

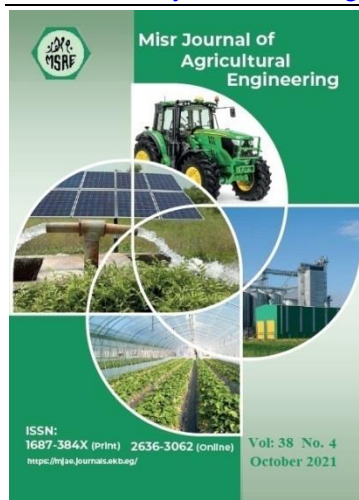
DEVELOPMENT OF A TURNIP CUTTING MACHINE

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Keywords:

Slicing Machine; Turnip;
Productivity; Uniformity
index; Efficiency

ABSTRACT

The main aim of the present study is to develop, to fabricate and to evaluate a cutting machine for turnip fingers to be used in small and medium production like stainless steel and mild steel were used in fabrication. The machine productivity increased with increased turnip size, slice thickness and cutting speed. The uniformity index increases with increasing turnip size, slice thickness and cutting speed. The cutting efficiency increased from 95.361 to 96.674 and 95.130 to 96.864 % with increased turnip size from small to large, slice thickness from 9 to 12 mm, respectively, while it decreased from 97.524 to 94.716 % with increased cutting speed from 250 to 550 rpm, respectively. The specific energy consumption decreased with increased turnip size, slice thickness and cutting speed. The total cost of slicing machine decreased from 0.081 to 0.043, 0.074 to 0.049 and 0.073 to 0.048 LE kg⁻¹ with increased turnip size from small to large, slice thickness from 9 to 12 mm and cutting speed from 250 to 550 rpm, respectively.

1. INTRODUCTION

Turnip is one of the Cruciferae family crops which used in pickles industry. Turnip is considered very low-calorie root vegetables and it is very good source of anti-oxidants. It contains vitamins B, C, K, proteins, fibers and minerals, as well as potassium, calcium, magnesium, sulphur and iron. It also helps the body scavenge harmful free radicals, prevention from cancers, inflammation, and helps boost immunity (**Shattuck and Keith, 1998**). The total cultivated area of turnip is about 35695.2 feddan (14873 ha). This area produced about 265600 Mg in 2019 according to **CAPMS (2019)**.

The chips and other snack foods in the world accounts for overall turnover of 2.2 billion dollars considering 70 % of it per manufacturing and technology research centers in the world. Also, the quality of chips plays a vital role in the hotel management. Due to uneven thickness of the slices arising from improper tools, a lot of wastage of vegetables is happening leading to loss of productivity and other miscellaneous damages to vegetables. The chips makers are at the risk of injuring their fingers and having difficulty in producing the type of slices they wanted (**Kartika and Arahamth, 2014**).

Fellow (2003) reported that the reduction in size of agricultural products is brought about by mechanical means without change in chemical properties of the materials. They are used to

improve the eating quality or suitability of foods for further processing and to increase the range of available products. With the development of a variety of cutting tools for size reduction, a lot of drudgery had been removed from processes which hitherto were tedious to accomplish. The size of agricultural products may be reduced by several ways. The main methods used are crushing, impact, shearing and cutting. Size reducing devices include crushers, slicers, grinders, and hammer mills.

Cutting has been described as the continuous process in which penetration of a sharp knife through a material result in a new surface due to failure in shear accompanied by deformation in bending and compression (**Lawson, 2004**). The method is particularly well adapted to the reduction of sizes of vegetables, fruits, fish, meat, roots and tubers. Cutting operation for large scale processing is used severally today in food processing industries, outdoor catering services, confectionaries, snacks centers and restaurants.

The slicer consists of material inlet system, cutting system, material outlet system and manual elevator system. The material inlet system is very simple; because it's a household slicer which doesn't have a large quantity to slice, the manual feed is used. It is not only lower the costs, but also reduces the size of the slicer (**He et al., 2013**).

The design of the slicer is in accordance with principles of ergonomics, easy to operate, convenient, safe and high stability. The shape and appearance, which is simple and decent, occupy less space and easy to carry, has greater aesthetic value. The overall structure is concise and reasonable (**Jiang, 2013**).

Several types of cutting machine are available. They include knives with one cutting edge, shear with two cutting edges and saw with many cutting edges. They may be operated manually or electrically (**Wilson and Kirk, 1982**).

After careful study of indigenous way of turnip cutting, it was observed that it involves a lot of physical labor and material wastage. Therefore, to improve the processing method and enhance it hygienic level, there is need of mechanization of the slicing method. The main aim of the present study is to develop, to fabricate and to evaluate a slicing machine for turnip slices to be used in small and medium production units, such as restaurants and hotels in order to save time and energy.

2. MATERIALS AND METHODS

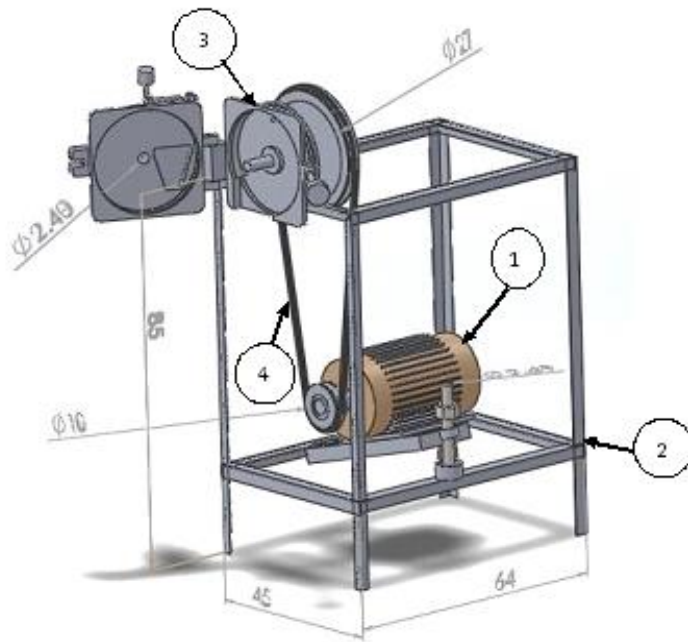
The main experiment was carried out at Agricultural and Bio-Systems Engineering Department, Faculty of Agriculture Moshtohor, Benha University, Egypt during 2020 season to develop, to fabricate and to evaluate a slicing machine for turnip fingers.

2.1. Materials

The turnip was brought from the local farms, at the beginning of the season. The turnip was inspected and divided into three size categories, small size < 50 mm, medium size from 50 to 80 mm and large size > 80 mm for turnip.

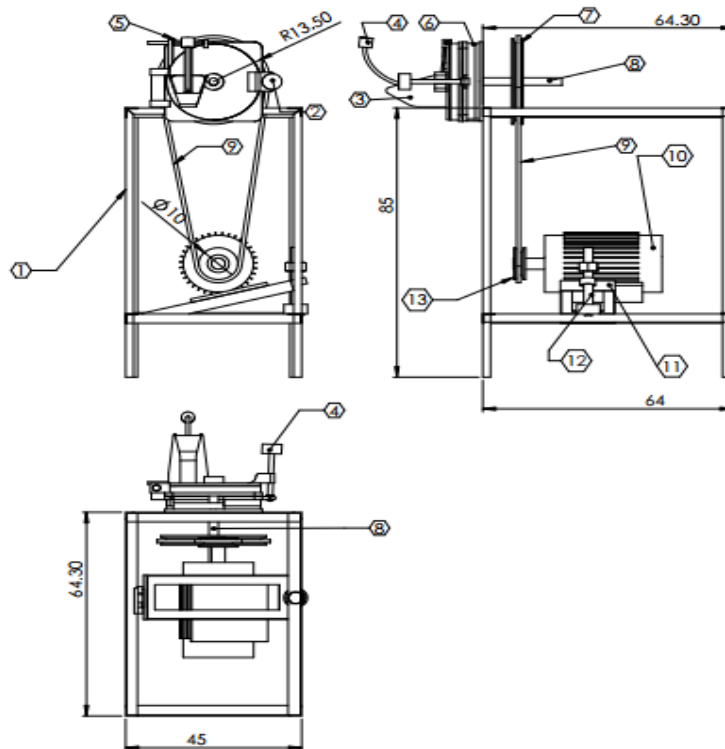
2.1.1. Machine description

The electrically operated turnip cutting machine was designed, fabricated and evaluated. Figs. 1 and 2 show the isometric drawing, the orthographic drawing and the picture of the machine. The components of the machine include the machine frame, the feeding unit, cutting unit and power transmission unit.



1. Motor, 2. Frame, 3. Cutting unit and 4. Belt

Fig. 1. Isometric drawing of the cutting machine.



- | | | |
|-------------------|-------------------------|------------------------------|
| 1. Main frame | 6. Housing | 11. Motor base |
| 2. Locking pin | 7. Cutting shaft pulley | 12. V- belt adjustment screw |
| 3. Feeding door | 8. Cutting shaft | 13. Motor pulley |
| 4. Feeding Handle | 9. V- shape belt | Dimension, cm |
| 5. Handle hinge | 10. Electric motor | Scale, 1:10 |

Fig 2. Orthographic drawing of the cutting machine.

2.1.2. The machine frame

The main frame of the machine was constructed from steel angles (30×30×3 mm for wide, high and thickness, respectively). Dimensions of the machine frame are 650 mm long, 450 mm for wide and 850 mm for high. All important parts of cutting machine were constructed from anti-rust materials.

2.1.3. Feeding unit

The turnips are fed manually, one by one into the hopper that attached with the pusher plate and has lever. The lever (handle) can be raised and lowered by hinge to feed and push the turnip by pusher plate into the slicing zone (rotating plate). The handle can be adjusted to prevent the pusher plate from coming in contact with the plate or blade. The hopper opening built-with the slicer door that can be opened to change the various types of rotating plates. To close the door after plate changing, the locking pin was used.

2.1.4. Cutting unit

The cutting unit consists of two parts:

The first part is cutting blades: This part consists of two circular plates (230 mm diameter and made of copper), stainless steel cutting blade is installed on the first plate. To adjust the thickness of the slices the spacers between the blades and the circular plate were designed. To obtain the thicker or thinner slices, just increase or decrease the spaces behind the blades to the desired width by loosening the bolts, and then fix the bolt. The second part consists of seven knives made of stainless steel for cutting turnip to fingers.

The second part is the housing: The housing is used to hold and release the various plates inside the cavity of it. In the center of the housing, the hole of the shaft which transfers the motion from motor to the rotating plate was constructed. To remove slice plate assembly from housing, the door was opened and raised the locking pin and the assembly will be free for removal by pulling outward. The cut turnips (fingers) are discharged through the lower end of the housing. The body of slicer which comprises of the door and housing were formed from raw molten aluminum.

2.1.5. Transmission system

The machine cutting is driven by 0.75 kW (1.0 hp), single phase electric motor. The power was transmitted to main shaft of the slicer by different changeable sizes of pulleys and V-shaped belts, to regulate the speed of motor from 1488 rpm to the required cutting speeds, which are 250, 350, 450 and 550 rpm (3, 4.2, 5.4 and 6.6 m s⁻¹).

2.2. Methods

The developed machine was evaluated by studying the effect of machine parameters such as speed and product parameters, such as size and slice thickness on the productivity, uniformity index, losses, efficiency, power requirements and cost.

2.2.1. Experimental design

The treatments were arranged in a split-split plot design in five replications. Three turnip sizes are small size < 50 mm, medium size from 50 to 80 mm and large size > 80 mm. Four cutting speeds are 250, 350, 450 and 550 rpm. Four slice thicknesses are 9, 10, 11 and 12 mm.

2.2.2. Measurements

2.2.2.1. Machine productivity

The machine productivity (kg h^{-1}) was defined as the load of the turnip divided by the total cutting time. The machine productivity was estimated the following equation:

$$Pr = \frac{L}{T} \quad (1)$$

Where:

Pr = Machine productivity, kg h^{-1}

L = The load, kg

T = The load time, h

2.2.2.2. Slice size uniformity index

The uniformity of size of slice was determined by sorting out the different size ranges of cut. The uniformity Index (U.I) was computed from the relationship below according to (Akande *et al.*, 2008).

$$U.I = \frac{\text{No. of fingers with same dimension}}{\text{Total No. of chips collected}} \times 100 \quad (2)$$

Where:

U.I = The uniformity index, %

2.2.2.3. Loss percentage:

Loss percentage incurred by machine was estimated from the following equation (Abd El-Haq *et al.*, 2016):

$$P.L = \frac{\text{Total mass of sample} - \text{Mass after cutting}}{\text{Total mass}} \times 100 \quad (3)$$

Where:

P.L is the percentage of loss, %

2.2.2.4. Machine cutting efficiency

Machine cutting efficiency was estimated from the following equation (Abd El-Haq *et al.*, 2016).

$$\eta = (100 - P.L) \quad (4)$$

Where:

η is the machine cutting efficiency, %

2.2.2.5. Power and energy requirement for slicing machine

The power requirement (kW) was estimated by using the clamp meter to measure the line current strength (I) and the potential difference value (V).

The total electric power requirement under machine working load (P) was calculated according to Kurt (1979) by the following equation:

$$P = \frac{I \times V \times \cos\theta}{1000} \quad (5)$$

Where:

P = The power requirement to cutting turnip, kW

I = The line current strength, Amperes.

V = The potential difference, Voltage.

Cos θ = The power factor, equal 0.8.

The specific energy consumption (SEC) in kW.h kg⁻¹ was calculated by using the following equation:

$$SEC = \frac{P}{Pr} \quad (6)$$

Where:

SEC = The specific energy consumption, W.h kg⁻¹

2.3. Total Costs

The cost calculation based on the following parameters was also performed according to **Suliman (2007)**:

Fixed costs (Fc)

- Depreciation costs (D_c)

$$D_c = \frac{P_d - S_r}{L_d} \quad (7)$$

Where:

D_c = The depreciation cost, LE (Egyptian pound) year⁻¹. (\$ = 15.63 EGP)

P_d = The Machine price, 3000 LE.

S_r = The salvage rate (0.1P_d) LE.

L_d = The Life expected, year.

- Interest costs (I_n):

$$I_n = \frac{P_d + S_r}{2} \times i_n \quad (8)$$

Where:

I_n = The interest, LE year⁻¹.

i_n is the interest as compounded annually, decimal. (12%)

Shelter, taxes and insurance costs (S_i):

Shelter, taxes and insurance costs were assumed to be 3 % of the purchase price of the machine (P_m).

Then:

$$\text{Fixed cost} = D_c + I_n + 0.03 P_m / \text{hour of use per year} \quad (9)$$

Variable (operating) costs (Vc):

- Repair and maintenance costs (R_m):

$$R_m = 100 \% \text{ depreciation cost} / \text{hour of use per year} \quad (10)$$

- Energy costs (E):

$$E = EC \times EP \quad (11)$$

Where:

E = The energy costs, LE h⁻¹.

EC = The electrical energy consumption, kWh.

EP = The energy price, 0.57 EGP kW⁻¹.

Labor costs (L_a):

$$L_a = \text{Salary of one worker} \times \text{No. of workers} \quad (12)$$

Where:

L_a = The Labor costs, LE h⁻¹.

Salary of one worker = 10 LE h⁻¹.

No. of workers = 1

Then:

$$\text{Variable costs} = R_m + E + L_a \quad (13)$$

Total costs (T_c):

$$\text{Total costs} = \text{Fixed costs} + \text{Variable costs} \quad (14)$$

2.4. Statistical analysis

The statistical analysis for the data obtained was done according to **Snedecor and Cochran (1980)** and the treatments were compared using Least Significant Differences (LSD) test at 99% confidence level (**Gomez, 1984**).

3. RESULTS AND DISCUSSIONS

3.1. Machine productivity

Figs. 3, 4 and 5 show the machine productivity of the turnip cutting as affected by the turnip size from small (>50 mm) to large (<80 mm), the slice thickness from 9.0 to 12.0 mm and cutting speed from 250 to 550 rpm. The results indicate that the machine productivity increases with increasing turnip size, slice thickness and cutting speed. It indicates that when the turnip size increased from small to large, the machine productivity significantly increased from 246.249 to 452.356 (by 45.56%) kg h⁻¹. It also indicates that when the slicer thickness increased from 9.0 to 12.0 mm, the machine productivity significantly increased from 280.026 to 421.881 (by 33.62%) kg h⁻¹, while the machine productivity significantly increased from 290.427 to 434.313 (by 33.13%) kg h⁻¹ when the cutting speed increased from 250 to 550 rpm.

It could be noticed that increasing the turnip size from small (<50 mm) to large (>80 mm), tends to increase the machine productivity from 190.044 to 400.367, 215.038 to 428.509, 273.444 to 433.884 and 306.468 to 546.666 kg h⁻¹ at 250, 350, 450 and 550 rpm cutting speeds, respectively. The results also indicate that the machine productivity increased from 190.044 to 306.468, 280.869 to 449.805 and 400.367 to 546.666 kg h⁻¹ at small (<50 mm), medium (50 – 80 mm) and large (>80 mm) turnip sizes, respectively when the cutting speed increased from 250 to 550 rpm as shown in fig. 3. The trend of these results agreed with those obtained by **Aniyi (2006) and Fayose (2007)**.

The statistical analysis showed that the differences between the obtained data of machine productivity due to the effect of turnip size (A), slicer thickness (B) and cutting speed (C) were significant. The analysis showed also that the interaction between both AC and ABC were non-significant. On the other hand, the interaction between the effect of both AB and BC on the data was significant.

Regarding the effect of turnip size and slice thickness on the machine productivity, the results indicate that the machine productivity increases with increasing the turnip size and slicer thickness. It increased from 200.443 to 375.230, 231.588 to 408.454, 261.469 to 487.694 and 291.495 to 538.048 kg h⁻¹ at 9.0, 10.0, 11.0 and 12.0 mm slice thickness, respectively, when the turnip size increased from small (<50 mm) to large (>80 mm).

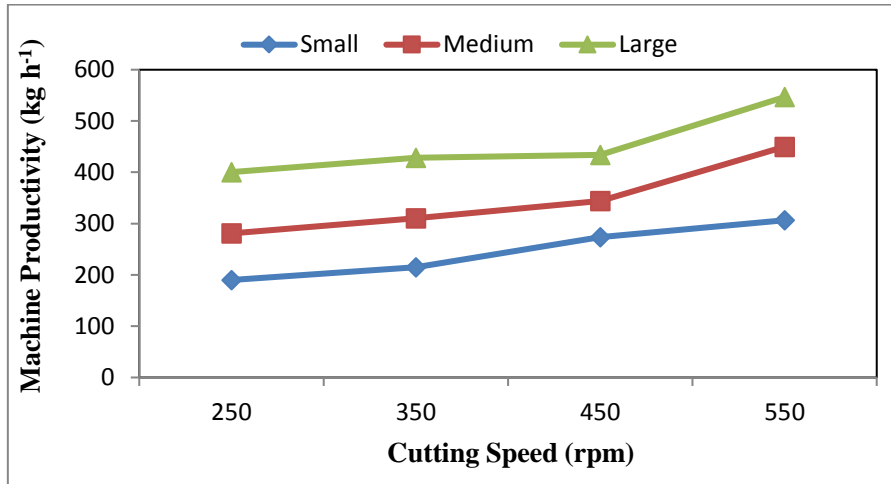


Fig. 3. Machine productivity at different turnip sizes and cutting speeds.

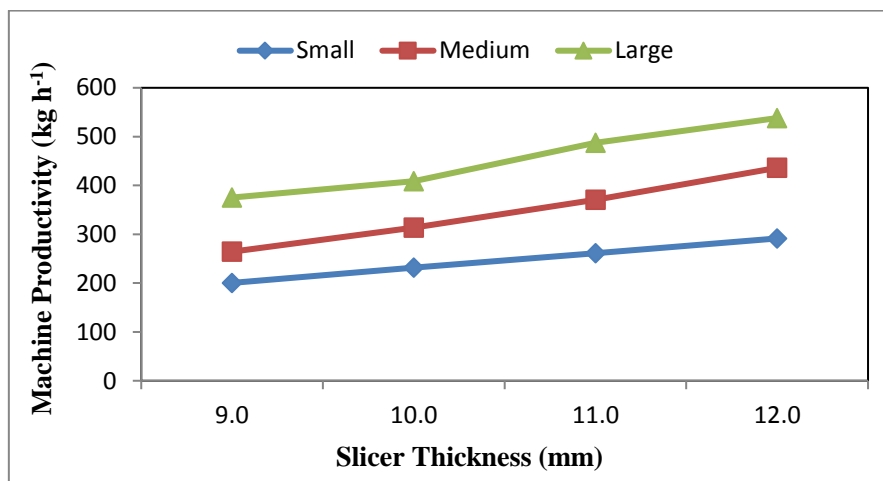


Fig. 4. Machine productivity at different turnip sizes and slice thicknesses.

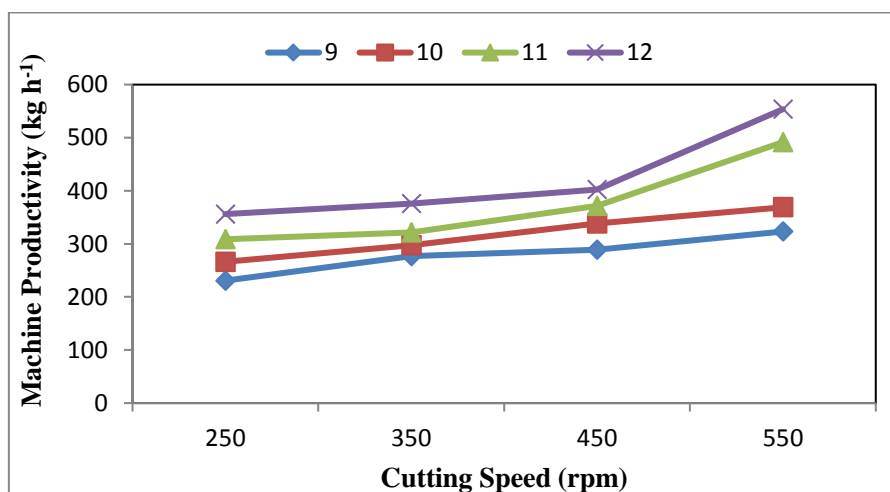


Fig. 5. Machine productivity at different slice thicknesses and cutting

The results also indicate that the machine productivity increased from 200.443 to 291.495, 264.407 to 436.100 and 375.230 to 538.048 kg h⁻¹ at small (<50 mm), medium (50 – 80 mm) and large (>80 mm), respectively, when the slicer thickness increased from 9.0 to 12.0 mm as shown in fig. 4.

The results also indicate that the machine productivity increased from 230.730 to 323.211, 266.251 to 368.922, 308.660 to 491.550 and 356.066 to 553.568 kg h⁻¹ at 250, 350, 450 and 550 rpm cutting speed, respectively, when the slicer thickness increased from 9.0 to 12.0 mm. The results also indicate that the machine productivity increased from 230.730 to 356.066, 277.172 to 375.532, 288.992 to 402.358 and 323.211 to 553.568 kg h⁻¹ at 9.0, 10.0, 11.0 and 12.0 mm slicer thickness, respectively, when the cutting speed increased from 250 to 550 rpm as shown in fig. 5.

3.2. Uniformity index

Figs. 6, 7 and 8 show the uniformity index of the turnip cutting as affected by the turnip size from small (>50 mm) to large (<80 mm), the slice thickness from 9.0 to 12.0 mm and cutting speed from 250 to 550 rpm. The results indicate that the uniformity index increases with increasing turnip size, slice thickness and cutting speed. It indicates that when the turnip size increased from small to large, the uniformity index significantly increased from 77.5 to 84.6 (by 8.39%) %. It also indicates that when the slice thickness increased from 9.0 to 12.0 mm, the uniformity index significantly increased from 75.9 to 85.2 (by 10.92%) %, while the uniformity index significantly increased from 77.3 to 84.2 (by 8.19%) % when the cutting speed increased from 250 to 550 rpm.

Fig. 6 shows the effect of turnip size and cutting speed on the uniformity index. It is obvious that the uniformity index increased with increasing cutting speed from 250 to 550 rpm at different turnip sizes. It could be seen that the uniformity index values were 74.4, 76.5, 79.3 and 79.7 %, respectively, at small turnip size, while they were from 76.9, 79.6, 82.5 and 85.0 %, respectively, at medium turnip size and 80.8, 83.9, 85.9 and 87.8 %, respectively, at large turnip size, when the cutting speeds were 250, 350, 450 and 550 rpm.

Fig. 7 shows the effect of turnip size and slice thickness on the uniformity index. It is clear that the uniformity index increased with increasing slice thickness from 9.0 to 12.0 mm at different turnip sizes. The results indicated that the uniformity index ranged from 71.2, 76.3, 79.6 and 82.8 %, respectively, at small turnip size, while it ranged from 76.0, 79.6, 83.2 and 85.3 %, respectively, at medium turnip size and it ranged from 80.6, 84.4, 85.8 and 87.7 %, respectively, at large turnip size, when the slice thicknesses were 9.0, 10.0, 11.0 and 12.0 mm.

Fig. 8 shows the effect of cutting speed and slice thickness on the uniformity index. The results indicate that the uniformity index increases with increasing the cutting speed and slicer thickness. It increased from 71.7 to 83.3, 74.2 to 84.7, 76.9 to 86.2 and 80.9 to 86.8 % at 250, 350, 450 and 550 rpm cutting speed, respectively, when the slice thickness increased from 9.0 to 12.0 mm. The results also indicate that the uniformity index increased from 71.7 to 80.9, 75.3 to 84.1, 79.0 to 84.9 and 83.3 to 86.8 % at 9.0, 10.0, 11.0 and 12.0 mm slice thickness, respectively, when the cutting speed increased from 250 to 550 rpm.

Figs. 9a, b, c and d show the frequency distribution of the thickness of slice (9.0, 10.0, 11.0 and 12.0 mm) of the turnip cutting.

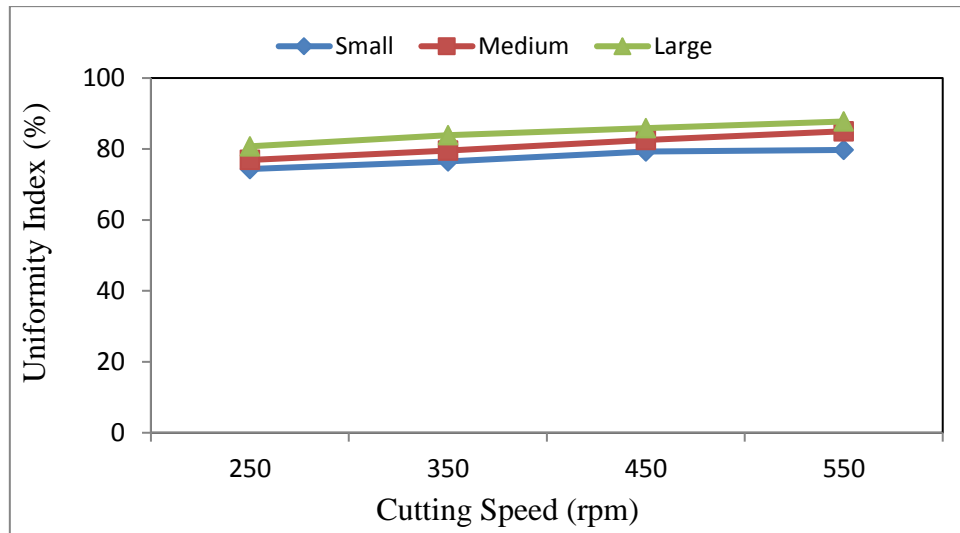


Fig. 6. Uniformity index at different turnip sizes and cutting speeds.

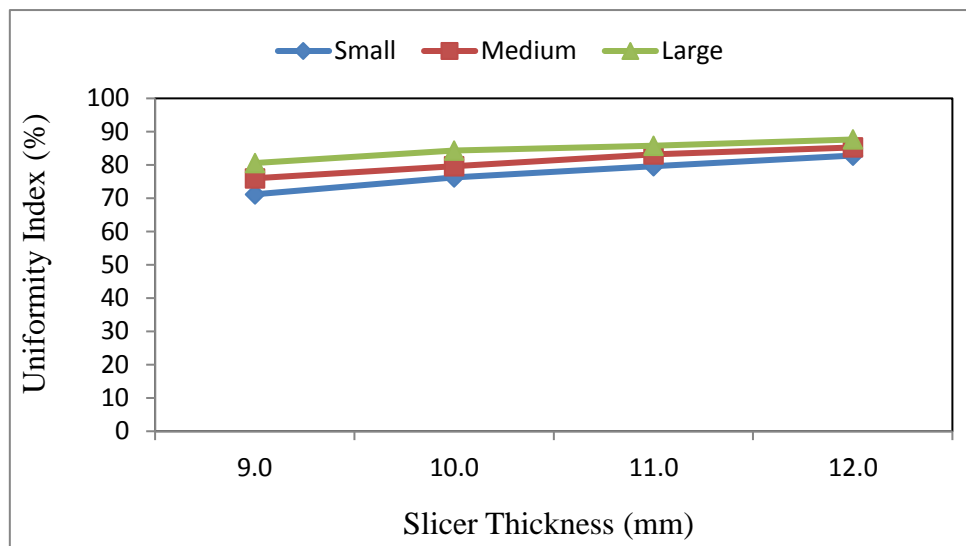


Fig. 7. Uniformity index at different turnip sizes and slice thicknesses.

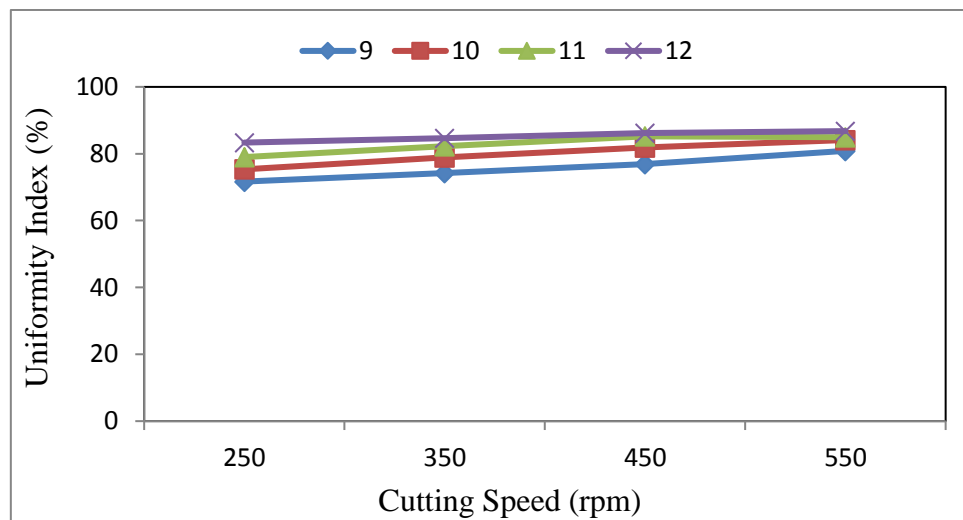


Fig. 8. Uniformity index at different slice thicknesses and cutting speeds.

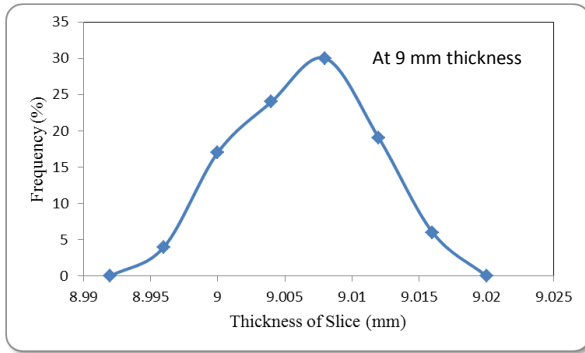


Fig. 9a

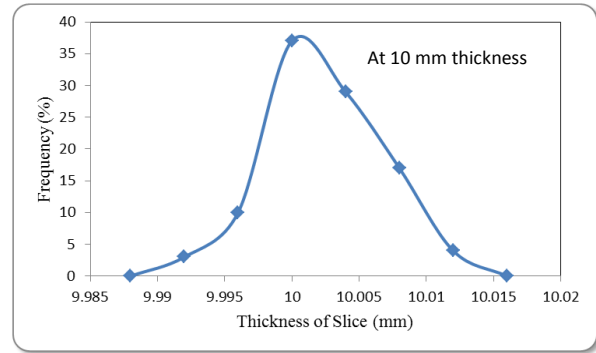


Fig. 9b

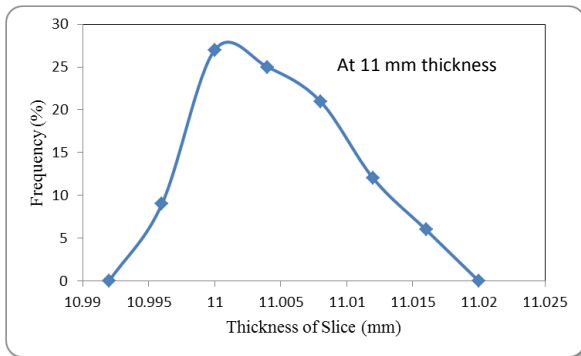


Fig. 9c

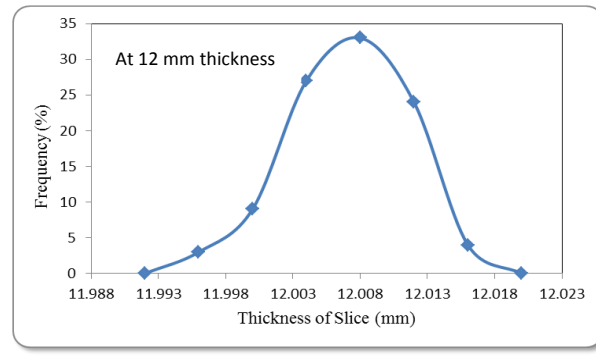


Fig. 9d

Fig. 9. The frequency distribution of the thickness of slice of the turnip cutting

3.3. Slicing efficiency:

Figs. 10, 11 and 12 show the cutting efficiency as affected by the turnip size from small (>50 mm) to large (<80 mm), the slice thickness from 9.0 to 12.0 mm and cutting speed from 250 to 550 rpm. The results indicate that the cutting efficiency increases with increasing turnip size and slicer thickness and it decreases with increasing cutting speed. It indicates that when the turnip size increased from small to large, the cutting efficiency significantly increased from 95.361 to 96.674 (by 1.36%) %. It also indicates that when the slice thickness increased from 9.0 to 12.0 mm, the cutting efficiency significantly increased from 95.130 to 96.864 (by 1.97%) %. On the other hand, the cutting efficiency significantly decreased from 97.524 to 94.716 (by 2.88%) % when the cutting speed increased from 250 to 550 rpm.

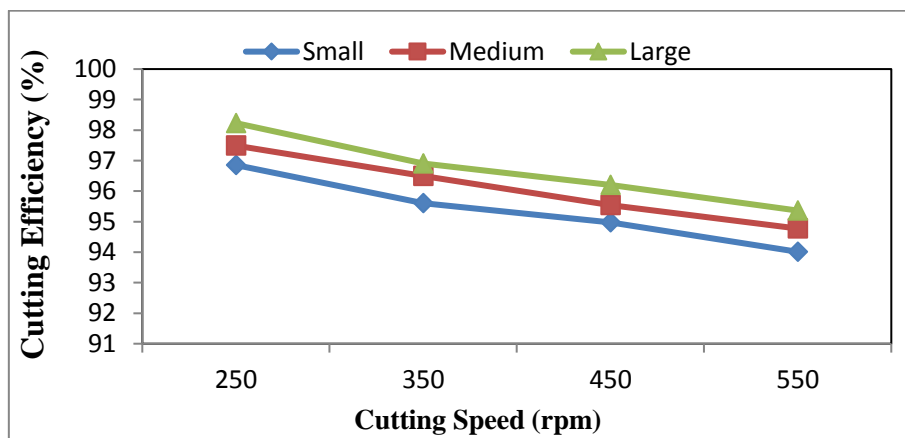


Fig. 10. Cutting efficiency at different turnip sizes and cutting speeds.

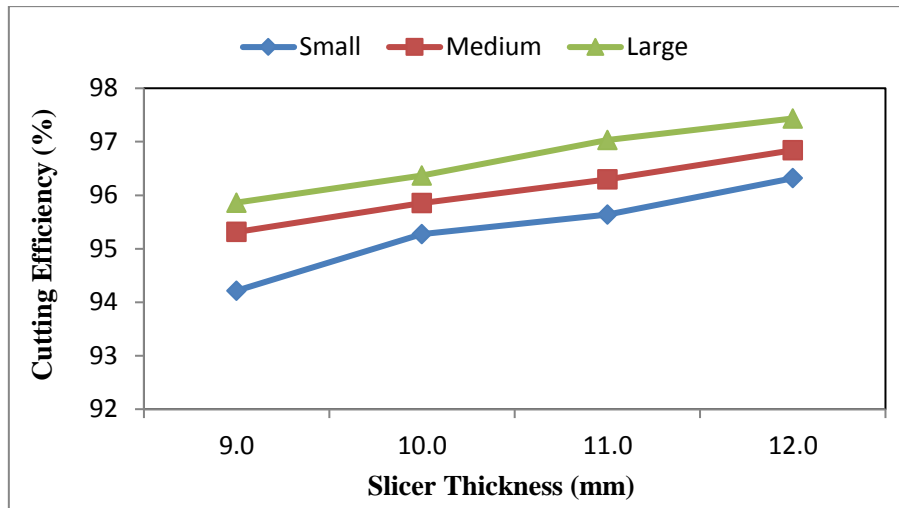


Fig. 11. Cutting efficiency at different turnip sizes and slicer thicknesses.

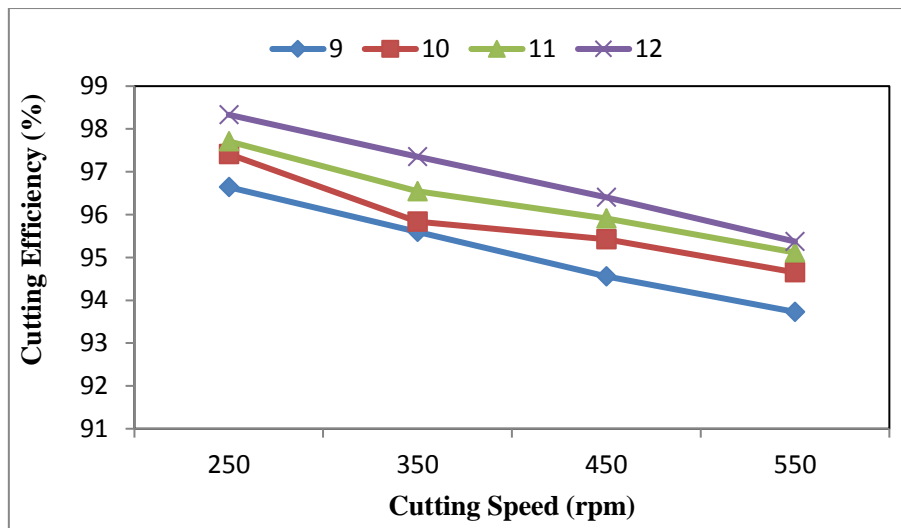


Fig. 12. Cutting efficiency at different slice thicknesses and cutting speeds.

Fig. 10 shows the effect of turnip size and cutting speed on the cutting efficiency. The results indicate that the cutting efficiency decreased with increasing cutting speed from 250 to 550 rpm at different turnip sizes. It could be seen that when the cutting speed increased from 250 to 550 rpm cutting efficiency decreased from 96.853 to 94.012, 97.491 to 94.774 and 98.229 to 95.363 %, respectively, at small, medium and large turnip size, while it increased from 96.853 to 98.229, 95.604 to 96.904, 94.976 to 96.201 and 94.012 to 95.363 %, respectively, at 250, 350, 450 and 550 rpm cutting speed, when the turnip size increased small (<50 mm) to large (>80 mm).

Fig. 11 shows the effect of turnip size and slice thickness on the cutting efficiency. It is clear that the cutting efficiency increased with increasing slicer thickness from 9.0 to 12.0 mm at different turnip sizes. The results indicated that the cutting efficiency ranged from 94.216, 95.273, 95.639 and 96.318 %, respectively, at small turnip size, while it ranged from 95.313, 95.853, 96.295 and 96.841 %, respectively, at medium turnip size and it ranged from 95.863, 96.368, 97.032 and 97.435 %, respectively, at large turnip size, when the slice thicknesses were 9.0, 10.0, 11.0 and 12.0 mm.

Fig. 12 shows the effect of cutting speed and slice thickness on the cutting efficiency. The results indicate that the cutting efficiency increased from 96.640 to 98.332, 95.599 to 97.353, 94.553 to 96.401 and 93.729 to 95.371 % at 250, 350, 450 and 550 rpm cutting speed, respectively, when the slice thickness increased from 9.0 to 12.0 mm. The results also indicate that the cutting efficiency decreased from 96.640 to 93.729, 97.410 to 94.651, 97.711 to 95.115 and 98.332 to 95.371 % at 9.0, 10.0, 11.0 and 12.0 mm slice thickness, respectively, when the cutting speed increased from 250 to 550 rpm.

3.4. Specific energy consumption

Figs. 13, 14 and 15 show the specific energy consumption of the turnip cutting as affected by the turnip size from small (>50 mm) to large (<80 mm), the slice thickness from 9.0 to 12.0 mm and cutting speed from 250 to 550 rpm. The results indicate that the specific energy consumption decreases with increasing turnip size, slice thickness and cutting speed. It indicates that when the turnip size increased from small to large, the specific energy consumption significantly decreased from 3.100 to 1.680 (by 45.81%) W.h kg⁻¹. It also indicates that when the slice thickness increased from 9.0 to 12.0 mm, the specific energy consumption significantly decreased from 2.821 to 1.901 (by 32.61%) W.h kg⁻¹. The specific energy consumption significantly decreased from 2.870 to 1.803 (by 37.18%) W.h kg⁻¹, when the cutting speed increased from 250 to 550 rpm, respectively.

Fig. 13 shows the effect of turnip size and cutting speed on the specific energy consumption. The results indicate that the specific energy consumption decreased with increasing cutting speed from 250 to 550 rpm at different turnip sizes. It could be seen that when the cutting speed increased from 250 to 550 rpm the specific energy consumption decreased from 3.938 to 2.320, 2.762 to 1.694 and 1.911 to 1.394 W.h kg⁻¹, respectively, at small, medium and large turnip size, while it decreased from 3.938 to 1.911, 3.397 to 1.727, 2.744 to 1.689 and 2.320 to 1.394 W.h kg⁻¹, respectively, at 250, 350, 450 and 550 rpm cutting speed, when the turnip size increased small (<50 mm) to large (>80 mm).

Fig. 14 shows the effect of turnip size and slice thickness on the specific energy consumption. It is clear that the specific energy consumption decreased with increasing slice thickness from 9.0 to 12.0 mm at different turnip sizes. The results indicated that the specific energy consumption ranged from 3.711, 3.276, 2.891 and 2.547 W.h kg⁻¹, respectively, at small turnip size, while it ranged from 2.790, 2.395, 2.115 and 1.736 W.h kg⁻¹, respectively, at medium turnip size and it ranged from 1.964, 1.790, 1.548 and 1.420 W.h kg⁻¹, respectively, at large turnip size, when the slice thicknesses were 9.0, 10.0, 11.0 and 12.0 mm.

Fig. 15 shows the effect of cutting speed and slice thickness on the specific energy consumption. The results indicate that the specific energy consumption decreases with increasing the slice thickness and the cutting speed. It decreased from 3.452 to 2.248, 2.841 to 2.090, 2.712 to 1.856 and 2.280 to 1.410 W.h kg⁻¹ at 250, 350, 450 and 550 rpm cutting speed, respectively, when the slicer thickness increased from 9.0 to 12.0 mm. The results also indicate that the specific energy consumption decreased from 3.452 to 2.280, 3.111 to 1.959, 2.670 to 1.562 and 2.248 to 1.410 W.h kg⁻¹ at 9.0, 10.0, 11.0 and 12.0 mm slicer thickness, respectively, when the cutting speed increased from 250 to 550 rpm.

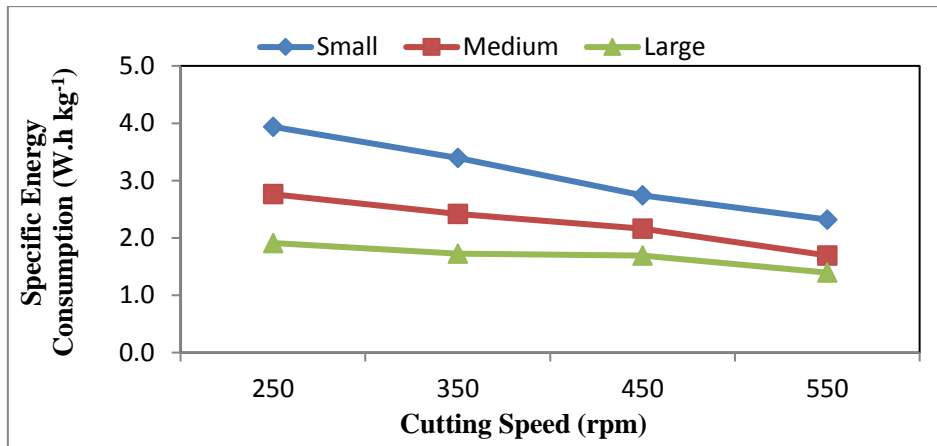


Fig. 13. Specific energy consumption at different turnip sizes and cutting speeds.

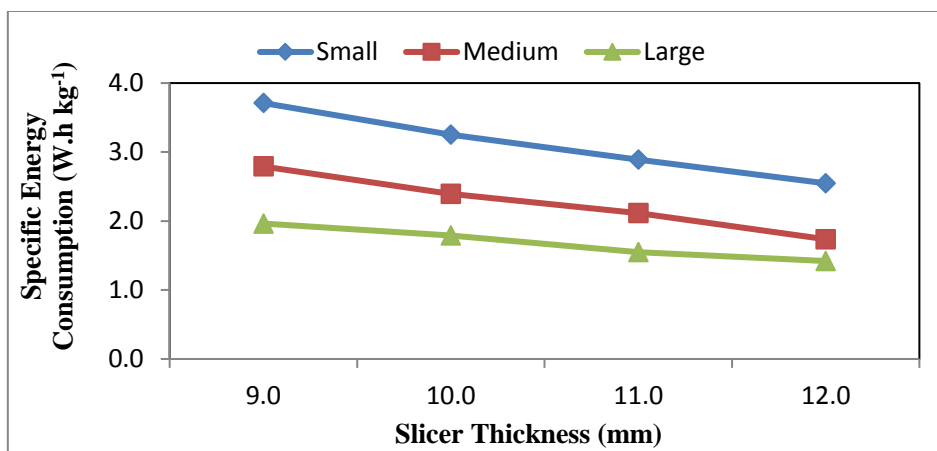


Fig 14. Specific energy consumption at different turnip sizes and slice thicknesses.

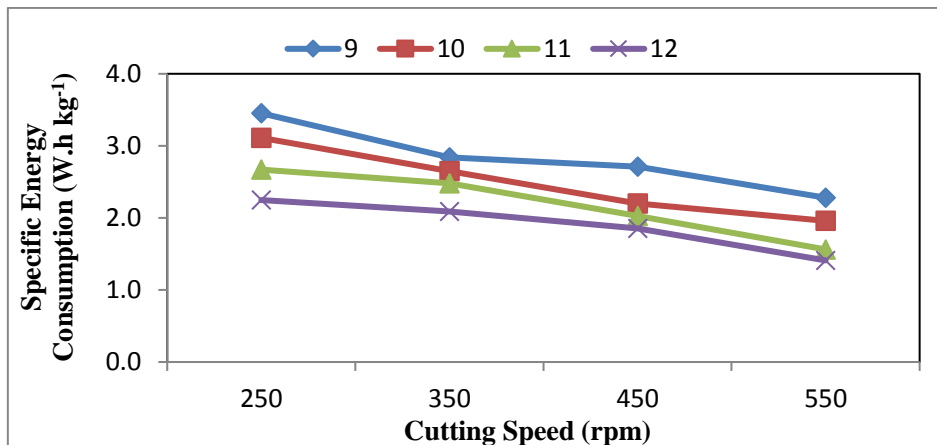


Fig. 15. Specific energy consumption at different slice thicknesses and cutting speeds.

3.5. The total costs of slicing machine

Table 1 shows the total costs of turnip cutting of the turnip cutting as affected by the turnip size from small (>50 mm) to large (<80 mm), the slice thickness from 9.0 to 12.0 mm and cutting speed from 250 to 550 rpm. The results indicate that the total costs of turnip cutting decreases with increasing turnip size, slice thickness and cutting speed. It indicates that when the turnip size increased from small to large, the total costs of turnip cutting significantly

decreased from 0.081 to 0.043 (by 46.91%) LE kg⁻¹. Also, it indicates that when the slicer thickness increased from 9.0 to 12.0 mm, the total costs of cutting process significantly decreased from 0.074 to 0.049 (by 33.78%) LE kg⁻¹. The total costs of turnip cutting significantly decreased from 0.073 to 0.048 (by 34.35%) LE kg⁻¹, when the cutting speed increased from 250 to 550 rpm.

Table 1: Total costs of turnip cutting at different turnip sizes, slice thicknesses and cutting speeds.

Categories	Thickness, mm	Cutting speed, rpm				Mean	
		250	350	450	550		
		Total Costs of Cutting Machine, LE kg ⁻¹					
Small	9.0	0.118	0.100	0.099	0.075	0.098	
	10.0	0.113	0.093	0.073	0.063	0.086	
	11.0	0.096	0.087	0.060	0.059	0.076	
	12.0	0.080	0.074	0.059	0.053	0.067	
	Mean	0.102	0.089	0.073	0.063		
Medium	9.0	0.088	0.072	0.067	0.063	0.073	
	10.0	0.078	0.066	0.055	0.049	0.062	
	11.0	0.064	0.062	0.057	0.035	0.055	
	12.0	0.051	0.048	0.047	0.032	0.045	
	Mean	0.070	0.062	0.057	0.045		
Large	9.0	0.059	0.050	0.049	0.044	0.051	
	10.0	0.048	0.046	0.045	0.044	0.046	
	11.0	0.044	0.042	0.042	0.031	0.040	
	12.0	0.041	0.039	0.038	0.027	0.036	
	Mean	0.048	0.044	0.044	0.037		
Mean of size (A)	0.081 ^c		0.058 ^b		0.043 ^a		
Mean of thickness (B)	0.074 ^d		0.064 ^c		0.057 ^b		
Mean of Speed (C)	0.073 ^d		0.065 ^c		0.058 ^b		
LSD at 0.05	A	B	C	AB	AC	BC	ABC
	0.003	0.003	0.002	N. S	N. S	0.005	N. S

The results indicate that the total costs of cutting machine decreased with increasing cutting speed from 250 to 550 rpm at different turnip sizes. It could be seen that when the cutting speed increased from 250 to 550 rpm the total costs of cutting machine decreased from 0.102 to 0.063, 0.070 to 0.045 and 0.048 to 0.037 LE kg⁻¹, respectively, at small, medium and large turnip size, while it decreased from 0.102 to 0.048, 0.089 to 0.044, 0.073 to 0.044 and 0.063 to 0.037 LE kg⁻¹, respectively, at 250, 350, 450 and 550 rpm cutting speed, when the turnip size increased small (<50 mm) to large (>80 mm).

The effect of turnip size and slice thickness on the total costs of turnip cutting. It is clear that the total costs of turnip cutting decreased with increasing slice thickness from 9.0 to 12.0 mm at different turnip sizes. The results indicated that the total costs of turnip cutting ranged from 0.102, 0.089, 0.073 and 0.063 LE kg⁻¹, respectively, at small turnip size, while it ranged from

0.070, 0.062, 0.057 and 0.045 LE kg⁻¹, respectively, at medium turnip size and it ranged from 0.048, 0.044, 0.044 and 0.037 LE kg⁻¹, respectively, at large turnip size, when the slicer thicknesses were 9.0, 10.0, 11.0 and 12.0 mm.

The results indicate that the total costs of turnip cutting decreases with increasing the slice thickness and the cutting speed. It decreased from 0.088 to 0.057, 0.074 to 0.054, 0.072 to 0.048 and 0.061 to 0.037 LE kg⁻¹ at 250, 350, 450 and 550 rpm cutting speed, respectively, when the slicer thickness increased from 9.0 to 12.0 mm. The results also indicate that the total costs of turnip cutting decreased from 0.088 to 0.061, 0.080 to 0.052, 0.068 to 0.042 and 0.057 to 0.037 LE kg⁻¹ at 9.0, 10.0, 11.0 and 12.0 mm slice thickness, respectively, when the cutting speed increased from 250 to 550 rpm.

4. CONCLUSION

The experiment was carried out to study, to develop, to fabricate and to evaluate a cutting machine for turnip fingers to be used in small and medium production units. The obtained results can be summarized as follows:

- The machine productivity increased from 246.249 to 452.356 kg h⁻¹, when the turnip size increased from small to large. It increased from 280.026 to 421.881 kg h⁻¹ when the slicer thickness increased from 9.0 to 12.0 mm, while, it increased from 290.427 to 434.313 kg h⁻¹ when the cutting speed increased from 250 to 550 rpm.
- The uniformity index and cutting efficiency increased with increasing turnip size, slice thickness and cutting speed.
- The specific energy consumption decreased from 3.100 to 1.680 W.h kg⁻¹, when the turnip size increased from small to large, while, it decreased from 2.821 to 1.901 (by 32.61%) W.h kg⁻¹, when the slice thickness increased from 9.0 to 12.0 mm and the specific energy consumption decreased from 2.870 to 1.803 W.h kg⁻¹, when the cutting speed increased from 250 to 550 rpm, respectively.
- The total costs of cutting machine decreased from 0.081 to 0.043 LE kg⁻¹, when the turnip size increased from small to large, while, it decreased from 0.074 to 0.049 LE kg⁻¹, when the slicer thickness increased from 9.0 to 12.0 mm and the total costs of cutting machine significantly decreased from 0.073 to 0.048 LE kg⁻¹, when the cutting speed increased from 250 to 550 rpm.

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تطوير اله لتقطيع اللفت

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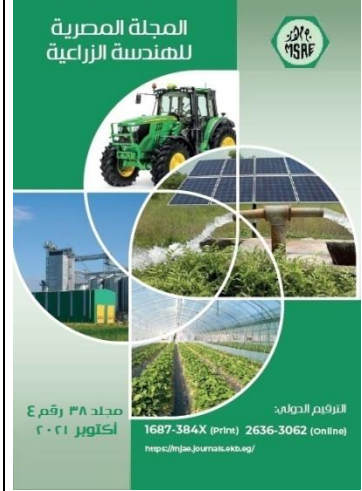
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الملخص العربي

تهدف هذه الدراسة الى تطوير وتقييم اله لتقطيع درنات اللفت الى أصابع بإستخدام مواد خام محلية تستخدم لوحدات الانتاج الصغيرة والمتوسطة مثل المطاعم والفنادق لتوفير الوقت والطاقة. وكانت اهم النتائج المتحصل عليها كمايلي:-

- زادت انتاجية الالة من ٢٤٦,٢٤٩ الى ٤٥٢,٣٥٦ ومن ٢٨٠,٠٢٦ الى ٤٢١,٨٨١ ومن ٢٩٠,٤٢٧ الى ٤٣٤,٣١٣ كجم ساعة^١ بزيادة مقاس درنات اللفت من الصغيرة الى الكبيرة وزيادة سمك الشرائح من ٩ الى ١٢ مم وزيادة سرعة التقطيع من ٢٥٠ الى ٥٥٠ لفة كل دقيقة، على الترتيب.
- زاد دليل الانتظامية بزيادة مقاس درنات اللفت وزيادة سمك الشرائح وزيادة سرعة التقطيع.
- زادت كفاءة القطع من ٩٥,١٣٠ الى ٩٦,٨٦٢ ومن ٩٥,١٣٠ الى ٩٦,٨٦٢ % بزيادة مقاس درنات اللفت من الصغيرة الى الكبيرة وزيادة سمك الشرائح من ٩ الى ١٢ مم، على الترتيب. بينما انخفضت كفاءة التقطيع من ٩٧,٥٢٤ الى ٩٤,٧١٦ % بزيادة سرعة التقطيع من ٢٥٠ الى ٥٥٠ لفة كل دقيقة.
- انخفض استهلاك الطاقة النوعى للاله من ٣,١٠٠ الى ١,٦٨٠ ومن ٢,٨٢١ الى ١,٩٠١ ومن ٢,٨٧٠ الى ١,٨٠٣ وات ساعة كجم^١ بزيادة مقاس درنات اللفت من الصغيرة الى الكبيرة وزيادة سمك الشرائح من ٩ الى ١٢ مم وزيادة سرعة التقطيع من ٢٥٠ الى ٥٥٠ لفة كل دقيقة، على الترتيب.
- انخفضت التكاليف الكلية للاله التقطيع من ٠,٠٨١ الى ٠,٠٤٣ ومن ٠,٠٧٤ الى ٠,٠٤٩ ومن ٠,٠٧٣ الى ٠,٠٤٩ جنيه كجم^١ بزيادة مقاس درنات اللفت من الصغيرة الى الكبيرة وزيادة سمك الشرائح من ٩ الى ١٢ مم وزيادة سرعة التقطيع من ٢٥٠ الى ٥٥٠ لفة كل دقيقة، على الترتيب.



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الكلمات المفتاحية:

اللفت، الإنتاجية، دليل الانتظامية، الكفاءة، التكاليف