Performance Evaluation of a Small Machine for Chopping Fodder Beet

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ABSTRACT

This research aims to evaluate small local prototype forage chopper machine performance during chopping fodder beet tubers. The independent variables including, four levels of fodder beet tubers moisture content of 81.6, 74.4, 66.2 and 57.9 % (w. b), four levels of cutter head speeds namely 18.8, 21.2, 23.50 and 25.8 m/s, and four levels of feed mechanism speeds of 0.41, 0.79, 1.13 and 1.45 m/min. During the execution of the present experiment the blade holders are inclined at 129° resulting in a cutting angle of the knives of 22°. The test results for modified forage chopper performance found that, the highest percentage of chopping length suitable silage (category of 3 - 6 cm) obtained at cutter head speed of 25.8m/s, feed mechanism speed of 0.41m/min and moisture content of 66.2%. The highest of actual capacity, machine efficiency recorded were 3.412Mg/h and 88.41%, respectively. Also, experiment recorded minimum of total losses, unit energy required and total losses cost of 7.65%, 0.767kW.h/Mg and 35.92 L.E/h, respectively. Too, minimum of criterion function cost was 134.71 L.E/h. Silage was made from the results suit chopping length, it found that the percentage of ammonia does not exceed 8%, the degree of PH was less than three. Also, silage was kept with leaves and legs in good condition. And the most suitable moisture content in the material used to be preserved is 65 - 70% (w. b). Moisture and all these indicators are proof that the silage is good and the interactions are done in a good way.

Keywords: Fodder beet tubers, Chopping length, Chopper efficiency, Total machine losses, Energy requirements and losses cost.

INTRODUCTION

The Beet (Beta vulgaris) belonging to family Amaranthaceous, is a biennial crop grown for its fleshy and swollen roots. It is a temperate crop being cultivated in many parts of the world for sugar, fodder and vegetable purpose. Also, it popularly called as sugar beet, fodder beet& beet root, respectively. Beet is successfully grown as a fodder crop and used as valuable source of green fodder for cattle in many developed countries (Niazi et al., 2000). Fodder beet considered as one of the most important crops for farmers. In Egypt, the fodder beet yearly is grown with cultivated area about 9674 ha (23905feddan) and quantity of production was 244626 tons (FAOSTAT, 2014). Fodder beet contains high water and sugar; it increases milk productivity and is suitable forage for dairy cows. The fodder beet is used by mixing it with straw to improve the concentrate. With either type, the mounting or shape of the knives is such that cutting occurs progressively from one end to the other to minimize peak moment requirements (Culpin, 1981). Srivastava et al. (2003) estimated the power consumed in gathering, conveying and compressing the material to be cut, in chopping the material and in conveying it. Power losses in forage include bearing friction, friction of cut material on the cutter head housing. Power divided roughly as follows: 20 % in gathering and feeding, 40 % in the cutter head and 40 % for blowing.

Kholief et al (2001) develop and evaluate fodder beet chopping machine to obtain beet sizes suitable for small ruminants feeding and to avoid clogging during chopping process. Results indicated that, the optimum operation condition was obtained at rotor speed of 350 rpm, beet feed rate of 9.9 Mg/h and beet moisture content of 84.15% (w.b). Whereas, the minimum values of energy consumed of 1.411 and 0.748 kW.h/Mg were obtained under above conditions for original and modified machine, respectively. Also, an acceptable beet sizes of 25 and 56 % for < 2 cm however, they were 23 and 21 % for > 2 – 4 cm for the two proposed machines. Meanwhile, machine productivity of 6.278 and 9.165 Mg/h were occurred under the same conditions. Moreover, the cost calculations indicated that the original chopping machine costs about 1.46 times the modified machine. Khader (1997) concluded that the four movable knives could be used for producing animal fodder, silage or compost according to residues cutting length. The optimum operating condition as silage to chopped feed. Also, it can be processed into pellets or used in silage. Silage process was hoped to participate in solving the serious problems of feed shortage of livestock. With either type, the mounting or shape of the knives is such that cutting occurs progressively from one end to the other to minimize peak moment requirements.
MATERIALS AND METHODS

A- Chopping machine manufactured before adjustment:

Field experiments were carried out during 2015-2016 at Rice Mechanization Center, Meet El-Dyba, Kafr El-Sheikh Governorate. The general components part of small forage chopper machine was used in the present study are shown in Fig. 1. It consists of:-

- Feeding mechanism with spring-loaded rolls to compress and hold the material for chopping.
- Chopping unit that including flywheel-type cutter head with four impeller blades around the periphery that throw or impel the chopped material up the discharge pipe and into the wagon.

Also, Fig. 2 illustrated schematic drawing of using forage chopper machine. Table 1 summarizes the technical specifications of the tested forage chopper machine.

![Fig. 1. Photography of used forage chopper machine.](image1)

![Fig. 2. Schematic drawing of using forage chopper machine.](image2)
The chopping machine was powered by an electric motor of 10 kW. The rotational speed of axe was measured using a multi range hand tachometer chronometrical type, readings were given in r.p.m. The proposed machine was used for chopping fodder beet Monovert variety; the physical properties are shown in Table 2.

Table 2. Some physical properties of fodder beet roots (Monovert variety).

<table>
<thead>
<tr>
<th>No. of sample</th>
<th>Mass, kg</th>
<th>Length, cm</th>
<th>Average diameter, cm</th>
<th>Volume, cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.15</td>
<td>32.72</td>
<td>14.75</td>
<td>2971.7</td>
</tr>
<tr>
<td>2</td>
<td>2.95</td>
<td>29.51</td>
<td>15.56</td>
<td>2994.5</td>
</tr>
<tr>
<td>3</td>
<td>3.07</td>
<td>33.25</td>
<td>16.25</td>
<td>3065.2</td>
</tr>
<tr>
<td>4</td>
<td>3.24</td>
<td>31.60</td>
<td>14.57</td>
<td>2876.0</td>
</tr>
<tr>
<td>5</td>
<td>2.87</td>
<td>30.45</td>
<td>13.62</td>
<td>2752.5</td>
</tr>
<tr>
<td>Total</td>
<td>15.28</td>
<td>157.53</td>
<td>74.75</td>
<td>14659.9</td>
</tr>
<tr>
<td>Mean</td>
<td>3.06</td>
<td>31.51</td>
<td>14.95</td>
<td>2931.98</td>
</tr>
</tbody>
</table>

B- Chopping machine manufacturing:

The general adjustment parts on the cutting roller are as follows:

1- Portable small-scale multi-crop chipper machine was developed and constructed to slice different crops into choice sizes at no risk of injuries to fingers. (Fig.3)

2- Eight cutting blades mounted on a cutting roller in the perimeter and distributed on oblique axes at an angle of 129 degrees and the edge of these blades at a sharp angle of 22 degrees as shown in Fig.3.

3- The body is designed and made of the body of the roller drum with an inner diameter of 30 cm connected to eight longitudinal lines attached to the inclined cutting knives so, effective diameter is 50 cm. Each knife was 12.5 cm wide, and 10 cm long mounted on the edge of the drum. Another set of small knives with a width of 5 cm caused the pressure of the chopped parts and the body of the cutting roller.

4- Ten fixed U-shaped knives with dimensions of 5x10 cm installed at the cutting rotor inlet and outlet to increase the impact of shear forces on the agricultural material used.

5- Replace the sieve of the machine with a polished cavity to increase the effect of expelling chopped materials.

6- And adjust the concave cylinder containing rectangular beams with dimensions of 3x8 cm, tapping the rapid passage of the chopped material and thus allow to cut into small parts.

Investigated variables:

The performance of used forage chopper was in the present study evaluated under the following treatments:

- Four levels of fodder beet tubers moisture content of 81.6, 74.4, 66.2 and 57.9 % (w.b) respectively.
- Four levels of cutter head speeds namely 18.8, 21.2, 23.50 and 25.8 m/s,
- Four levels of feed mechanism speeds of 0.41, 0.79, 1.13 and 1.45 m/min.

During the execution of the present experiment, the blade holders are inclined at 129° and the knives cutting angle of 22°.

Measurements:

The fodder beet tubers were collected and rotor cutting speed was measured and adjusted by tachometer. The chopped materials were dropped out machine after cutting at threshing room through concave. Samples of cutting material were taken from each experiment to laboratory which separated and classified into three classes using hand sieves as follows: first class >3cm, second class 3-6cm and third class >6cm (referred to Luis et al. 1993).

Moisture content: It was determined using the oven method according to ASHRAE, 1999. The following formula was used for determination:

\[
\text{Moisture content} = \frac{M_1 - M_2}{M_2} \times 100, \% \quad (1)
\]

Where:

- \(M_1\) moist mass, g, and
- \(M_2\) dry mass, g.

Machine capacity: It was calculated by using the following formula by Mady, 1999:

\[
P = \frac{W \times 3600}{T}, \text{ Mg } / \text{h} \quad (2)
\]

Where:

- \(P\) machine capacity, Mg/h;
- \(W\) mass of the sample, Mg, and
- \(T\) time in sec.

Cutting stationary chopper efficiency: Cutting efficiency was calculated by measuring the beet tuber length before cutting and the length of particles after cutting. That according to the following equation (Elfathiet al., 2010).

\[
\eta_c = \frac{L_o - L_r}{L_o} \times 100, \% \quad (3)
\]

Where:

- \(\eta_c\) = cutting efficiency, %;
- \(L_o\) = length before cutting, cm and
- \(L_r\) = length after cutting, cm.
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Total machine losses: machine losses were calculated as follow:

\[ \text{Total machine losses} = \frac{M_{sl}}{M_d} \times 100\% \quad \ldots \quad (4) \]

Where:
\[ M_{sl} = \text{mass of split portion of beet tuber losses in ground after cutting operation, kg}; \]
\[ M_d = \text{total mass of beet tuber entering to machine for cutting, kg}. \]

The power consumption (W) was calculated from the values of Ampere (I) and Volt (V). The amount of power required for operating the electric motor has been calculated according to Lockwood and Dunstan (1971):

\[ \text{Power consumption (W)} = \sqrt{3} \times I \times V \times \cos \varphi \times \eta \ldots \quad (5) \]

Where:
\[ I = \text{current strength, Amperes}; \]
\[ V = \text{potential difference}; \]
\[ \cos \varphi = \text{power factor, decimal (being equal 0.71) and } \eta = \text{mechanical efficiency of motor assumed 90\%}. \]

Hence, the energy requirements can be calculated as follows:

\[ \text{Energy requirements} = \frac{\text{Power required}}{\text{Machine capacity}}, \text{kWh/Mg} \ldots \quad (6) \]

Operating cost: The total cost need for operation was estimated by the following formula (Hunt, 1984):

\[ \text{Operating cost} = \frac{\text{Machine cost}}{\text{Yield output}}, \text{LE/Mg} \ldots \quad (7) \]

Here, machine cost was determined by the following formula (Hunt, 1984):

\[ C = \frac{P}{h} (\frac{a + i}{2 + t + r}) + (0.9 \times w \times s \times f) + m \times 144, \text{LE/h} \ldots \quad (8) \]

Where:
\[ C : \text{hourly cost, LE/h.} \]
\[ P: \text{price of machine, L.E.} \]
\[ a: \text{life expectancy of the machine, h.} \]
\[ h: \text{yearly working hours, h/year.} \]
\[ i: \text{interest rate/year.} \]
\[ t: \text{taxes ratio} \]
\[ r: \text{repairs and maintenance ratio} \]
\[ 0.9: \text{factor accounting for lubrication} \]
\[ w: \text{specific fuel consumption, l/hp.h.} \]
\[ f: \text{fuel price, L.E/l} \]
\[ m: \text{monthly average wage, L.E.} \]
\[ 144: \text{reasonable estimation of monthly working hours.} \]

And also:

\[ \text{Criterion function cost} = \text{(operating cost + losses cost)}, \text{LE/Mg} \ldots \quad (9) \]

RESULTS AND DISCUSSION

Performance evaluation of anew small local chopper machine for fodder beet tubers cutting:

Cutting length categories:

Results in Figs. 4 show the effect of cutter head speed and feed mechanism speed at different fodder beet tuber moisture content for cutting fodder beet tubers on cutting length categories.

Fig. 4. Effects of tubers moisture content, cutter head speed and feed mechanism speed on chopping lengths of fodder beet tubers.
The results indicate that, increasing cutter head speed or decreasing both of fodder beet tubers moisture content and feed mechanism speed, < 3cm and 3-6cm categories led to increase while > 6cm category was decreased. As it has been known from many previous studies that the cut lengths 3-6 cm are suitable for the work of silage and get the best specifications, percentage of cutting fodder beet tubers lengths of 3-6 cm is the best level required. Results noticed that, the highest percentage of cutting fodder beet tubers lengths of <3cm recorded 42.23% at cutter head speed of 25.8 m/s, feed mechanism speed of 0.79 m/min and moisture content of 57.9 % w. b. Also, the highest percentage of cutting fodder beet tubers lengths of 3-6 cm of 47.52 % recorded at cutter head speed of 25.8 m/s, feed mechanism speed of 0.41 m/min and moisture content of 66.2 %. And the highest percentage of > 6 cm category of 44.83 % obtained under cutter head speed of 18.8 m/s, feed mechanism of 1.45 m/min and moisture content of 81.6 % w. b. While, the minimum percentage of cutting fodder beet tubers lengths < 3 cm of 19.37 % recorded at cutter head speed of 18.8 m/s, feed mechanism speed of 1.45 m/min and moisture content of 81.6 % w. b. And the minimum percentage of cutting fodder beet tubers lengths of 3-6 cm of 30.11 % recorded at cutter head speed of 18.8 m/s, feed mechanism speed of 1.45 m/min and moisture content of 57.9 % w. b. Also the minimum percentage of > 6 cm category of 9.87 % recorded at cutter head speed of 25.8 m/s, feed mechanism speed of 0.41 m/min and moisture content of 57.9 % w. b.

**Actual machine capacity and machine efficiency:**

From Fig. 5 results indicated that, actual machine capacity was increased with increasing both of cutter head speed and feed mechanism speed. While, it was increase with decreasing of moisture content levels at all experiment points. Results also noticed that, the maximum actual capacity value of 3.412 Mg/h recorded at moisture content of 57.9 % w. b., cutter head speed of 25.8 m/s. and feed mechanism of 1.45 m/min. While, the minimum actual capacity value of 1.174 Mg/h recorded at moisture content of 81.6 % w. b., cutter head speed of 18.80 m/s. and feed mechanism of 0.41 m/min respectively. On other hand, Fig.6 illustrated that modified forage chopper machine efficiency was increased with increasing of cutter head speed from 18.8 to 23.50 m/s, but it was decreased with cutter heads speed of 25.8 m/s. also, it was increased with increasing of feed mechanism speed at all experimental points. Also, it was increased with decreasing beet tubers moisture content. Generally, results noticed that the maximum modified forage chopper machine efficiency value of 88.41% recorded at moisture content of 57.9 % w. b., cutter head speed of 25.8 m/s. and feed mechanism of 1.45 m/min. While, the minimum modified forage chopper machine efficiency value of 64.61% recorded at moisture content of 81.6 % w. b., cutter head speed of 18.80 m/s. and feed mechanism of 0.41 m/min respectively.
Total beet tubers losses:

Total chopping losses are considered the efficacious indication during investigating the performance of small forage chopper machine. Results in Fig. 7 show that, total losses of modified forage chopper machine were increased by increasing both of cutter head speed and feed mechanism speed or decreasing of fodder beet tubers moisture content. So, results show that total losses increased from 7.65 to 10.34% at increase of feed mechanism speed from 0.41 to 1.45 m/min under cutter head speed of 18.8 m/s and moisture content of 81.6% w. b. Also, total losses are increased from 7.65 to 9.56% at increase of cutter head speed from 18.8 to 25.8 m/s under feed mechanism speed of 0.41 m/min and moisture content of 81.6% w. b. Also, It was decreased from 7.65 to 11.43% at increase moisture content of 81.6 to 57.9% w. b. under cutter head speed of 18.8 m/s and feed mechanism speed of 0.41 m/min, respectively.

Fig. 7. Effects of tubers moisture content, cutter head speed and feed mechanism speed on total losses at chopping fodder beet tubers.

Specific energy:

Fig. 8 illustrated that specific energy required was increase with increasing of cutter head speed. This results because several of the energy components are proportional to the square or cube of the speed (Kepner, et al., 1982). While, specific energy required was decreased with increasing of feed mechanism speed and with decreasing moisture content at all experimental levels. It was evident that, the increment in feed mechanism speed from 0.41 to 1.45 m/min decreases the specific energy from 1.211 to 0.767 kW.h/Mg at cutter head speed of 18.8 m/s and fodder beet tuber moisture content of 57.9%, respectively. Also, it was decreased from 1.604 to 1.211 kW.h/Mg at cutter head speed of 18.8 m/h and feed mechanism speed of 0.41m/min with decreasing moisture content from 81.6 to 57.9% w. b., respectively. Also, it was decreased from 1.604 to 1.114 kW.h/Mg at increase feed mechanism speed from 0.41 to 1.45 m/min with cutter head speed of 18.8 m/s and moisture content of 81.6% w. b., respectively. Results noticed also that, maximum of specific energy value of 2.661 kW.h/Mg, recorded at moisture content of 81.6% w.b. cutter head speed of 25.8 m/s, and feed mechanism speed of 0.41 m/min. While, minimum of specific energy value was 0.767 kW.h/Mg recorded tubers moisture content of 57.9% w. b. cutter head speed of 18.80 m/s. and feed mechanism of 1.45 m/min respectively.

Fig. 8. Effects of tubers moisture content, cutter head speed and feed mechanism speed on specific energy at chopping fodder beet tubers.

Losses cost:

It is found that, losses cost is increased with increasing both of cutter head speed and feed mechanism speed and decreasing moisture content (Fig. 9). So, the minimum losses cost value of 35.92 LE/h recorded under cutter head speed of 18.8 m/s, feed mechanism speed of 0.41 m/min and tubers moisture content of 81.6 % w. h. While, maximum losses cost value was 235.58 LE/h recorded under cutter head speed of 25.8 m/s, feed mechanism speed of 1.45m/min and fodder beet tubers moisture content of 57.9 % w. h.
Fig. 9. Effects of tubers moisture content, cutter head speed and feed mechanism speed on losses cost at chopping fodder beet tubers.

Operating cost and Criterion function cost:

Fig. 10 illustrate that, operating cost is decreased with increasing both of cutter head speed and feed mechanism speed. Also, it was decreased with decreasing fodder beet tubers moisture content. Where the lowest value of operating cost was 73.82 L.E/h recorded using cutter head speed of 25.8 m/s, feed mechanism speed of 1.45 m/min and fodder beet tubers moisture content of 57.9 % w. b. While, maximum value of operating cost of 104.52 L.E/h recorded with cutter head speed of 18.80 m/s, feed mechanism speed of 0.41 m/min and tubers moisture content of 81.6% w. b., respectively. On the other hand, Fig. 9 noticed also that, criterion function cost was increased with increasing both of cutter head speed and feed mechanism speed and it was increased with decreasing of fodder beet tubers moisture content. Results told that, the lowest value of criterion function cost of 134.71 LE/h records at cutter head speed of 18.8 m/s, feed mechanism speed of 0.41 m/min and tubers moisture content of 81.6% w. b. And maximum value of criterion function cost of 300.41 L.E/h recorded with cutter head speed of 25.8m/s, feed mechanism speed of 1.45m/min and fodder beet tubers moisture content of 57.9% w. b. Also through the intersection curves between criterion function cost and operating cost, it can determine the optimum point for the machine operation, which is then the least amount of criterion function cost and operating cost and through Fig.10. The optimum operation condition point for cutting fodder beet tubers at cutter head speed of 23.5 m/s, feed mechanism speed of 1.13m/min and fodder beet tubers moisture content of 74.4% w.b., respectively.

Fig. 10 . Effects of tubers moisture content, cutter head speed and feed mechanism speed on operating cost and criterion function cost at chopping fodder beet tubers.

Fodder beet silage:

For the possibility of evacuation of the ground and because the fodder beet is vulnerable to damage when storage. Keeping it in silage was a good technique. The following steps were followed:  
A- Thrones are separated from the roots (lack of separation hinders the work of cutting machines later).  
B- Fodder beet leaves for two weeks on a thick mattress of coarse materials (hay - firewood - straw) so as not to contaminate the soil and to absorb the resulting juicer. The place must be well ventilated shaded and left until the required humidity  
C- Fodder beet cut with a modified mincing machine and mix beets chopped sticks and corn cobs minced by 150 kg / ton fodder beet, in order to increase the proportion of dry matter and to absorb the juice produced from fodder beet.  
D- To increase the proportion of protein in the silage was added urea by 5 kg / ton fodder beet was dissolved in a quantity of water and spray the solution regularly on the fodder beet cut.

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E- Due to the speed of fermentation of beet sugars was accelerating the completion of filling and cover the pile with plastic and then a good layer of soil (about 30 cm) and then pressed well.

F- It was making 3-2 slots in each wall of the pile open when necessary to drain excess juice when the proportion of moisture exceeds the appropriate limit. To be closed those openings after the full drainage of this juice

It has been possible to obtain good quality silage characterized by the following:
1- The percentage of ammonia is about 8% evidence that the silage is good and the reactions are done in a good way.
2- The degree of PH was in the range of 3.6 - 4 and is ideal for silage.
3- The quality of silage was judged by understanding the relationship between the ratio of lactic acid relative to other organic acids.
4- The color of the silage is close to the natural color of the material green or light brown, which gave an indication of the quality of silage
5- Silage was judged to be good by keeping the leaves and stems in good condition
6- There were slight traces of butyric acid and the smell of ammonia, which gave an indication of the quality of silage.

CONCLUSION

From the above results the following conclusions are derived:
1- The optimum conditions operation of modified forage chopper machine at determined as follows: at cutting fodder beet tubers was at cutter head speed of 23.5 m/s, feed mechanism speed of 1.13 m/min and tubers moisture content of 74.4% w.b. under using swinging knives.
2- The increments in cutter head and feed mechanism speeds tend to increase the actual capacity and efficiency of stationary chopper. The maximum values of actual capacity and efficiency were 3.412 Mg/h and 88.41% at fodder beet tubers moisture content of 57.9% w.b, feed mechanism speed of 1.45 m/min and cutter head speeds of 25.8 m/s, respectively.
3- The results illustrated that the maximum value of chopping length category 3-6 mm suit for silage was recorded at tubers moisture content of 66.2%, cutter head and feed mechanism speeds of 25.8 m/s and 0.41 m/min, respectively.
4- From the energy point of view it can be stated that, the highest value of unit energy was 2.661kW.h/Mg at fodder beet tubers moisture content of 81.6% w.b, cutter head speed of 25.8m/s and feed mechanism speeds of 0.41 m/min, respectively. However, the lowest value was 0.767 kW.h/Mg recorded at tubers moisture content of 57.9% w.b, cutter head speed of 18.8 m/s and feed mechanism speeds of 1.45 m/min, respectively.
5- Minimum value of total losses was 7.65% and minimum value of losses cost was 35.92LE/h recorded at tubers moisture content of 81.6% w.b., cutter head speed of 18.8m/s and feed mechanism of 0.41 m/min, respectively.
6- Minimum value of operating cost was 73.82LE/h recorded at cutter head speed of 25.8m/s, feed mechanism speed of 1.45m/min and tubers moisture content of 57.9% w.b. While, minimum value of criterion function cost for cutting fodder beet tubers was 134.71 L.E/h, recorded at cutter head speed of 18.80m/s, feed mechanism speed of 0.41 m/min and tubers moisture content of 81.6% w.b.
7- Previous results noticed that, swinging knives suit for cutting fodder beet tubers for silage category 3-6 cm. Also, it is evident that, the ultimate analysis of the constituents of corn gave good quality silage for all treatments.

REFERENCES


تثبيت عوارض على محيط الأسطوانة لتثبيت السكاكين عليها. كما تم تثبيت عوارض على محيط أسطوانة التلقيم لتفادي خروج الفضلات، وتم استبدال الألة بتوجيف مستوى لزيادة معدل التقطيع والفرم، وتم توجيه الماء المفرمل الألواح الخارجية. والدراسات على النحو التالي: المحتوى الرطوبـي للدرنات بنسبة 19.6٪، وعدد ثمانية سكاكين تقطيع بوضع مائل بزاوية 129٪. هذه السكاكين كانت لها شفرات جافة بزاوية 21°، كانت السكاكين بعرض 12.5 سم وطول 10 سم. تم إجراء التدريب على المحطة المحلية لتفادي التوقف في الألة. في حين أن الحد الأدنى لقيمة تكلفة الدالة المعيارية لتكاليف فرم درنات بنجر العلف كان 4.60 د.ساعة/ميجا جرام. وتم قياس معدل الفرق الكلي، وكان أدنى قيمة لتكاليف الفقد كانت 91.15 د.ساعة/ميجا جرام. وتم قياس معدل الفرق الكلي، وكان أدنى قيمة لتكاليف الفقد كانت 91.15 د.ساعة/ميجا جرام. وتم قياس معدل الفرق الكلي، وكان أدنى قيمة لتكاليف الفقد كانت 91.15 د.ساعة/ميجا جرام. وتم قياس معدل الفرق الكلي، كان أدنى قيمة لتكاليف الفقد كانت 91.15 د.ساعة/ميجا جرام. وتم قياس معدل الفرق الكلي، كان أدنى قيمة لتكاليف الفقد كانت 91.15 د.ساعة/ميجا جرام. وتم قياس معدل الفرق الكلي، كان أدنى قيمة لتكاليف الفقد كانت 91.15 د.ساعة/ميجا جرام.