ORIGINAL ARTICLES

Developing a local extraction watermelon seeds machine

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ABSTRACT

An extractor watermelon seeds machine (EWM) was developed and evaluated at El-Kasassin Horticulture Research station Ismailia Governorate. The performance of the developed machine was evaluated based on broken seeds, seed loss, size of cutting peel, cutting efficiency machine extraction efficiency and extraction cost comparing with traditional method. The experiments were carried out at El-Kasassin Horticulture Research station Ismailia Governorate during two seasons 2010 and 2011. The main objectives of this study is to develop and evaluate of an extractor watermelon seeds machine (EWM), it saves the farmers efforts and time and maximize watermelon peel benefits as a green feed for animals. It can be operated using an electrical motor 2hp (1.5 KW). The studied factors in the present work, which affect the performance of extraction of watermelon seeds and cutting peel machine, are chosen to be in the following ranges and magnitudes: Feed rate 20, 30 and 40 kg/min, three levels of flesh from fruit peel cutting unit rotational speeds 150, 250 and 350 rpm (1.11, 1.85 and 2.59 m/s forward speeds), two types of perforated concave holes circular and square hole and different time-span of extracting after harvesting (0, 2, 4 and 6 days). At the same operating conditions the specific energy consumption decreased by increasing both, time-span after harvesting and feeding rates, while on contrary relation with cutting unit speed. The seed losses and damage increased with increasing cutting unit speed from 1.11 to 2.59 m/s and time-span after harvesting and using concave with square holes. Operation cost analysis showed that the extraction cost by the developed machine was 219.38 L.E/fed while the manual cost 1200 L.E/fed. Hence, a saving of above 81.72% can be achieved as well as about 6 -7 ton/fed green fodder for animals.

Kew words: local extraction, watermelon seeds, machine

Introduction

Watermelon seeds are strategic vegetable products in Egypt that can be exported to several Arab countries, Amir (2004), said. Consequently, in order to increase watermelon seed production quantity and quality, the agricultural engineering researchers have realized the need to develop, use, and improve modern watermelon machinery technology, as mentioned by Todd et al (1983) and Chen et al (1996). Amir (2004), indicated that the manual process is both time and effort-consuming. Whereas, 25 -30 workers are needed /fED. According to Egyptian Ministry of Agriculture and Land Reclamation Report (2008), the total area of watermelon seed is about 182529 fed., with an average yield of 530 kg/fed. Hassan (2000), indicated that a great future is waiting production of watermelon seeds in the developing countries (including Egypt) due to two reasons: high contents of proteins and fats and proper contents of amino and fatty acids. The second may be attributed to availability of plantation in different soils and environmental conditions.

Abo-Haded (2003), reported that watermelon represent a significant amount of total Egyptian agricultural exports. Teotia and Nwajinka (1984) and Onyemelukwe (1991), reported that traditional method of extracting melon seeds involves manual cracking of the fruits with wooden clubs or cutting off the head or tail poring the fruits with a knife. The fruit so treated is left about 7 days to decompose, and then the seeds are removed by washing in water. They cleared that the traditional method requires a lot of time and labor. George (1985), stated that the sweet melon and melon seeds are extracted by cutting up fruits manually or mechanically then scattered seeds should be separated from pulp by washing with water manually or mechanically.

Kalra et al (1983), developed a manually operated seed extractor which comprised a rotary drum with corrugations and a helix fixed on its surface. He added that the extractor also included a stationary expanded metal concave, a feed hopper and a holding frame. Todd et al (1983), stated that the motorized seed extractor is more efficient than hand operated one especially when handling more than 50 fruit per lot. The essential elements of seed extractor are 2 counter-revolving, fruit-crushing rollers, a rotating drum for separating the seed.
from pulp and flesh, an interconnecting gravity transfer chute, and a seed collection pan. The designed machine is driven by a 3hp gasoline engine.

Ahmed (1982), reported that the speed of rotating of the threshing drum plays an important role on the efficiency and damage to pods. On Faba beans crop, Abou El-Kheir (1988), suggested that a high threshing drum speed is essential to decrease the summation of grain loss out-put of the machine, it increases both threshing and cleaning efficiencies. He also indicated that the threshing drum speed should be low to minimize mechanical grain damage.

Amir (2004), manufactured and evaluated a locally prototype for extracting watermelon seeds, the extraction of watermelon seeds using the developed equipment saved extraction cost and time by 50 and 62% compare to manual method. To obtain maximum watermelon extracting and cleaning efficiency, the machine must be operating under following conditions: 60 kg/min feed rate, 4.71 m/s drum speed, 4 knives on the drum, 40 mm clearance between drum and concave, 8 cleaning brushes with 4.71 m/s speed, and extraction operation must be done after 7 days after harvesting.

EL-Behiry et al (1997), found that the operational costs per hour were estimated according to traditional price for all machines. The costs of threshing Mg of grain depends on the machine productivity, therefore, it was decreased. Abu Shieshaa et al (2007), investigated the effect of moisture content on some physical and mechanical properties of watermelon seeds and their kernel. The average length, width, thickness, mass and hardness of 100 seeds were 12.42, 7.80, 2.37mm, 0.097g and 64.8N, respectively, at a seed moisture content of 9.53% (w.b.) corresponding values of kernel, were 10.3, 6.50, 1.64mm, 0.061g and 14.0N. The highest values of bulk and true densities of seed were 600 and 1000 kg/m3, the galvanized metal gave the lowest values of coefficient of friction at all seed moisture content for seed and kernel. The increase of seed moisture content from 9.53% to 24.08% increased the angle of repose from (27 to 43 deg) and (31 to 44 deg) for seed and kernel respectively.

Tayel et al (2010), studied the effective factors on cucurbita pepo crop seeds damage and losses by using seed extracting prototype. The results revealed that the seed extracting machine operated successfully under field conditions of 0.116 Mg/min feed rate, 2.48 m/s drum speed, 15mm drum-concave clearance and six days time span after harvesting achieved the minimum values of seed damage.

Therefor, the objectives of the present research are:
1- Development a local machine for extracting watermelon seeds and watermelon peels utilization as a green fodder for animals.
2- Evaluating the developed machine performance under different operating parameters, and comparing it with the manual method.

Materials And Methods

An extractor watermelon seeds and peel cutting machine was developed and fabricated in a local shop. The experiments have been carried out at El-Kasassin Horticulture Research station Ismailia Governorate during two seasons 2010 and 2011 in order to study the effect on extraction effectiveness, Feed rate, two types of perforated concave holes, different periods between harvesting and extraction process, Skin cutting drum speed, different blades of cutting peel knifes and different time spans after harvesting. Watermelon (Citullus Lanatus var.) was sown on Mars and harvested during August. Some physical properties of watermelon fruits and seeds were measured. The average of randomly selected handered fruits was recorded as shown in table 1.

A- Stationary extraction machine specifications:
1. Overall dimensions: 95, 90 and 110 cm for length, width and height respectively.
2. Flesh separation unit from fruit skin: conical shaped having two bases 3 and 8 cm diameter and 9 cm height.
3. Crushing drum: 18 cm diam., 45 cm length, covering with plastic brush 4 cm length and 4 rows screw bolts 3 cm length which distributed in a volute shape, the screw bolts supported the plastic brush and help it to flesh breaking easily. There is a metal partition to prevent the peel from falling on crushing drum.
4. Concave: 45 cm length, 19 diam., the experiments was done under two types of perforated concave holes dimensions (circular hole 15 mm diam and square hole 15X15 mm).
5. Galvanize steel transfer chute: 45X55 cm.
6. Feeding opening: 30 cm length and 17cm width.
7. Cutting peels drum: 25 cm length and 15 cm diam.
8. Knifes type: three fixed knifes, with 4 cm same distance between them, having (2, 3 and 4 blades) Fig. (1, 2 and 3).
Fig. 1: Shematic diagram of extraction watermelon seeds machine.
1-Half watermelon fruit, 2- Flesh cutting unit, 3- Galvanize transfer chute, 4- Feeding opening, 5- Crushing drum, 6- Concave, 7-Seeds + water outlet, 8- Sieve, 9-Seeds, 10- Electric motor 2hp, 11- Main frame, 12- Gear box, 13- Washing pipe, 14-Peels hopper, 15- Cutting peels drum.

Fig. 2: The developed extraction watermelon machine.

_Extraction watermelon seeds from soft fruits include the following steps:_

1. Cutting and smashing the fruits manually into two halves by using a knife.
2. The labor put two halves on two rotary conical units to separate the flesh and seeds from its peel.
3. The crushing drum with plastic brush and welding with volute screw bolts which support the brush for separating seeds only from flesh.
4. Washing water and plastic brush with suitable clearance help to remove the gelatin surrounding the seeds.
5. The empty peel is put directly in the cutting unit to begin green feed to animals.

Fig. 3: The schematic diagram of the developed extraction watermelon machine crushing drum.

The following variables were studied:

1. Flesh cutting unit speeds were 150, 250 and 350 rpm, (1.11, 1.85 and 2.59 m/s).
2. Feeding rates were (20, 30, and 40 kg/min).
3. Two types of perforated concave holes of dimensions were (circular hole of 15 mm Diam. and square hole of 15x15 mm).
4. Time-spans of extracting after harvesting were (0, 2, 4 and 6 days).

Two experiments were done, the first was carried out to measure the effect of some operating parameters i.e., flesh cutting unit speed, using watermelon fruits after different time spans 0, 2, 4 and 6 days and two holes concave types on seed loss, damage % and extracting efficiency to determine the best concave holes. The second experiment was done to measure the effect of flesh cutting unit speeds, different feeding rates and different time spans after harvesting to determine the consumed power and criterion cost.

Measurements:

1- Physical properties of watermelon fruits and seeds:
   Physical properties of watermelon fruits and seeds were measured using:
   1- Dimensions of fruits and seeds
   2- Volume of watermelon fruits by water displacement, "V"
   3- Mass of fruits "m" and mass of seeds "M".
   4- Density of fruits by \( \rho \) which = m / V

<p>| Table 1: Physical properties of watermelon fruits and seeds. |
|---------------------------------|-----|-----|-----|-----|</p>
<table>
<thead>
<tr>
<th>Physical properties</th>
<th>Max.</th>
<th>Min.</th>
<th>Average</th>
<th>C.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watermelon fruits:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height in mm</td>
<td>225</td>
<td>90</td>
<td>151</td>
<td>11.5</td>
</tr>
<tr>
<td>Diameter in mm</td>
<td>192</td>
<td>70</td>
<td>115</td>
<td>9.4</td>
</tr>
<tr>
<td>Mass, g</td>
<td>4064</td>
<td>725</td>
<td>1820</td>
<td>91.26</td>
</tr>
<tr>
<td>Volume in cm³</td>
<td>3718</td>
<td>670</td>
<td>1790</td>
<td>48</td>
</tr>
<tr>
<td>Density of fruits in g/cm³</td>
<td>1.08</td>
<td>1.04</td>
<td>1.03</td>
<td>9.48</td>
</tr>
<tr>
<td>Watermelon seeds:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of 100 seeds in g</td>
<td>18.75</td>
<td>10.66</td>
<td>14.12</td>
<td>3.55</td>
</tr>
<tr>
<td>Length in mm</td>
<td>14.5</td>
<td>12.1</td>
<td>13.70</td>
<td>19</td>
</tr>
<tr>
<td>Width in mm</td>
<td>8.7</td>
<td>7.1</td>
<td>8.19</td>
<td>15</td>
</tr>
<tr>
<td>Thickness in mm</td>
<td>3.2</td>
<td>2.7</td>
<td>2.99</td>
<td>26</td>
</tr>
</tbody>
</table>

2-Determination of seeds damage (broken) and losses:

The criteria of the performance evaluation included damage or broken seeds and seed losses as follow:
The percentage of damage seeds \( M_d \) was calculated using the following formula:
**Damaged seeds (%)** = \( \frac{M_d}{M_t} \times 100 \)

Where \( M_t \): is the total mass of seeds contained in fruits sample in (g).

The seed losses were determined by rescuing the expelled peels and washing water from collection sieve, seeds manually collected and weighted and calculated as follow:

**Seed losses (%)** = \( \frac{M_o}{M_c + M_o} \times 100 \)

\( M_o \): mass of the total seeds expelled out of the machine with peels and washing water, (g),

\( M_c \): mass of collected seeds, (g).

3-**Machine extracting efficiency %:**

The efficiency of the machine in seed extraction was calculated according to the following equation:

Extracting efficiency % = \( \frac{M_c}{M_t} \times 100 \)

4-**Estimation of energy requirements:**

Total consumed power (kW) for extraction seeds and cutting peels was estimated using super clamp meter (700-k type) as follow:

**Total consumed power, R. p (kW) =\sqrt{3} I V \eta \cos \theta / 1000**

Where:

- \( I \): Line current strength in amperes.
- \( V \): is the potential difference (voltage) being equal to 220 V.
- \( \cos \theta \): Power factor (being equal to 0.71)
- \( \eta \): Mechanical efficiency assumed (90%).

The extracting machine specific energy requirement for watermelon seeds was calculated as follow:

**Specific energy requirement in (kWh/Mg) =**

\[ \frac{\text{Consumed power (kW)}}{\text{Machine productivity (Mg/h)}} \]

5-**Operating cost:**

The total cost for each operation extraction seeds and cutting peels per hour are estimated according to the conventional way of estimating both fixed and variable costs. While the cost per unit was calculated using the following equation:

Cost per mass unit of watermelon seeds (L.E/ Mg) =

\[ \frac{\text{Total cost (L.E/h)}}{\text{Machine productivity (Mg/h)}} \]

**Results:**

**Seed losses:**

The average values of seed losses were affected with many parameters such as flesh cutting unit speeds, type of concave hole and time-span after harvesting fruits. The total seed losses are the sum of unmatiurety seeds, out with washing water and peel residual. It observed that increasing flesh cutting speed tends to increase seed losses due to increasing vibration and instability of the fruit over flesh cutting unit. Also, the data indicated that using concave with square hole led to increasing seed losses because this holes allow the flesh with seeds to get out quickly with a short survival time to separation process. It is noticed that increasing time-span lead to increasing seed losses in respect that decomposition the internal components of fruits and peel weakness, consequently the labor cannot catch the fruits for separation flesh and seeds. There are many parameters have effects on seed losses ratio.

The presented data in Fig. (4) explains that 250 rpm flesh cutting unit speed and concave with circular hole gave the minimum percentage of seed losses 1.2%, while the maximum seed losses 7.5% was recorded at 350 rpm flesh cutting unit speed and concave with square hole and 6 days time-span after harvesting.
Seed damage:

Most of seed damage were done owing to and during cut the fruits into two half's and during separation flesh and seeds from its peel. There are many parameters were affected in seed damage ratio such as flesh cutting unit speeds, type of concave hole and span time after harvesting. The late span time lead to decomposition of internal fruits components; change the physical properties of fruits and its color and swelling the seeds and emergence the fetal. All these defects reduce the marketing values of fruits. Fig. (5) Shows the relation between each flesh cutting unit speed and different time span under two concave holes on seed damage, the percentage of damage seeds was inversely proportional to flesh unit speed and late extraction after harvesting. The minimum percentage of seed damage 0.13 %, while the maximum seed losses 1.9% was recorded fewer than 150 rpm and 350 rpm flesh unit speed after 2 and 6 days, when using concave with circular and square hole respectively.

Extracting seed efficiency:

Watermelon seeds extracting efficiency is a function to seed losses and damage. The design of flesh cutting unit, a metal partition to prevent the peel from falling on crushing drum, crushing drum with plastic brush, type of concave hole shape and diameter, washing water to removing surrounding gelatin on the seeds. It can be observed from Fig. (6) that the maximum value of seed extraction efficiency (98.7%) was obtained at a 250 rpm flesh cutting unit speed, circular concave hole and two days span time after harvesting. The seed extraction efficiency increased with increased span time even two days and decreased after that owing to the previous reasons. Also, the concave hole shape was affect on extraction efficiency, however the minimum value (90.6%) was recorded at a cutting unit speed 350 rpm, concave with square hole and 6 day time span after harvesting.

Energy requirements:

The energy requirements are a measure for all parameters affecting the extraction process. It increased as increasing flesh cutting unit speed while decreased by increasing feed rate and time span after harvesting. Results obtained in Fig. (7, 8 and 9) show that increasing feed rate from 20 to 40kg/min under constant flesh cutting speed decreased the percentage of energy requirement from 36.25 to 18.75 ,36.24 to 18.5 , 34.25 to 18.23 and 33.5 to 17.13 kWh/Mg at 0, 2 ,4 and 6 day time span after harvesting respectively. That result trend may be due to power required to the feed rates from fruits increasing and flesh cutting speed; the capacity increased that result more torque to extraction seeds.

Cost analysis:

A detailed cost analysis of different elements included in the extracting processing was carried out in order to evaluate the economical feasibility of seeds watermelon extracting machine. In this study some parameters were calculated as the absolute total including both fixed and variable costs per hour according to (ASAE, 1980) and price level of 2011.It can be found:

**Table 2:** The calculation cost for extracting watermelon seeds machine comparing to manual method.

<table>
<thead>
<tr>
<th>Item of cost analysis</th>
<th>Watermelon seeds extractor machine</th>
<th>Manual extracting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A-fixed costs:</strong>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment price L.E</td>
<td>4000</td>
<td></td>
</tr>
<tr>
<td>Expected life ,h</td>
<td>5 x 400 = 2000</td>
<td></td>
</tr>
<tr>
<td>Interest rate,</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Machine salvage rate 10%,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital depreciation, L.E/h.</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Capital profit, L.E/h.</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>Annual Taxes, insurance and housing, L.E/h.</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Total hourly fixed cost, L.E/h.</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td><strong>B- Variable costs</strong>:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair and maintenance.</td>
<td>1.62</td>
<td></td>
</tr>
<tr>
<td>Electric energy cost</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>Labor cost (2 labor)</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>Grease and daily services</td>
<td>1.19</td>
<td></td>
</tr>
<tr>
<td>Total variable costs</td>
<td>13.17</td>
<td></td>
</tr>
<tr>
<td>Total operation costs L.E/h</td>
<td>15.67</td>
<td></td>
</tr>
<tr>
<td>Total operation costs L.E/fed.</td>
<td>219.38</td>
<td>1200</td>
</tr>
</tbody>
</table>
Fig. 4: Effect of the Operation Parameters on Seed Losses.

Fig. 5: Effect of the Operation Parameters on Seed Damage.

Fig. 6: Effect of the Operation Parameters on Extraction Efficiency.

Fig. 7: Effect of the Operation Parameters on consumed and specific Energy under F1.
These costs were estimated at the best operating conditions for using extracting machine at 250rpm, 30 kg/min. for flesh cutting unit speed, feeding rate and concave with circular hole 15mm diameter. The average number of watermelon fruits 20802/fed., and 1054 g average mass of fruit as reported by Amir (2004). Therefore, the average total yield about 21.9Mg /fed. On the other hand, manual extraction cost required about 30-40 labor (one day) /fed. The total operation cost 219.38 and 1200 L.E/fed in mechanical and manual extraction respectively, it was a very significant cost reduction.

There are additional benefits from watermelon peels utilization as green fodder for animals which represent about 0.33% from fruit mass or about 7Mg /fed green fodder.

Conclusion:

The mechanical watermelon seeds extraction and peels utilization is developed and manufactured to fit most watermelon planting areas, in order to save costs and raise the living standards of farmers. The seed extraction machine was operated successfully under field conditions. Three flesh cutting unit speeds 150, 250 and 350 rpm, (1.11, 1.85 and 2.59 m/s), three feeding rates (20, 30, and 40 kg/min), two types of perforated concave holes dimensions (circular hole 15mm diam. and square hole 15X15mm) and Time-span of extracting after harvesting (0, 2, 4 and 6 days). The results summarized as follow:

1- The minimum percentage of seed losses 1.2%, minimum percentage of seed damage 0.13 % and maximum value of seed extraction efficiency (98.7%) was obtained at a 250 rpm flesh cutting unit speed, circular concave hole and two days span time after harvesting.

2- the extraction cost by the developed machine was 219.38 L.E/fed which the manual cost 1200 L.E/fed hence, a saving of above 81.72% can be achieved as well as about 6-7 ton/fed green fodder for animals

References


