Misr J. Ag. Eng., 24(3): 469-491 FARM MACHINERY AND POWER

MECHANIZATION SYSTEMS FOR SUGARBEET FIELD-LOADING ON TRUCKS

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ABSTRACT

The aim of this study is to investigate factors relevant to the mechanization of sugarbeet loading through some choices after harvesting. Different methods were compared to study loadling time and productivity for different systems, including economical feasibility. Study included: designing a conveyor to load lorry trucks and trailers; and path determination of the sugarbeet after separating from the conveyor. The main results and conclusions can be summarized as follows:

- *The productivity in descending order for one laborer of different loading methods is as follows: power loader (20.1 ton/h) > conveyor aided with apron platform (5.43 ton/h) > conveyor without apron platform (4.10 ton/h), and > manual loading (1.07 ton/h) resp.*
- *The loading costs are as follows in descending order: engine-operated conveyor (24.15 L.E./trailer) < loader (35.57 L.E./trailer)< conveyor attached to tractor (69.61 L.E./trailer), and < manual loading (72 L.E./trailer).*
- *The trash ratio for loading by power loader was 14.5 to 30% (the factory deducts the trash from total mass of sugarbeet on lorry or trailer when the trash ratio exceeds 8%).*
- *The lowest ratio of buckets missing of conveyor with access platform and netting was 4.3% at 14.2 cm/s conveyor speed, platform height 15 cm, and angle of platform slope 0^o and 20^o with the horizontal.*
- *The equation of tuber trajectory in air when thrown by hands is:*

$$y = -\frac{g}{2\, v_0^2\, [\cos(\theta)]^2}\, x^2 + \tan(\theta)\, x + y_0$$

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: x, y = Cartesians coordinates, “m”,

g = Gravity acceleration, (9.81 m/s^2),

v_0 = Initial speed, “m/s”,

y_0 = Initial height of throwing “m”,

θ = Projectile angle, “deg”.

INTRODUCTION

Sugar is one of the important products in the world. Its production depends on two main crops, namely: sugarcane and sugarbeet. The total Egyptian production of sugar (between 1978 and 2002) has increased from 593.14 to 1372 thousand tons (ratio of increasing about 131%). However, the sugar from sugarbeet is about 396100 ton (28.86% from the total production in 2002). The area and productivity of sugarbeet increases.

(according to Afifi, 2003.) are as follows:

Year	Area,10^3 fed.	Productivity, in M tons
1982	16.9	0.2137
2002	153.8	3.168
% Increase	810	1380

Sugarbeet crop faces some problems of decreased quality and value, due to being left in the field after harvesting before transporting to the sugar factory. Some problems are as follows:

1- The roots loose some natural characteristics due to drying leading to difficulty of slicing.

2- Decreasing in saccharose content and quality characteristics required for manufacturing.

3- Increasing the percentage of non-sugar materials, such as mineral non-sugars and others, which affect quality characteristics.

The loss values vary depending on the variety of sugarbeet, harvesting time, damage happening while harvesting and handling, duration time between harvesting and manufacturing and storing conditions.

As a result of shortage in labor and transporting, the farmers leave the crop in the field for days after harvesting before transporting to the sugar factory. This leads to losses in tubers weight, sugar content and quality.

Loading trailer of 10 tons needs 10 persons. Loading time overlaps with rice planting which requires more labor.

This research contributes to the mechanization of loading beets through comparing different machines, handling times, productivities and crop quality for each system. It includes also the following objectives:

- Study of losses of loading for each operation (manual, loader, and conveyor).
- Study of costs for each system including losses.
- Recommending the best appropriate system for field conditions.
- Design of conveyor for loading of sugarbeet and carrying out tests and studies on small-scale prototype.

Kepner et al. (1982) mentioned that one of the basic mechanical operations performed in production of sugarbeet is elevating the beets and separating them from clods and other foreign materials. **Vaccari et al. (1988)** noted that in the Mediterranean countries, the effects of damage of sugarbeet roots are more critical because of warm and humid climate at late harvest time (May and June). This climate requires no more 48 h between harvesting in field and processing in sugar factory. **Shoughy (2004)** studied the effect of weather conditions and delaying period before processing under various storage conditions. He recommended the necessity of transporting and manufacturing sugarbeet just after harvesting or storing it under cooling in factory to reduce sugar losses. **Whitey and Cochran (1978)** concluded that a transport system depends upon several components, which are identified as follows:

1 – Loader or chopper harvester.	2 – Transport units.
3 – Capacity of units.	4 - Field to mill distance.
5 – Average speed of transport.	6 – Mill waiting time.

El-Danasory and El Awady (1998) studied developing a cart to move on the narrow roads. The results indicated that the height of centre gravity of loads varied in wide range according to bulk density of agricultural material and type of transport mean.

MATERIALS AND METHODS

1- Lift conveyor:

Design of the proposed lift conveyor is shown in fig. (1).

The conveyor prototype was constructed (ratio between small-scale prototype and the original scale of conveyor = 1/4) to lift sugarbeet from ground level to trailer top as shown in fig. (2), in the machine laboratory, Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University.

The prototype is made up of two sided chains “286 cm” length. The chains turn around sprockets of “13.56 cm” diameter. There are 31 pins between the links of the two chains. The distance between the chains is “33.5 cm”. Some of these pins carry buckets. The buckets hold the sugarbeet while being lifted. The two bearings are mounted through slots for chain tightening.

The conveyor is covered by netty retention for preventing sugarbeet wedging or falling between the axles.

The frame is made from steel angle sections 40*40*4 mm fig. (2). The base frame is made of square sections 500*500 mm. The conveyer carrier frame was made from two steel angle sections 240 cm length.

Two pneumatic ground wheels, of 35 cm diameter and 7 cm width were used.

The conveyor is attached to a small power unit through a pulley and belt, as shown in figs. (2). The speed ratio can be changed through pulleys 20, 15, and 10 cm diameter, mounted on the ground wheels axle. There are two driven pulleys with “5 and 10cm” diameters connected with the lift conveyer.

The power unit (Awady, 1986) was used in this study as shown in fig. (2). The power unit had 5 Hp (3.75 kW) gasoline engine, rated at 3500 rpm, and overall diameter of wheels = 40 cm.

The conveyor was connected to the power unit through two pulleys and belt.

An apron platform was used to prevent the sugarbeet from impeding the conveyor or stopping it (when sugarbeet jams between ground and conveyor), and to facilitate feeding of sugarbeet on the conveyor. The platform is made from steel sheet. It is mounted on the frame steel L-section. A slot is used for adjusting the apron platform height and angle. It was built from steel sheet “2mm” thick and “45cm” length and ”55cm” width.

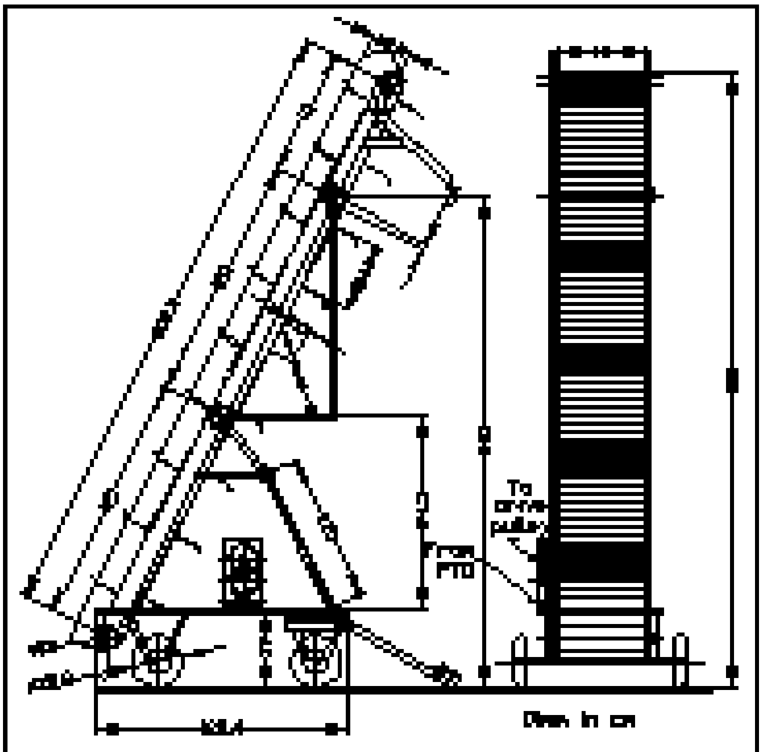


Fig. 1: Design of proposed lift conveyor.

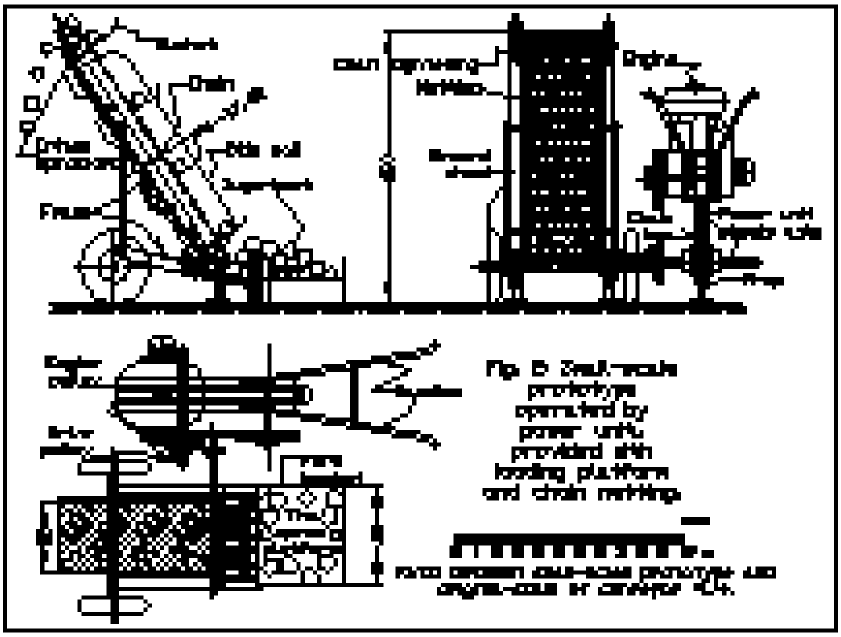


Fig. 2: Small-scale prototype operated by power unit, provided with loading platform and chain markings.

2- Computer model:

Computer model aims to: determine the factors which affect on beet trajectory, determination of the suitable initial speed, and ejection angle at different horizontal distances between laborer and trailer, which affect on vertical heights reached by thrown beets.

A "PC" was used to elaborate the suitable trajectory of the tuber model as shown in flow-chart diagram (3) "MATLAB – version 6.5" was used in electronic modeling of the trajectory. Computer configuration is P III 750 MHz. The program starts by asking the user to input initial throwing height, velocity and angle and draws the path of tuber in air.

The equation (2) used is according to what is stated in the section "3-3-2 theoretical study", with the relevant nomenclature.

$$y = y_0 + x * \tan(\theta) - {g * x^2} / {2 * v^2 \cos^2(\theta)}$$

To calculate the trajectory of (tuber) height "y" is calculated at different distances "x".

The trajectory of tuber in air is drawn graphically.

3- Instrumentations:

Sugarbeet volume: A tank was used to measure volume of sugarbeet by water displacement. The cylinderical tank was built from sheet steel "1 mm" thickness, "40 cm" diameter and "75 cm" height. There is a hole with welded mouth piece at "65 cm" from bottom to spill out the displaced water. Graduated cylinder was used to estimate the volume of displaced water with accuracy of "10 ml" and of "1 liter" capacity.

- Table balance with measuring range (0.1 to 40 ton was used to determine the weight of transported sugarbeet at the mill.

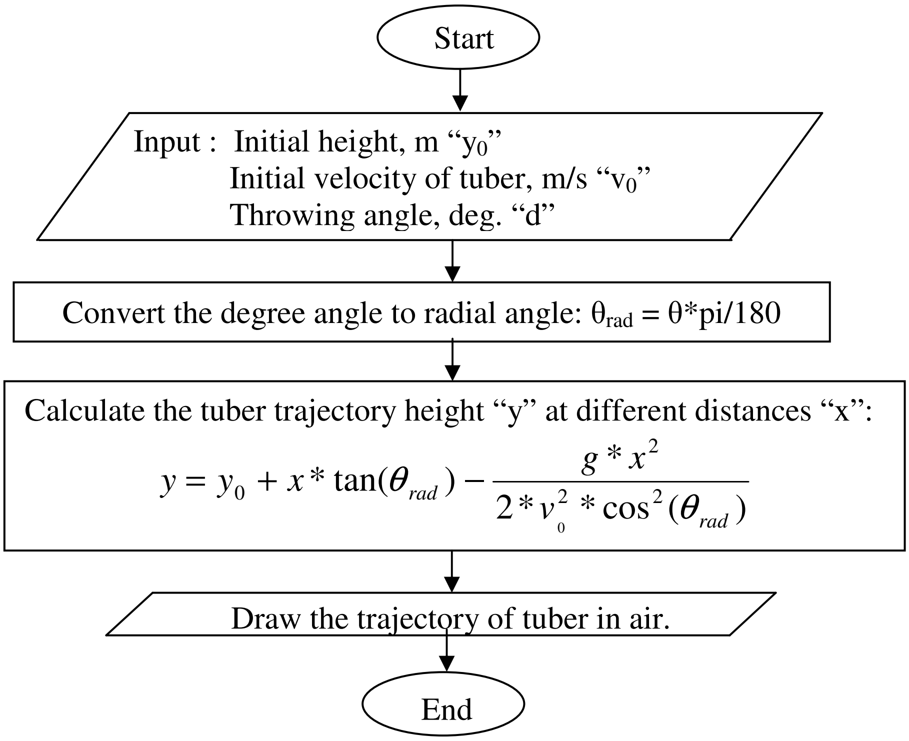


Fig. 3: Flowchart of drawing for trajectory of tuber in air when thrown by hands. (Matlab \ Simulink Software)

4-Physical properties of sugarbeet :

Physical properties of sugarbeet were measured in average by using:

1- Dimensions in three orthogonal dimensions (a, b, c), as shown in fig. (4).
2- Volume of sugarbeet by water displacement, "V".
3- Mass of sugarbeet , "M".
4- Density of sugarbeet by, "ρ":

$$\rho = M/V \quad \Rightarrow \quad (1)$$

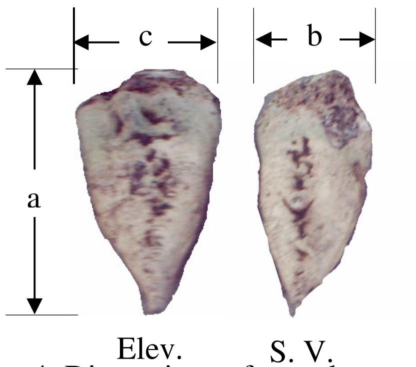


Fig. 4: Dimensions of sugarbeet in three orthogonal dimensions.

5- Theoretical study :

5-1 Tuber trajectory in air when thrown by hands:

Final equation obtained from this conclusion depended on “Matlab\Simulink” software. The model was used to determine the best variable values of initial velocity, and ejection angle at different horizontal and vertical distances to properly load the trailers.

The trajectory of tuber when thrown by hands fig. (5), can be determined by using the following relationships:

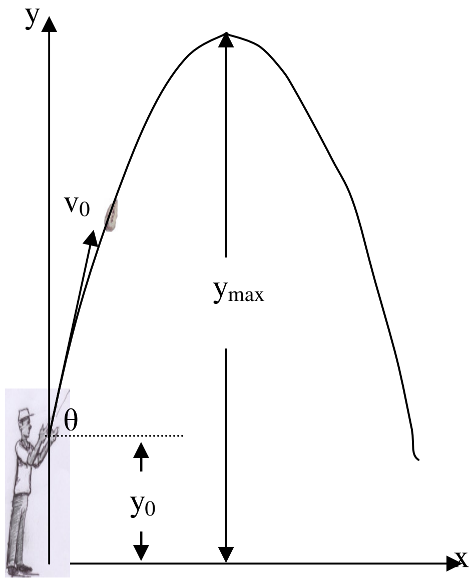


Fig. 5: Trajectory of tuber in air after thrown by hands.

$$m\,\ddot{y} = -m\,g, \qquad m\,\ddot{x} = 0$$

$$\dot{y} = -\int g\ dt = -g\ t + v_0\ \sin(\theta), \qquad \dot{x} = v_0\ \cos(\theta)$$

$$y = \int(-g\ t + v_0\ \sin(\theta))\ dt = -\frac{1}{2}\ g\ t^2 + v_0\ \sin(\theta)\ t + y_0$$

$$x = \int(v_0\ \cos(\theta)\ dt = v_0\ \cos(\theta)\ t + 0 \Rightarrow t = \frac{x}{v_0\ \cos(\theta)}$$

: x starting from zero.

∴ The Cartesian equation of the projectile:

$$\therefore\ y = -\frac{g}{2\ v_0^2\ [\cos(\theta)]^2}\ x^2 + \tan(\theta)\ x + y_0 \quad \Rightarrow \quad (2)$$

:	x, y	= Horizontal and vertical distances resp., “m”, fig. (5).
	g	= Gravity acceleration, (9.81 m/s^2)
	$\ddot{x},\ \ddot{y}$	= Horizontal and vertical accelerations, resp.,
	$\dot{x},\ \dot{y}$	= Initial horizontal and vertical velocities, resp.,
	t	= Time
	v_0	= Initial speed, “m/s” as shown in fig. (5),
	θ	= Ejection angle, “degs” as shown in fig. (5).

5-2 Trajectory coordinates of sugarbeet after leaving conveyor:

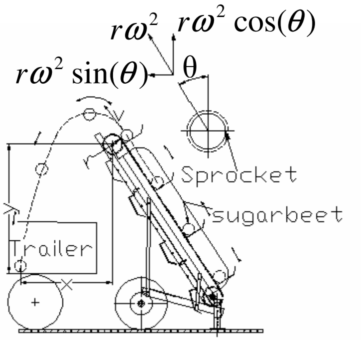


Fig 6: Sugarbeet trajectory.

Studying the coordinates of sugarbeet after leaving conveyor aims at its best position relative to trailer. The path and drop place of sugarbeet, when leaving the conveyor, can be determined by the following relationships:

$$y'' = r\omega^2 \cos(\theta) - g,\; x'' = r\omega^2 \sin(\theta)$$

$$y' = [r\omega^2 \cos(\theta) - g]t + y'_0, \quad x' = r\omega^2 \sin(\theta)t + x'_0$$

: x and y starting from zero.

$$y = \frac{1}{2}[r\omega^2 \cos(\theta) - g]\, t^2 + y'_0\, t, \quad x = r\,\omega^2 \sin(\theta)\,\frac{t^2}{2} + x'_0\, t$$

From fig. (6): $x'_0 = v\sin(\theta)$, $y'_0 = v\cos(\theta)$, $v = \omega\, r$, $v^2 = \omega^2\, r^2$

$$x = \frac{v^2}{r}\sin(\theta)\,\frac{t^2}{2} + v\sin(\theta)\, t, \quad y = (\frac{v^2}{r}\cos(\theta) - g)\,\frac{t^2}{2} + v\cos(\theta)\, t$$

y = 125 cm, for the small model.

$$\therefore \quad (\frac{v^2\cos(\theta)}{D} - \frac{g}{2})t^2 + v\cos(\theta)\, t - y = 0$$

$$t = \frac{-v\cos(\theta) - \sqrt{v^2\cos^2(\theta) - 4(\frac{v^2\cos(\theta)}{D} - \frac{g}{2})(-y)}}{\frac{2v^2\cos(\theta)}{D} - g} \quad \Rightarrow \quad (3)$$

$$x = \frac{v^2}{D}\sin(\theta)t^2 + v\sin(\theta)t \quad \Rightarrow \quad (4)$$

: x, y = Horizontal and vertical distances resp., as shown in fig.(6),
x'', y'' = Horizontal and vertical acceleration resp.,
x'_0, y'_0 = Initial horizontal and vertical velocity resp.,
t = Time   θ = angles. as shown in fig. (6).
v = Linear speed. ω = angle velocity.
D = Sprocket diameter. g = Gravity acceleration,

The results of eq. 4 are shown in fig. (9) compared with experiments on the small model.

5- 3 Dimensional analysis for conveyor productivity:

Factors which affect productivity of conveyor with or without apron platform charge, can be collected as follows:

Symbol	Definition	Dims.
P	Conveyor productivity with apron platform, "ton/h"	M/T
P_0	Conveyor productivity without apron platform, "ton/h"	M/T
v_c	Linear speed of conveyor, "cm/s"	L/T
V_b	Bucket volume, "cm^3"	L^3
ρ	Mean density/tuber, "g/cm^3"	M/L^3
s	Apron platform height, "cm"	L
θ	Platform angle, "degree"	$(MLT)^0$
N	No. of throwings per time, "shoots/min"	(1/T)

<u>Case (1):</u> Conveyor without apron platform charge:

In this case, factors which affect productivity of conveyor are as follows:

$$P_0 = f(N, v_c, V_b, \rho)$$, resulting groups are:

$$\pi_1 = \frac{P_0}{N V_b \rho}, \qquad \pi_2 = \frac{v_c}{N V_b^{1/3}} \Rightarrow (5).$$

<u>Case (2):</u> Conveyor with apron platform:

$$P = f(v_c, V_b, s, \theta, \rho)$$

$$\pi_1 = \frac{(P - P_0)}{v_c \rho V_b^{2/3}}, \qquad \pi_2 = \theta, \qquad \pi_3 = \frac{s}{V_b^{\frac{1}{3}}} \Rightarrow (6).$$

<u>6- Description of lorry and trailer:</u>

Data in table 1 show the dimensions of privately-owned lorry truck:

Table 2: Dimensions of lorry and trailer (cm).

		Lorry	Trailer
box	Height	175	200
	Width	250	300
	Length	560	500
Box height from ground		120	130
Wheel diameter		110	

7- Productivity:

Studying the productivity of the loading operation for each system depended on measuring averages of: mass of sugarbeet, number of laborers, and loading time for each systems.

7-1 Loader-trailer system:

Cycle time for loading and unloading = loading time + traveling time + unloading time (with empty bucket) + returning time + idle time.

Trailer loading time = average loading time X No. of cycles.

Capacity of loader bucket "kg" =

mass of sugarbeet loaded / No. of bucket cycles.

7-2 Conveyor:

The conveyor data are established as follows:

- Conveyor speed, " 14.2, 31.25, and 62.5 cm/s"
- Diameter of log wheel, "13.56 cm".
- Theoretical speed = conveyor speed "rpm" X π X 13.56 /60 "cm/s".
- Conveyor length "286 cm".
- Time of 10-conveyor revolutions (loading, and unloading buckets).
- Actual speed = 286 / time per conveyor revolution.
- Time of trailer loading.
- Number of total buckets loading.
- Number of empty buckets loading.
- Ratio of empty buckets:

$$Empty\ buckets\,\% = \frac{No.\ of\ \ empty\ buckets}{Total\ \ No.\ of\ \ buckets} \times 100$$

- Average mass of bucket loading:

$$Av.\ mass\ of\ \ bucket\ loading \quad = \quad \frac{mass\ of\ \ sugar\ beet}{average\ No.\ of\ \ buckets\ loading}$$

- Conveyor loading: The conveyor loading was calculated by stopping conveyor after ten buckets, then measuring number and mass of sugarbeets for each bucket in the conveyor prototype.

- Number of sugarbeets on bucket:

$$Number\ of\ \ sugarbeets\ on\ bucket = \frac{Number\ of\ \ sugarbeets\ on\ conveyor}{Number\ of\ \ buckets\ on\ conveyor\ side\ "4\ buckets".}$$

7-3 Manual loading:

- Time of trailer loading.

System productivity = Mass of sugarbeets / Time of loading

Laborer productivity for system = System productivity / No. of laborers

7- 4 Cycle time for manual loading:

- Number of throwings per trailer $= \dfrac{\text{sugarbeet mass per trailer}}{\text{av. beets mass * av. beet number per throwing}}$
- Number throwings per laborer
  = Number of throwings per trailer / Number of laborers
- Theoretical loading time =
  No. of laborer throwings * av. time per throwing by laborer
- Manual loading efficiency% $= \dfrac{\text{Theoretical loading time * 100}}{\text{Actual loading time}}$

8- Cost analysis:

Cost for each transportation and loading was determined as follows:

Operating cost was estimated according to **Awady (1978):**

$$C = p/h\ (1/e + i/2 + t + r) + (1.2kW * f * s) + w/144$$

: C	=Hourly cost in L.E.	i	=Interest rate.
p	=Capital investment in L.E.	kW	=Power of engine, (kW).
h	=Yearly operating hours.	t	=Taxes and overheads ratio.
e	=Life expectancy in years.	s	=Price of fuel per liter.

r =Repairs ratio to the total investment.

1.2 =A factor including reasonable estimation of the oil consumption in addition to fuel.

f =Specific fuel consumption lit/kW.h.

w =Labor wage per month in L.E.

144 =Reasonable estimation of monthly working hours.

- Rated rent was used to determine the loader, and tractor operating cost.

RESULTS AND DISCUSSION

1- Physical properties:

Density, mass, and volume of sugarbeet are shown in tables 2.

Table 2: Density, mass, and volume of sugarbeet (sample of 103 beets).

Physical prop.		Min.	Av.	Max.
Dims. "cm"	a	15	24.77	40
	b	5.72	10.67	17
	c	6.91	11.88	18
Mass "kg"		0.31	1.366	3.785
Volume "cm^3"		280	1195	3400
Density "kg/cm^3"		--	1.164	--

2-Computer-aided study on drawing the trajectory of tuber in air:

The computer was used to draw the trajectory of tuber in air by "Matlab software – version 6.5". Suitable path of tuber was obtained by the relevant nomenclature, in the "Materials and Methods" section " eq. (2).

Tuber height "y" was calculated at different distances "x", and drawing the trajectory in air was drawn. The trajectory can change by two variables (initial velocity "v_0", and throw angle "d"). Sample of path are shown in figs. 7 to 8.

- Fig. 7 shows the expected path of tuber in air from hands to trailer or lorry at initial height "y_0" =1.5 m, v_0 = 8.5 m/s and d = 75^o.

Fig. 8 shows that:

- Increasing the initial velocity "v_0", the maximum height "y_{max}" and horizontal distance "x" are increased at the same throw angle "d".
- When increasing the firing angle "d", the maximum height "y_{max}" is increased but horizontal distance "x" is decreased at the same initial velocity "v_0".

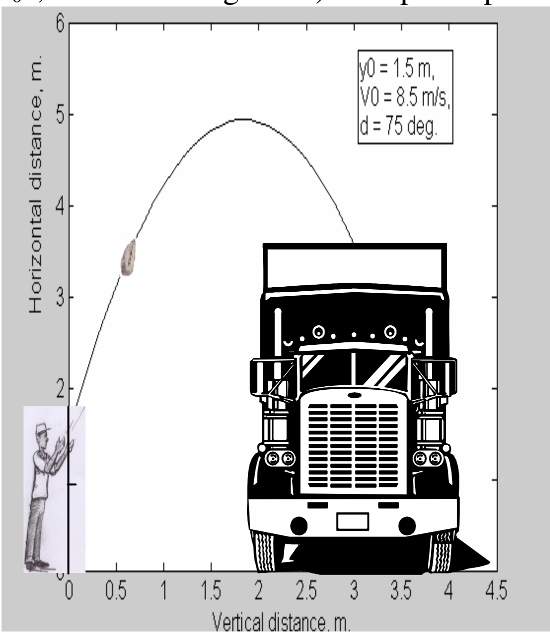


Fig. 7: Tuber trajectory in air when throwing by hands.

3- Trajectory of beets upon leaving conveyor:

Studying the coordinates of sugarbeet after leaving conveyor aims at determining best conveyor position relative to lorry or trailer. Fig. 9 shows the actual and theoretical paths for dropping sugarbeet "x: measured from small model" at constant height "y =125 cm". The theoretical path for dropping place of sugarbeet "x: was calculated from eq. 4".

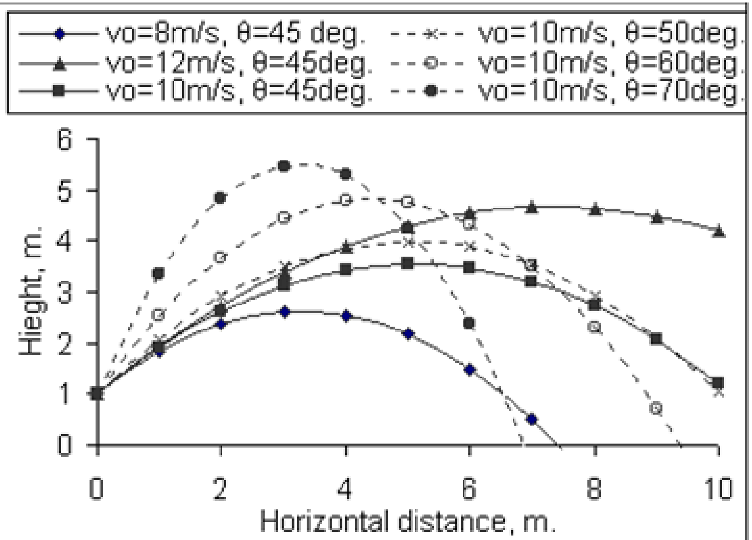


Fig. 8: Tuber trajectoryin air after throwing by hands.

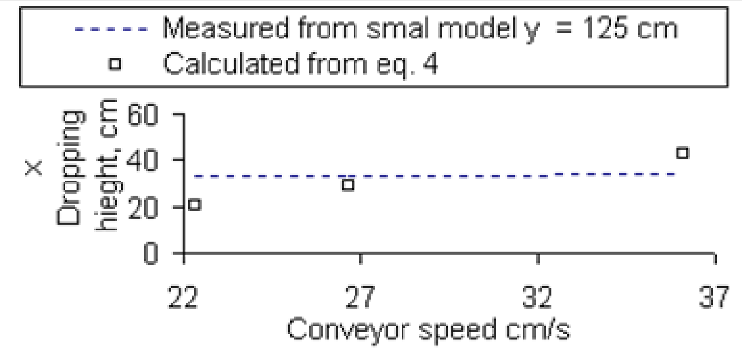


Fig. 9: Dropping distance of sugarbeet vs. conveyor speed at 125 cm dropping hieght.

where, t = time “s”, d = 7^{o}, v = π * D * N cm/s,
N = Speed (31.935, 40.096, and 51.238 rpm),
D =Diameter of sprocket “13.56 cm”, Y =Falling down height “125 cm”.

The calculated results show agreement with measured values around 30 cm/s.

4- Loading-rate parameters:

	Using loader	**Manual loading**
Haulage description	Lorry "table 1"	Trailer "table 1"
Lift height	3.5	
Loading time	24 min.	89 min.
Av. sugarbeet mass on haulage box	16.1 ton.	14.3 ton
Number of laborers	2	9
Productivity	20.1 ton/h/laborer	1.07 ton/h/laborer
Trash mass per lorry	2.33 ton (factory lab.).	Negligible*
Trash ratio	14.5%	Negligible*.

* the factory does not count trash of less than 8%.

5- Conveyor loading:

Studying the conveyor productivity of loading operation was carried out by using dimensionless groups including productivity by "ton/h/laborer", missing buckets%, lost-time%, mass and number of sugarbeets on conveyor and buckets.

5-1 Dimensional analysis for conveyor productivity:

Case (1): Conveyor without apron platform: (feeding by hands)

Fig. 10 shows the relationship between dimensionless groups as indicated in eq. (5). The curves indicate that:

- Group (1) represents the ratio of conveyor productivity to the rate of shooting, while group (2) represents the ratio of conveyor speed to the rate of shooting.
- The relation is flat with a max. value at the middle. The difference between the greatest and least values of group (1) was less than 0.045, that is 15.28%.

Case (2): Conveyor with apron platform:

Fig. 11 shows the relationship between dimensionless groups as indicated in eq. (6). The curves indicate that:

- The group (1) represents the net conveyor productivity with or without apron platform.
- The greatest value of group (1) was when group (2) was 0.498 at speed of 0.142 m/s.
- Data in table 3 show the maximum group (1) values with platform. At speed of 31 cm/s.

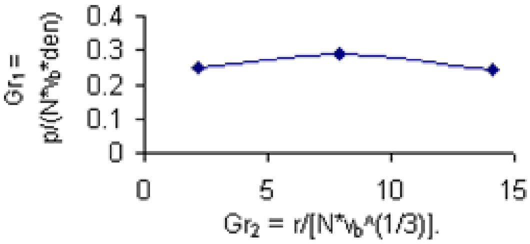
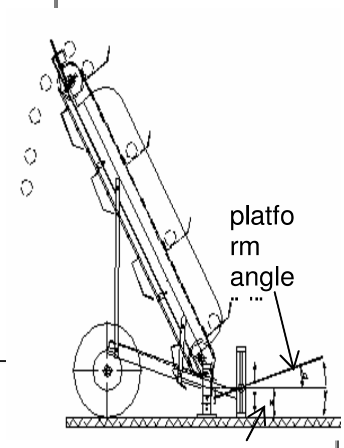


Fig. 10: Relationship between dimensionless groups of conveyor without platform.



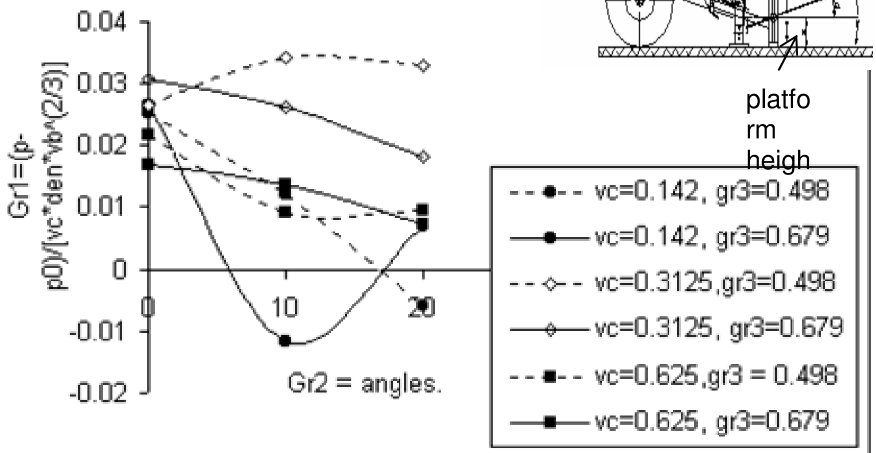


Fig. 11: Relationship between dimensionless groups of conveyor with platform.

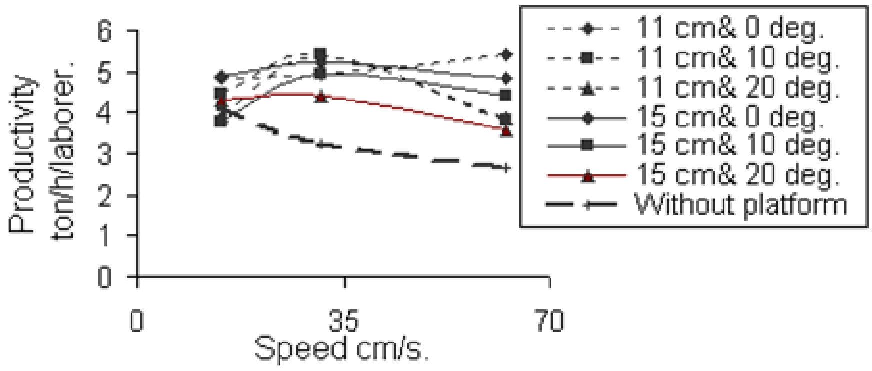


Fig. 12: Productivty of conveyor without and with platform apron at different drive axle speeds, platform heights and angles.

Table 3: Maximum of group (1) value with apron platform:

Group "θ" (angle)	Speed "v_c" m/s	Group (2) "$\frac{s}{V_b^{1/3}}$" (step height)	Group (1)
0	0.3125	0.679	0.031
10		0.498	0.034
20			0.033

5-2 Conveyor productivity:

Fig. 12 shows the productivity of conveyor with and without netting and apron platform at different speeds.

- Without netting and apron platform, the curve indicates that the productivity decreased (4.1 to 2.7 ton/h/laborer), when conveyor speed increased from 17.6 to 36.7 cm/s, as the ratio of sugarbeet mass on conveyor decreased and the ratio of lost-time and missing buckets increased. The productivity was approximately constant (2.73 to 2.68 ton/h/laborer), when conveyor speed increased from 36.7 to 75.89 cm/s, because the productivity of laborer (number of throwings) is constant.
- With netting and apron platform, the curves indicate that the productivity had maximum with conveyor speed. Apron platform increases the sugarbeet delivery. The greatest productivity was 5.43 ton/h/laborer, when conveyor speed was 31.25cm/s, platform height 11 cm, and angle of platform slope 10^o at horizontal, compared to without platform and netting, which was 4.1 ton/h/laborer.

5- 3 Missing-buckets ratio:

Figs. 13 shows the missing-buckets ratio of the conveyor with and without netting and apron platform at different conveyor speeds.

- Generally, the missing-buckets ratio increased with conveyor speed.
- Using the conveyor with apron platform and netting "as shown in fig. (2)" decreased the missing bucket ratio.
- The lowest ratio of missing-buckets of conveyor without the platform and netting was 9% at the 14.2 cm/s conveyor speed, compared to 4.3% for platform and netting at 14.2 cm/s conveyor speed. Platform height was 15 cm, and angle of platform slope was 0^o and 20^o with horizontal.

5- 4 Sugarbeet mass and number on conveyor and bucket:

Fig. 14 shows the sugarbeet mass and number on conveyor and bucket at different speeds.

- Generally, the mean mass and number of sugarbeets on conveyor and bucket decreased, with speed.
- For the conveyor without the platform and netting, highest mass and number on conveyor were 9.1 kg with 8.9 beets at 14.2 cm/s conveyor

speed, compared to 22.33 kg (4.24 kg per bucket) without platform and netting at 14.2 cm/s conveyor speed, platform height 15 cm, and angle of platform slope was 20^o with the horizontal.

- For the conveyor with the platform and netting, the greatest number on conveyor was 13.75 beets (3.44 beets/bucket) at 14.2 cm/s conveyor speed, platform height 15 cm, and angle of platform slope 0^o (horizontal). The difference between two heights of the platform (11, 15cm), was not

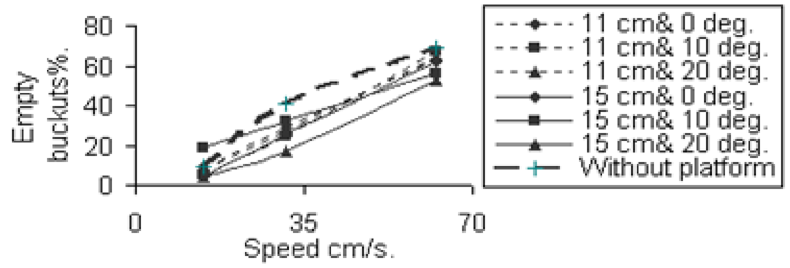


Fig. 13: Missing-buckets percentage of conveyor without and with platform apron at different conveyor speeds, platform heights and angles.

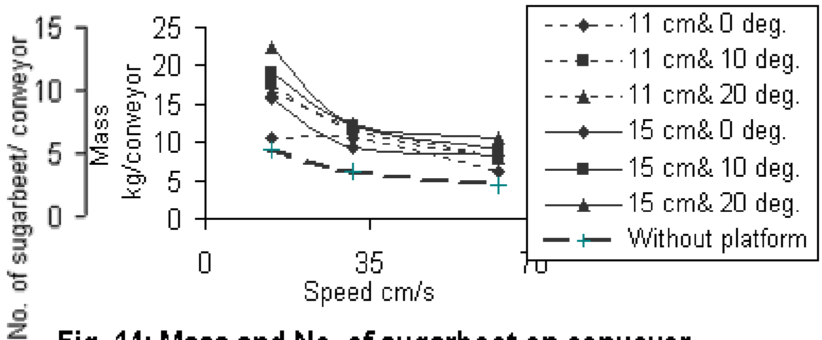


Fig. 14: Mass and No. of sugarbeet on conveyor (4 loaded buckects) at different conveyor speeds without and with platform heights and angles.

significant, because the sugarbeet piled on apron platform. It caused to increase height of sugarbeet on front of the bucket.

6- Comparison of productivity for the three loading methods:

Table (4) shows the productivity of different loading methods. The productivity is arranged from high to low, as follows:

Table (4): Productivity of different loading methods.

Method	Loader	Conveyor with apron platform	Conveyor without apron platform	Manual loading
Productivity ton/h/laborer	20.125	5.432 *	4.10*	1.074

* Taken as the greatest productivity per laborer from tests on the small-scale prototype, which is anticipated to be the same with the real- size equipment, since the feeding width/laborer is the same at the same elevator speed.

The greatest productivity is by using power loader, but the trash ratio is 14.5 to 30% (the factory deducts the trash from total mass of lorry or trailer when the trash ratio is more than 8%).

7- Cycle time of loading:

(a) Using power loader:

- Total loading time = 24 min.
- Sugarbeet mass on lorry box = 16.1 ton.
- Number of laborers = 2.
- Number of loading cycles by loader = 21.
- Elements of cycle loading time are shown in table 4 – 5:

Table 5: Elements of cycle loading for power loader time "s":

	Min.	Av.	Max.
Bucket loading	3.19	5.47	11.94
Traveling (unloading)	10.13	16.68	23.60
Returning	10.50	16.79	23.60
Turning	1.66	1.92	2.66
Unloading	3.78	5.88	7.30
Waiting	1.57	0.6	4.05
Actual total time	30.83	48.34	69.08

- Average total cycle time can be calculated from this equation:

= Total loading time / Number of loading cycles

= 24 / 21 = 1.14 min.

(b) Manual loading:

- Actual sugarbeet mass on trailer = 14.3 ton.
- Actual loading time = 89 min.
- Number of laborers = 9 laborers.

- Actual time of 100 throwings per laborer varied between 4.9725 and 8.858 min (average = 6.32 min).
- Average time per throwing by laborer = 0.0632 min.
- Average sugarbeet mass = 1.37 kg (from table 1)
- One sugarbeet/throwing.
- $$\text{Number of throwings per trailer} = \frac{\text{sugarbeet mass per trailer}}{\text{av. beet mass * av. beet number per throwing}}$$

  = 14300 / (1.37 * 1) = 10500 throwings/trailer
- Number of laborer throwing

  = Number of throwings per trailer / Number of laborers

  = 10500/ 9 = 1170 throwings/laborer/trailer
- Theoretical loading time

  = No. of laborer throwings * av. time per throwing

  = 1167* 0.0632 = 73.75 min.
- $$\text{Efficiency\%} = \frac{\text{Theoretical loading time * 100}}{\text{Actual loading time}}$$

  = 73.75 / 89 = 83%

8- Cost analysis for loading:

The cost of loading process per trailer or lorry is envisaged in four configurations: (1) the designed conveyor operated by a 30-hp (22.5 kW) tractor, (2) the designed conveyor operated by a 7-hp (5 kW) diesel engine, (3) tractor-mounted loader, and (4) manual loading for comparison.

The operation cost was estimated according to Awady (1978) as stated in the “Materials and Methods” section, with the relevant nomenclature stated therein, and the following given values:.

$$\mathbf{C = p/h\ (1/e + i/2 + t + r)+(1.2\ kW * f * s) + w/144}$$

Where “p” = 10, 170, 80 and 5 kL.E. for conveyor, loader, tractor, and elevator engine (5 kW), resp.; ”h” = 720, and 1000 h/y for conveyor, and loader, resp.; “e” = 10 years, “i” = 12%, “t” = 5%, “r” = 10%, “kW” = 22.5, 90, and 5 kW for tractor, loader, and elevator engine; ‘f’ = 0.33 lit/kW.h., “s” = 0.75 L.E., and “w” =300, and 500 for tractor, and loader.

Trailer or lorry capacity was assumed = 16 ton.

By using the cost components for the different systems, the final cost comparison for loading a trailer or lorry is shown in table (6). From the table, the cost is arranged from low to high as follows:

Conveyor operated by engine < loader < conveyor operated by tractor and at last < manual loading. The utilization of the conveyor operated by a 5 kW diesel engine is the most feasible for yearly operation of 700 h/y, compared with the other methods at 24.15 L.E./trailer.

Table 6: The cost comparision for loading a trialer or lorry:

<table>
<tr><th>Method</th><th colspan="2">Hourly cost “L.E.”</th><th>No. of laborers</th><th>Loading trailer time “h”</th><th>Total cost “L.E./trailer”</th></tr>
<tr><td>Conveyor with engine</td><td colspan="2">7.64*</td><td rowspan="7">2</td><td>1.84</td><td>24.15</td></tr>
<tr><td>Loader</td><td colspan="2">76.42*</td><td>0.4</td><td>35.57</td></tr>
<tr><td>Actual rent loader</td><td colspan="2"></td><td></td><td>45</td></tr>
<tr><td rowspan="2">Conveyor with tractor</td><td>conveyor</td><td>tractor</td><td rowspan="4">1.84</td><td rowspan="2">69.61</td></tr>
<tr><td>4.31*</td><td>22.65*</td></tr>
<tr><td rowspan="2">Conveyor whired tractor</td><td>conveyor</td><td>tractor</td><td rowspan="2">57.37</td></tr>
<tr><td>4.31*</td><td>20</td></tr>
<tr><td>Manual loading</td><td colspan="2"></td><td>9</td><td></td><td>72</td></tr>
</table>

*** by Awady eq. 1978**

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الملخص العربي

نظم ميكنة التحميل الحقلي لبنجر السكر

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يهدف البحث إلى دراسة:

1- تحميل البنجر على مقطورات بعدة وسائل: مثل التحميل اليدوي، آلة التحميل (power loader)، و جنزير رافع.
2- أزمنة و تكلفة عملية التحميل و العوامل المؤثرة عليها، مما يقلل فواقد البنجر و السكر في هذه الفترة.

و قد تم إنشاء نموذج معملي بنسبة تصغير 1|4 للرافع بسلاسل "جنازير" وجرافات، و أجريت عليه تجارب للحصول على نتائج يمكن الاستفادة منها في تصميم مرفاع متشابه بالحجم الطبيعي. و قد زود النموذج برصيف لتسهيل الشحن و شبكة من السلك على الجنزير لمنع الدرنات من الانحشار بين السلاسل.

وكانت أهم النتائج ما يلي:

- أعلى إنتاجية للجنزير الناقل كانت: في حالة وجود الرصيف و الشبكة، 5.43 طن/ساعة/عامل عندما كانت سرعة السير 31.25سم/ث، ورصيف ارتفاعه و زاوية ميله 11سم ،10^{5}.
- مقارنة بين طرق التحميل: عند ترتيب الإنتاجية من الأعلى إلى الأقل كانت: آلة التحميل بالجرار (اللودر) = 20.1 طن/ساعة/عامل، (أ) جنزير رافع مع وجود رصيف وشبكة = 5.432 طن/ساعة/عامل، (ب) جنزير رافع مع عدم وجود رصيف وشبكة = 4.1 طن/ساعة/عامل، ثم التحميل اليدوي = 1.074 طن/ساعة/عامل.
- تعد آلة التحميل المركبة على الجرار أعلى إنتاجية، و لكن يعيبها ارتفاع نسبة الشوائب في حمولة المقطورة، فهي تتراوح من 14.5 إلى 30% (من بيانات المصنع)، حيث يتم خصم نسبة الشوائب من حمولة الشاحنة أو المقطورة عندما تزيد نسبة الشوائب عن 8%.
- يمكن ترتيب تكلفة التحميل من الأقل إلى الأعلى كما يلي: الجنزير الرافع المستمد حركته من محرك منفصل < آلة التحميل بالجرار< الجنزير الرافع المستمد حركته من عمود الإدارة

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الخلفي للجرار < التحميل اليدوي. و من ثم يفضل استخدام الجنزير الرافع المستمد حركته من محرك منفصل قدرته حوالي 5 كيلووات، حيث أنه يعمل حوالي 700 ساعة في الموسم (العام) مقارنة بالطرق اليدوية.

- استنباط معادلة توضح مسار حركة البنجر عند التحميل اليدوي. و استخدام برنامج"Matlab –/Simulink, version 6.5" لرسم هذا المسار.

$$y \;=\; -\frac{g}{2\,v_0^2\,[\cos(\theta)]^2}\,x^2 + \tan(\theta)\,x + y_0$$

- تحديد مسار البنجر و إحداثيات سقوطه بعد مغادرة الجنزير لتحديد موضع المرفاع (elevator conveyor) حتى لا يخرج البنجر خارج المقطورة، وتحديد ما إذا كان يحتاج إلى موجه أو موزع للبنجر بعد السقوط. ويمكن حساب مسار البنجر (مكان السقوط "x") باستخدام المعادلة النظرية التالية:

$$x = \frac{v^2}{D}\sin(\theta)t^2 + v\sin(\theta)t$$

$$t = \frac{-v\cos(\theta) - \sqrt{v^2\cos^2(\theta) - 4(\frac{v^2\cos(\theta)}{D} - \frac{g}{2})(-y)}}{\frac{2v^2\cos(\theta)}{D} - g}$$

حيث:

: x، y: إحداثيات مكان سقوط بنجر السكر بعد مغادرة الجنزير الرافع (المسافة الأفقية و الرأسية على الترتيب)،

θ: الزاوية التي يصنعها البنجر على العجلة المسننة مع الرأسي عند مغادرة الجنزير "7^5".

g: عجلة الجاذبية الأرضية "981 سم/ث^2".

D: قطر العجلة المسننة "13.56سم". v: سرعة الجنزير "سم/ث"

تظهر توافقا عند سرعة 30 سم/ث للجنزير الرافع مع القياسات العملية.

- استخدام الجنزير الرافع مع وجود الرصيف و الشبكة على الجنزير أدى إلى زيادة متوسط حمولة الجرافة وانخفاض الوقت الضائع و الجرافات الفارغة.
- لا تتأثر إنتاجية الجنزير تأثرا ملحوظاً عند تغيير ارتفاع الرصيف من 11سم إلى 15 سم، وذلك لتراكم البنجر على الرصيف مما يزيد من ارتفاع البنجر أمام الجنزير.
- تزيد نسبة الجرافات الفارغة مع زيادة سرعة الجنزير. أقل نسبة للجرافات الفارغة في حالة وجود الرصيف و الشبكة كانت 4.3% و ذلك عند سرعة 14.2 سم/ث و ارتفاع الرصيف 15 سم، و زاوية ميله صفر^5، 20^5 مع الأفقي.
- متوسط حمولة الجرافة من البنجر، تقل مع زيادة سرعة الجنزير، فمثلاً: في حالة وجود رصيف و شبكة، كانت أقصى حمولة من البنجر 4.24كج للجرافة عند سرعة 14.2 سم/ث، و رصيف ارتفاعه 15سم، و زاوية ميله 20^5.