic roller were used and act similar the pressurized rollers. This mechanism pushed flowers upon the ground surface which affect the harvesting process [1].

**Figure 9. Cutter bar and conveyor mechanism**

This mechanism is suitable for Iran conditions but the cutter bar can not work near the ground. Then any of mentioned mechanisms can do “harvesting of saffron flower” as it desired [2]. The best mechanism is that could similar the act of human and in this study proposed apartus which harvest saffron as human.

**MATERIAL and METHOD**

A mechanism which harvest saffron as human-and proposed in this study-made from following parts:

- Main fram
- Pick up head consist of:
  - Roller
  - Conveyor which supports knives
  - Knives
- Power train(Transmission)
Chain
Spracket
• Wheels
These parts are shown in figure 10. After planning of first mechanism the size of all parts of machine were designed and calculated which in next parts (sessions) would be discussed.

![Figure 10. Proposed machine](image)

1-main fram
Main fram of this machine supports axis of rollers, triangular elements and wheels. Rollers installed between triangular elements which slide on main fram. Also bearings must be assembled on this fram so that the axis of them could displacement on it which adjusts the horizontal and vertical position of them to each other. With this arrangement every knife can contact with opposite knife and flower of Saffron in different angles. This mechanism allows conveyors chang their angles in relation to horizontal surface. The optimum angle in experiments obtained equal to 35 degrees. Figure 11 shows the position of triangular elements on main fram.

![Figure 11. Position of triangular elements on main fram](image)

2-Rollers
The endless Conveyoyrs which support knives assembled on two rollers. Then for this new mechanism four rollers are need. Two Rollers in front and the another two in rear of the machine as showed in figure 10. In producing of these rollers it is nessesary that their weight might be as less as possible. For this purpose the shaft surrounded by pipe which embeded in two ends of pipe (figure 12).

![Figure 12. Rollers](image)

To avoid impacting of knives it is necessary that lower roller’s diameter be smaller than the upper one. The specification of these elements are showed in table 1.

Table 1. Specification of elements used in rollers

<table>
<thead>
<tr>
<th>Specification Name</th>
<th>Inner dia</th>
<th>Outer dia</th>
<th>Lenght</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>pipe</td>
<td>-</td>
<td>70</td>
<td>350</td>
<td>3</td>
</tr>
<tr>
<td>plates</td>
<td>25</td>
<td>70</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Shaft</td>
<td>-</td>
<td>40</td>
<td>500</td>
<td>1</td>
</tr>
<tr>
<td>Shaft</td>
<td>-</td>
<td>25</td>
<td>500</td>
<td>1</td>
</tr>
<tr>
<td>Shaft</td>
<td>-</td>
<td>25</td>
<td>600</td>
<td>2</td>
</tr>
</tbody>
</table>

3-Head (harvesting mechanism)
This mechanism the heart of this machine. As early mentioned harvesting of saffron flowers are normally harvested in mid autumn and the flowers are picked by hand. Harvesting is best done in early hours of the day when it is cooler to minimize mechanical damage while picking and handling the flowers. The person picking the flowers must be in sound health and the hands particularly must be free of any contamination, infection or skin ailment. In addition the following conditions must be considered too:
The flowers must be harvested and handled in such a manner as to avoid mechanical damage and possible environmental contamination.

In harvesting and transportation, compression of the flower should be avoided.

Collecting the saffron in bunches is not recommended.

The producing saffron in filament form, the stigma should be removed from the flower together with at most 2-4 millimeter of the style.

Hence for the following reasons a new concept in saffron harvesting which contains all mentioned conditions is introduced.

1. Minimizing manual contact and the risk of contamination
2. Fast procedure
3. Visually more voluminous saffron
4. Maintaining the quality
5. Shorter drying time

This machine included two endless conveyors which in participation with each other complete saffron harvesting. These conveyors made from plastic or threaded plastic. The picking up knives installed on these conveyors in two rows with 50mm overlapping. The number of knives is 12 and size of them is 12*15cm (figure 13). The material which is used in making knives must be rigid enough and flexible too. With this type of material, the flowers received least damage. In this study threaded-PVC is used. Figure ... shows assembling of conveyors.

4-Power transmission

In this machine picking conveyors must be worked with the same speed and for this mean the axis of upper rollers selected as driving shafts. Driving gears have the same size with equal number of threads. In order to providing opposite direction for two picking conveyors, an idle pulley as shown in figure 14 is used.

5-Transporting wheels

The following parameters must be considered in design or selecting of Tyres.

1. Least rolling resistance
2. As small as possible (in point view of tyre's diameter)
3. Wide enough for decreasing stress on the soil
4. Adjustable
5. Available
Working of mechanism:

As shown in figure 13 the knives are installed on conveyors and are layed on conveyors except at two ends of conveyor where the knives contact with rollers. At these points when conveyors want to turn, the knives continue mowing on direct path while the pinned side of knives placed preped to radius of roller. After this position the pinned side of knives bigan to turn over axis of rollers. This process is done at the same time on both conveyors. When the free end of knives contact each other ,if any flower placed between them ,act of knives picked up the flower. As early mentioned the front knife turn over the roller which It’s diameter is smaller than the other one. Then by equal linear velocity of conveyors, rotary speed of conveyor and knife over front roller would be greater, because:

\[ V = R \omega \]

Where: \( V = \) velocity speed 
\( R = \) radius of rotation 
\( \omega = \) angular velocity

If \( R_1 \leq R_2 \) , \( R_1 = 0.5 \ R_2 \)
Then:
Because of: \( R_1 \omega_1 = R_2 \omega_2 \),
\( \omega_1 = 2 \ \omega_2 \)

Hence the front knife turn fast and for this reason the flower pussed to rear knife and after cutting, the flower layed on the rear knife. Finally The flower transported to the bin by the rear conveyor.

Conclusion

After manufacturing of mechanism it examined in laboratoary conditions. The examines showed that this mechanis work such other mechanical types which in this study were investigated. Result of This examines evaluate success of this design about 60%. It means that 40% of product were treated.
Finally we can say that because of Saffron’s special conditions, the mechanical systems could not harvest it completely. In the other hand, it is reasonable to use so complex systems which can do this important work completely.

Then we suggest development of the Agri-robot.
For the ones who don’t know anything about the cultivation of saffron, the development of the Agri-robot project may sound strange. In order to obtain one kg of saffron, it is necessary to pick about 100,000 to 130,000 flowers: so we can see how much time, and how much hard work is required[3].

The Agri-robot, which resolves the most difficult phases of such a cultivation, relieving the hard work, may indeed find its logical and even economical use. The working principle of Agri-robot is quite simple. The flower position is obtained basing ourselves upon the observation of the flower chromatic component. The same colour can be filtrated and analysed, through a vision system, digital or analoical[3].

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