Performance of cleaning unit for sesame and clover seeds based upon some physical and mechanical properties

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Abstract: Cleaning fine seeds necessitates the use of a specific machine. Studying the physical and engineering features of seeds is critical for determining cleaning machine design and development parameters. In this study, some parameters affecting sesame and clover seed cleaning machines were selected. Loading rate, machine efficiency, and purity are all affected by screen title angles, hole diameters, and sieve oscillation. The optimum performance was at sieve oscillation of 2.26 m s^{-1}, screen tilt angle of 3 degrees and round shaped screen 3 mm at 12% moisture content, loading rates were 50 and 50.94 kg h^{-1}, machine efficiency were 95.07% and 95.2% and purity were 99.78% and 99.78% for sesame and clover seeds, respectively.

Keywords: sesame seeds - clover seeds- cleaning machine- diameter hole - title angle - sieve oscillation.

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1 Introduction

One of the most crucial agricultural processes is seed cleaning. There were several methods for cleaning seeds, including the Air-Screen method, which was used in this study. In this study, sesame and clover seeds were used. Sesame and clover seeds utilised in the food, pharmaceutical, and chemical industries, as well as re-growth, were chosen for this study. Hanna et al. (2010) and Mohamed (2013) said that seed comprises weed seeds, other crop seeds, and inert stuff such as stems, leaves, broken seed, and dirt when it is harvested from the field.

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Size, shape, density, surface roughness, terminal velocity, electrical conductivity, colour, and resilience are the main qualities used to make separations. The seed being cleaned, the quantity of seeds and other impurities in the combination, and the purity requirements that must be satisfied all influence the Machine utilized and their placement in a processing line as reported by Shetty et al. (2017). The effect of air velocity and its optimization were also thought to be very helpful in determining the performance efficiency of the designed grain cleaning machine (Afolabi et al., 2019).

There are some studies were carried out to determine the most favorable engineering parameters of cleaning machines such as Sahay and Singh (1994), Awady et al. (2003) and Abd El-Tawwab et al. (2007). El-Sayed et al. (2021) reported that research and development of agro-machinery requires initially studying the design parameters for optimal operation of this machinery. Arafa (2007) reported that the sizes of round sieve holes were 3 mm for sesame seeds, which were the primary specifications of the sieve unit. For the overall area of the sieve for sesame seeds, the maximum live area was 0.3 and the pores on the sieve were 0.99/1 m^2.Werby (2013) studied examined three different clover seed varieties with a moisture content of 10.5%: AL-Mesqawi, AL-Khadrawi, and Al-Seadi. The diameters of round sieve holes for AL-Mesqawi, AL-Khadrawi, and Al- Seadi, respectively, were 3.0, 3.0, and 3.5 mm. The cell area was determined by the physical properties of clover seeds, and the form was determined by the percentage of sphericity. A screen aperture of 4 mm diameter and a percentage of sphericity of roughly 85 percent on length for circular holes can be used to achieve separation on the basis of length. Clover seeds (varieties AL-Mesqawi, AL-Khadrawi, and Al-Seadi) were suspended at a terminal velocity of 16 m s^{-1}. The main factors that determine purity and total losses in cleaning were cell form, sieve tilt angle, sieve oscillation, and air speed. Increases in air speed, sieve tilt angle, and sieve oscillation improved purity. Increased air speed, sieve tilt angle, and oscillation increased total losses. Air speed of 6 m s^{-1}, moisture content of 10.5%, sieve oscillation of 250 rpm, sieve tilt angle of 35, round shaped sieve 4 mm diameter, and feed rate of 500 kg h^{-1} provided the best results. Under these parameters, purity was 99% and total losses were 1%.

Nikku et al. (2014) reported that, when selecting the type and size of screen holes, the shape and size of the seed are considered (mechanical separation).Awgichew (2017) founded that, for all sieve slopes, the separation and cleaning losses increased with increasing sieve oscillation and feed rate. At all sieve slopes, however, increasing sieve oscillations and feed rates reduced separation and cleaning efficiency. For all sieve oscillations and input rates, the least losses and highest efficiency were reached at a 5^o sieve slope. At a sieve oscillation of 5 Hz, a feed rate of 3 kg min^{-1}, and a sieve slope of 5 degrees, the separation efficiency, cleaning efficiency, separation loss, and cleaning loss were 97.94, 98.58, 0.71, and 0.7 percent, respectively for tef seeds. EL-Shabrawy and Al-Rajhi (2020) reported after the bird has shelled the seeds and left the husks among the seeds, a portable apparatus for separating the spent husks from bird seed mixtures has been created. They discovered that a cleaning air speed of 4.0 m s^{-1}, a baffle angle of 35°, and a baffle without rubber resulted in the highest cleaning effectiveness (98.7%) for seed combination before feeding. At a cleaning air speed of 2.5 m s^{-1}, a baffle angle of 50°, and a rubber baffle, the lowest value of seed losses (0.3%) for seed mixture after feeding was attained. To maximize cleaning efficiency, use a cleaning air speed of 4.0 m s^{-1}, a baffle angle of 35°, and a baffle without rubber; to reduce seed losses, use a cleaning air speed of 2.5 m s^{-1}, a baffle angle of 50°, and a baffle with rubber. The major goals of this research are to find the best engineering parameters that effect seeds throughout the cleaning process.

2 Material and methods

In this experiment seeds were studied namely; sesame (*Sesamum indicum L.*) and clover seeds (*Trifolium alexandrinum L.*) Variety were AL-Mesqawi.

Initial experiments had been carried for determining the physical and engineering properties of seeds under study to select the best design parameters affecting cleaning in agricultural machinery. Results were as following (El-Sayed et al., 2021).

2.1 Machine description and specifications:

The machine unit prototype under investigation designed and developed in the Agriculture Engineering Department of the Faculty of Agriculture Zagazig University, Egypt. It was made in a local workshop in Zagazig, El-Sharkia Governote, Egypt using locally available materials. The machine was designed to clean a wide range of seed kinds while being simple to calibrate, operate, clean, repair, and maintain. A frame, a seed hopper, an oscillating dual-screen assembly, an air blower, and an electric motor make up the cleaning machine. As shown in Figure 1. General specifications of machine are: overall length 800 mm, overall width 500 mm, overall height 1445 mm, power of 0.22 kW (0.3 hp) and labor requirement 1 man. Construction includes 1 mm sheet metal and 30 × 30 × 3 mm. angle iron, rectangular and square steel iron section.

1-Physical properties of sesame and clover seeds were shown in Table 1 as means:

Table 1 Sesame and clover seeds physical properties

Parameter	Sesame	Clover
Length (L), mm	3.07	2.43
Width (W), mm	1.64	1.69
Thickness (T), mm	0.84	1.32
Geometric diameter (Dg), mm	1.61	1.75
Arithmetic diameter (Da), mm	1.85	1.81
Sphericity (S), %	52.48	72.01
Volume (V), mm^3	2.21	2.87
Area of surface (A*f*), mm^2	3.96	3.24
Area of transverse surface (A*t*), mm^2	1.07	1.76
Mass of 1000-seed, g	3.26	3.36
Bulk density (ρ), kg m^{-3}	1064.16	1377.84
Moisture content (MC), %	12	12

2- Engineering properties of seeds were shown in Table 2 as means:

Table 2 Engineering properties of seeds

Parameter	Sesame	Clover
Angle of repose, degree	27	34.5
Terminal velocity, m s^{-1}	5.45	8.75
Coefficient of friction		
-For grains (G.)	0.8923	0.901
-For grains with wood surface (W.)	1.283	1.303
-For grains with galvanized sheet (Gal.)	1.121	1.121
-For grains with plastic surface (P.)	0.966	0.95

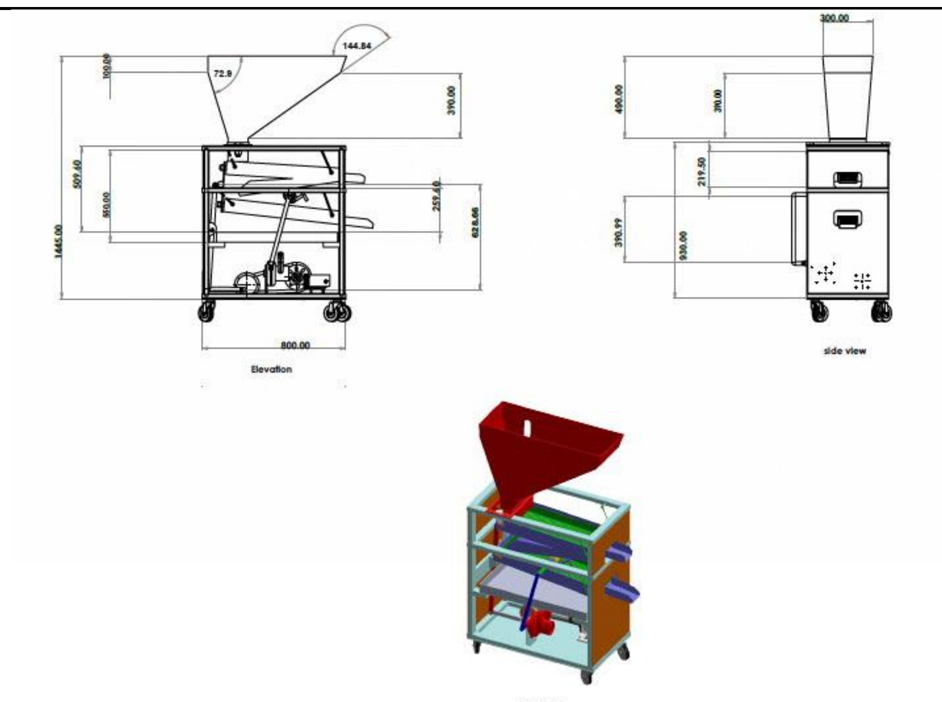

Figure 1 Sketch view of the cleaning machine (Dim. in mm)

Frame: Made of a hallow rectangular, square, channel shape steel iron section and angle section.

Hopper: Made of steel sheet metal of 1 mm thickness and angle iron steel 30 ×30 ×3 mm. Hopper is interrupted pyramid shaped with a manual control of feeding.

Screens: Made of steel sheet metal of 2 mm thickness. They consist of upper screen with an iron barrier fixed which the air outlet fixed under and lower screen and hang on four links adjustable in the rear to modify the sieve tilt angle. The upper screen for separating straw and chaff from seeds. The lower screen is mounted 200 mm below and analogous to the upper screen with 2 degrees title angle. The lower screen has 1 mm diameter holes to remove fine impurities and dust. The proper aperture -size of the screen was determined from physical properties of seeds.

Blower: The air blower made in china with 710 W, 3.08 A and 220 V with air discharge from 0 m^3 s^{-1} to 27 m^3 s^{-1}. The blower discharges air blast under the iron barrier. Air speeds for sesame and clover were selected as terminal velocity.

2.2 Measuring instrumentation:

Electrical balance: An electronic balance was used for weighing samples before and after cleaning. Its scale ranged from 0 to 40 kg max., with accuracy of 1 g.

Digital professional pocket scale: It was used in this study for measuring the weight of samples. It was made in China with accuracy of 0.01 mg.

Grain Moisture Meter: It was made in China, Model of AR991, with an accuracy of 0.1%. It was used for measuring the MC in percentage of the studied seeds on wet basis (w.b.).

Anemometer instrument: An anemometer instrument (UNI-T model of UT363S, china) was used for measuring the air speed and temperature. It is ranged from 0 to 30 m s^{-1}. The measurement theory depends on the declination of the sensor inside the instrument. The movement of air pushes the sensor then voltage indicates the variation of the air speed (source of power is battery).

Tachometer instrument: A tachometer instrument (UNI-T model of UT373, china) was used for measuring the rotational speed of motors and other machines it is ranged from 10 to 100000 rpm. The measurement theory depends on the laser light reflection on white duct tape. The reflection of laser light when motor rotating voltage indicates the rotation of the motor or the pulley (source of power is battery).

2.3 Test procedures for the experimental cleaning unit

This work was carried out in March 2022 in order to study some parameters affecting cleaning unit such as diameter of holes, sieve tilt angle, and sieve oscillation for sesame and clover seeds. Preliminary experiments were carried out to study the best amount of seeds to be added to the machine under study, and the optimal quantity was 750 g. All treatments replicated four times. All obtained data were statistically descripted as mean values.

Seeds-samples preparation:

For the present study, sesame seeds were acquired from a local market. Such seeds may well be a mix of several varieties. While, the clover seeds variety AL-Mesqawi were acquired from a farmer. The initial MC of the seeds was estimated to be 10.2% db. The MC was determined by Grain Moisture Meter-SMART SENSOR-AR991. The samples with the desired MC were prepared by adding distilled water as calculated by Sacilik et al. (2003):

$$Q = W_i \times (M_\mathrm{f} - M_\mathrm{i})/(100 - M_\mathrm{f}) \qquad (1)$$

Where:

Q : the mass of water to be added, kg,

W_i: the initial mass of the sample, kg,

M_i: the initial moisture content of the sample, % db.,

M_f: the final moisture content, % db.

The samples were divided into separate polyethylene bags and then the bags closed tightly. The samples were kept at 5℃ in a refrigerator for one week to enable the moisture to distribute uniformly through the seeds. Before beginning the experiment, the targeted quantity of the seeds was taken out of the refrigerator and allowed to equate to the room temperature for about 2 h (Coşkun et al. 2006).

2.4 Factor relating to the constructed cleaning machine

The following factors were tested to show their effect on cleaning effectiveness:

Screen tilt-angle: Three different screen tilt-angles were under test: zero, 3, 6 degrees for the upper screen.

Sieve oscillation: Three different sieve oscillations were under test: 0.53, 1.27 and 2.26 m s^{-1}.

Shape and diameter of holes of screen: round shape of screen holes was used with 2, 3 and 4 mm diameters.

Loading rate: 750 g added from hopper for each treatment.

Air speed: The terminal velocity for sesame and clover seeds was selected (5.45 and 8.75 m s^{-1}, respectively).

$Loading\ rate\ = mass\ of\ sample\ before\ cleaning / sievieng\ time$, kg $h^{-1.}$

Machine efficiency = mass of sample after cleaning/ $mass\ of\ sample\ before\ cleaning \times 100$, %

Purity=(mass of sample after cleaning- Impurities in the sample after cleaning) /mass of sample after cleaning×100, %

3 Results and discussion

3.1 Effect of hole screen diameter and screen title angle on seed loading rate

As shown in Figures 2, 3, 4 results were: increase the loading rate of sesame seeds by increasing sieve oscillations from 0.53 to 2.26 m s^{-1} because of the increased speed of locomotion of seeds inside the machine. Also, for three sieve oscillations under research, title angle increased with 2 mm hole diameter, and for 3 and 4 mm hole diameter in sieve oscillation 2.26 m s^{-1} due to the increase in the diameter of the sieve holes with the speed of locomotion of the machine. By increasing screen tithe angle with 3 mm hole diameter at 1.27 m s^{-1}. The loading rate increased from 1.12 to 15.17 kg h^{-1}, then reduced to 10.34 kg h^{-1}. Loading rate increased from 5.57 to 34.62 kg h^{-1} for 4 mm hole diameter, then reduced to 22.13 kg h^{-1}. By raising the screen tithe angle with a 3 mm hole diameter, the 0.53 m s^{-1} loading rate increased from 0.18 to 0.92 kg h^{-1}, then reduced to 0.22 kg h^{-1}. Loading rate increased from 0.13 to 1.77 kg h^{-1} for 4 mm hole diameter, then fell to 0.75 kg h^{-1}.

Loading rate increased with 2 and 4 mm hole diameter in 2.26 m s^{-1} sieve oscillation and with 4 mm hole diameter in 0.53 m s^{-1} sieve oscillation for clover seeds by raising screen title angle from 0 to 6 degrees because of the increased title angle and due to the high percentage of sphericity. However, utilising a 2 mm hole diameter in a 1.27 m s^{-1} sieve oscillation and a 3 mm hole diameter in a 0.53 m s^{-1} sieve oscillation reduced loading rate due to some seeds come out of the upper sieve hole. By raising screen tithe angle with 3 mm hole diameter in 2.26 m s^{-1} sieve oscillation, loading rate increased from 30 to 50.94 kg h^{-1} and then reduced to 47.37 kg h^{-1}. Loading rate increased because of the increased title angle and due to the high percentage of sphericity and reduced loading rate because some seeds come out of the upper sieve hole. Also, loading rate decreased from 27 to 15.17 kg h^{-1}, then increased to 18.12 kg h^{-1} by increasing screen tithe angle with 3 mm hole diameter in 1.27 m s^{-1} sieve oscillation, decreased from 36 to 30.68 kg h^{-1}, then increased to 37.5 kg h^{-1} by increasing screen tithe angle with 4 mm hole diameter in 1.27 m s^{-1} sieve oscillation, and decreased from 0.47 to 0.38 kg h^{-1}, then increased to 1.92 kg h^{-1} as shown in Figures 5, 6 and 7.

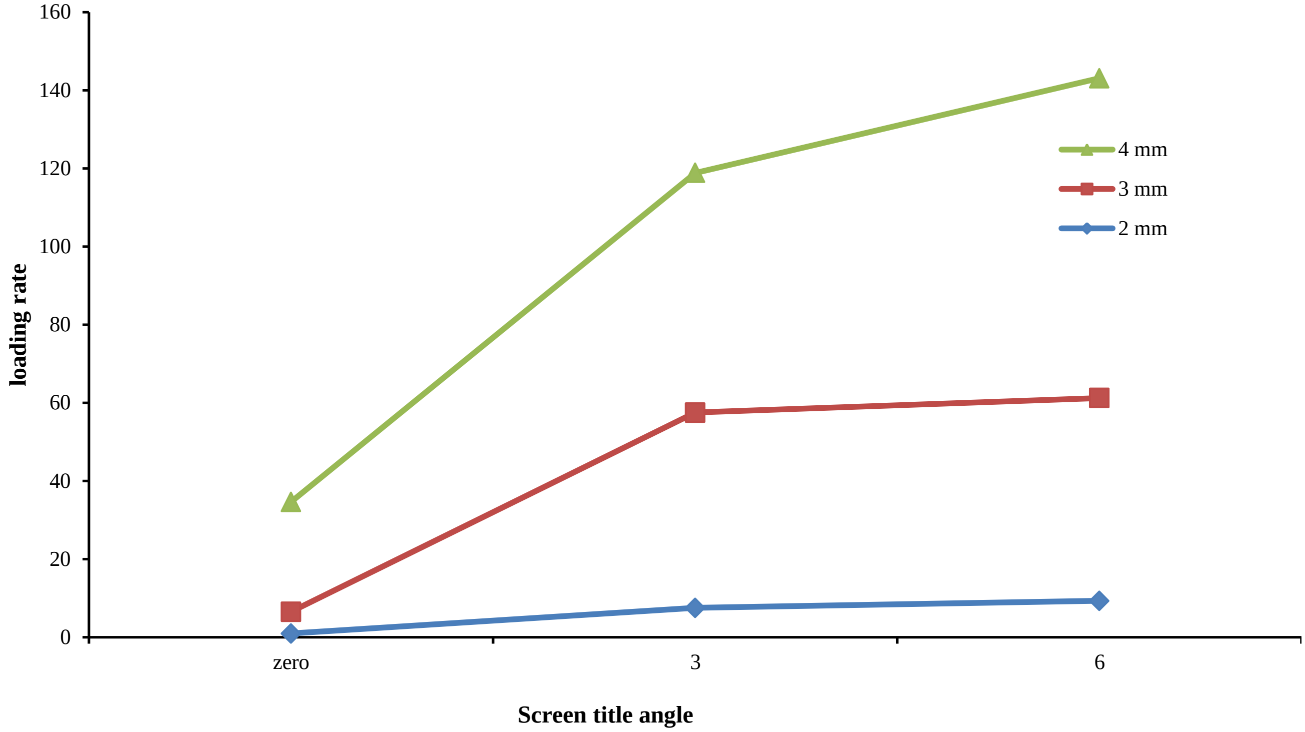

Figure 2 Effect of hole screen diameter and screen title angle on loading rate for sesame seeds in sieve oscillation 2.26 m s^{-1}

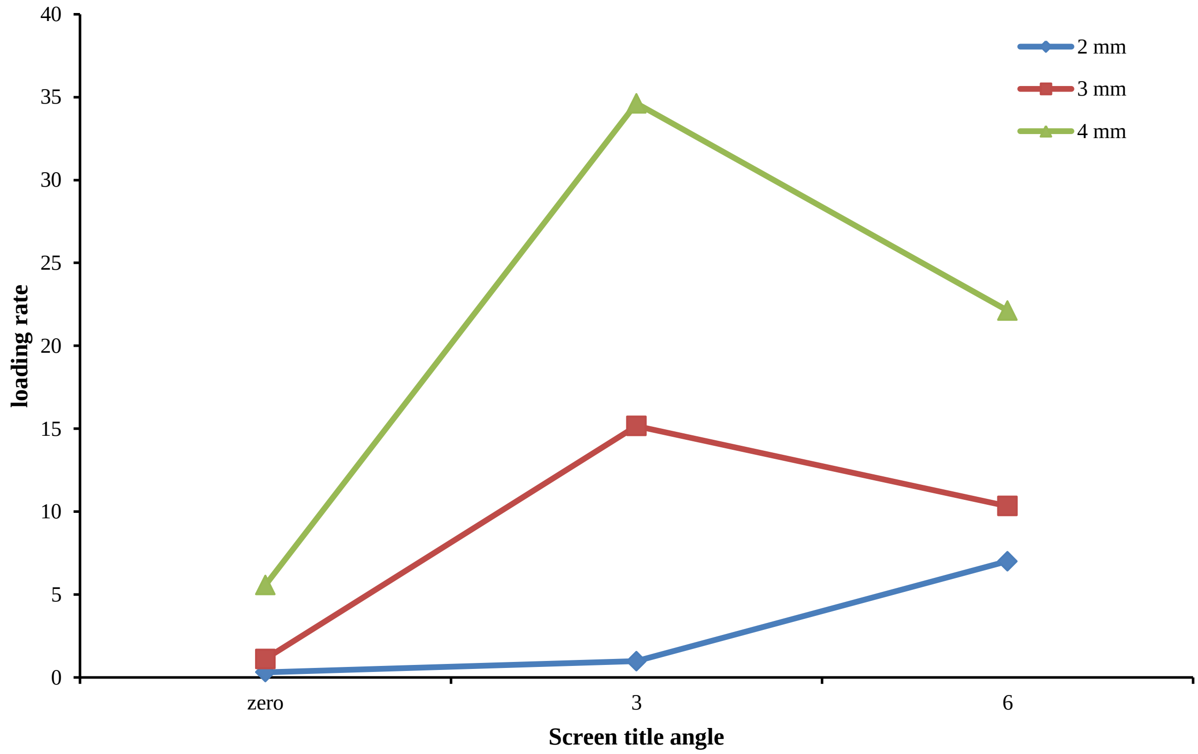

Figure 3 Effect of hole screen diameter and screen title angle on loading rate for sesame seeds in sieve oscillation 1.27 m s^{-1}

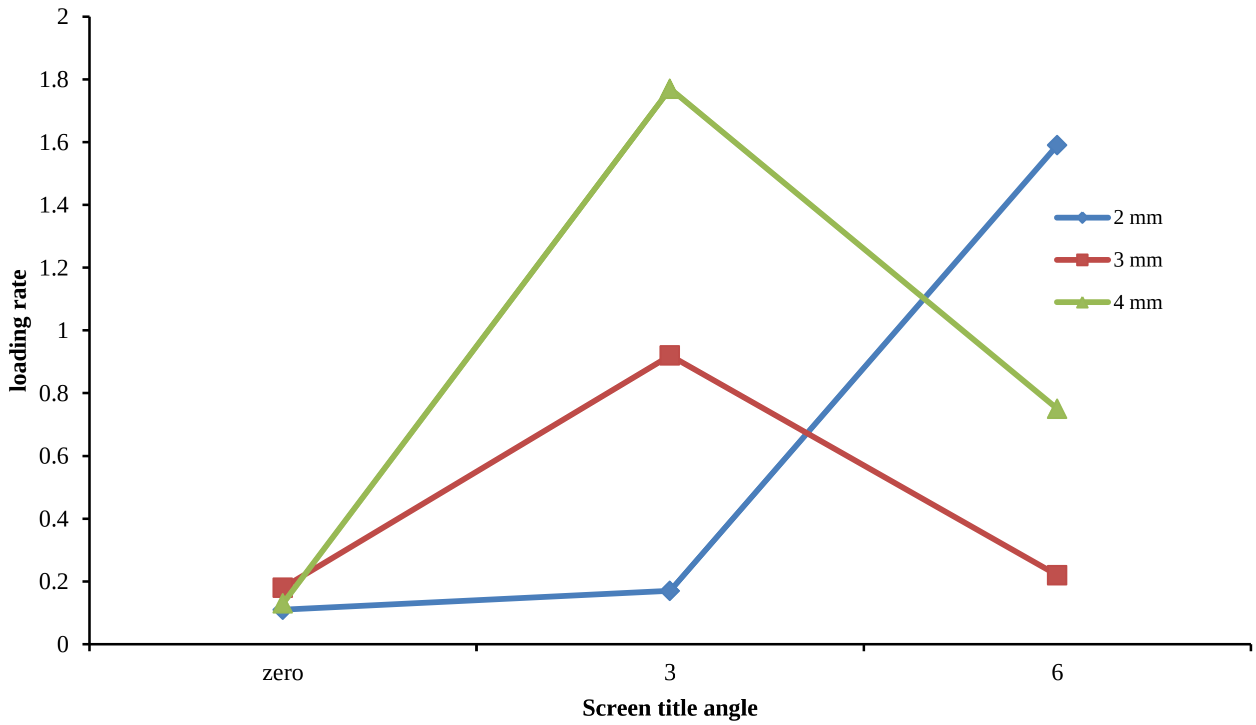

Figure 4 Effect of hole screen diameter and screen title angle on loading rate for sesame seeds in sieve oscillation 0.53 m s^{-1}

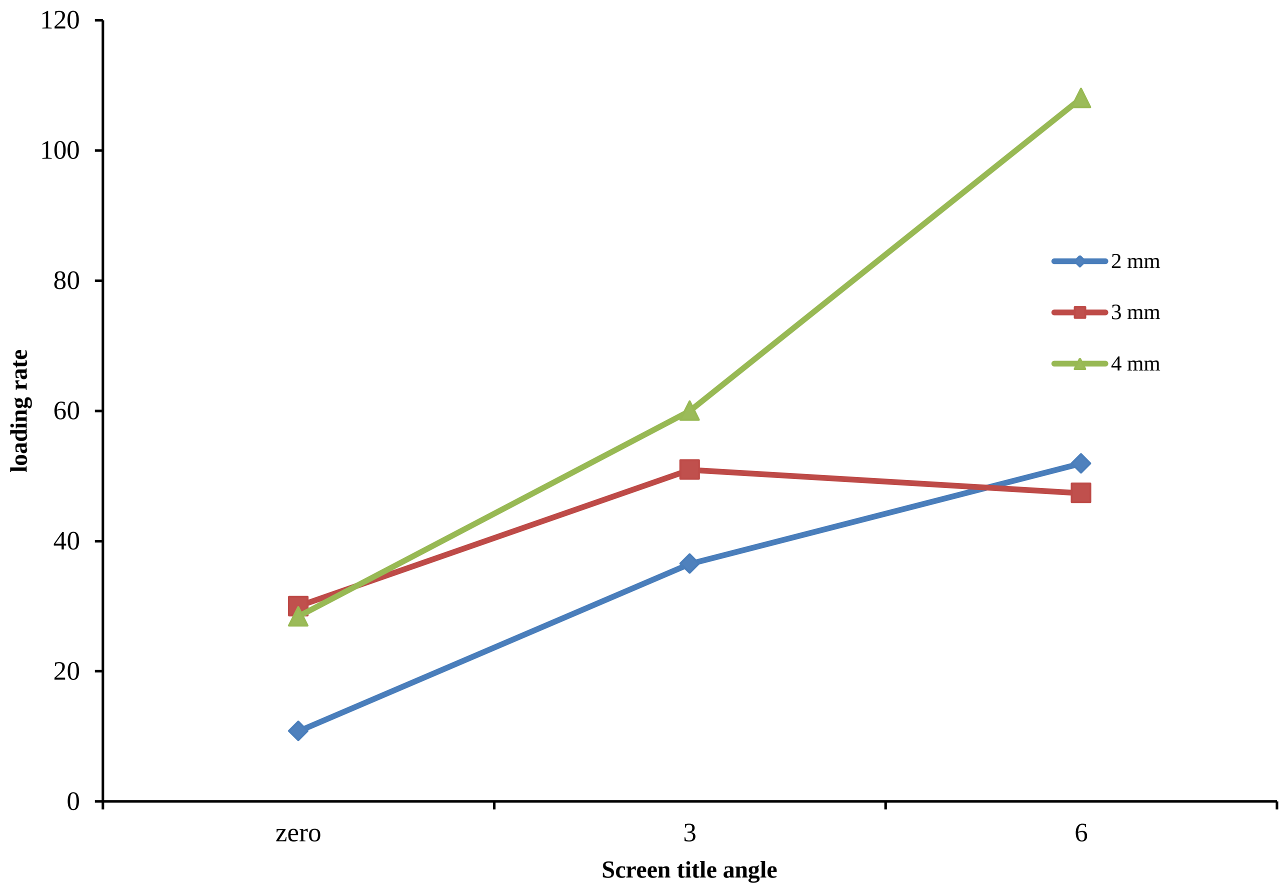

Figure 5 Effect of hole screen diameter and screen title angle on loading rate for clover seeds in sieve oscillation 2.26 m s^{-1}

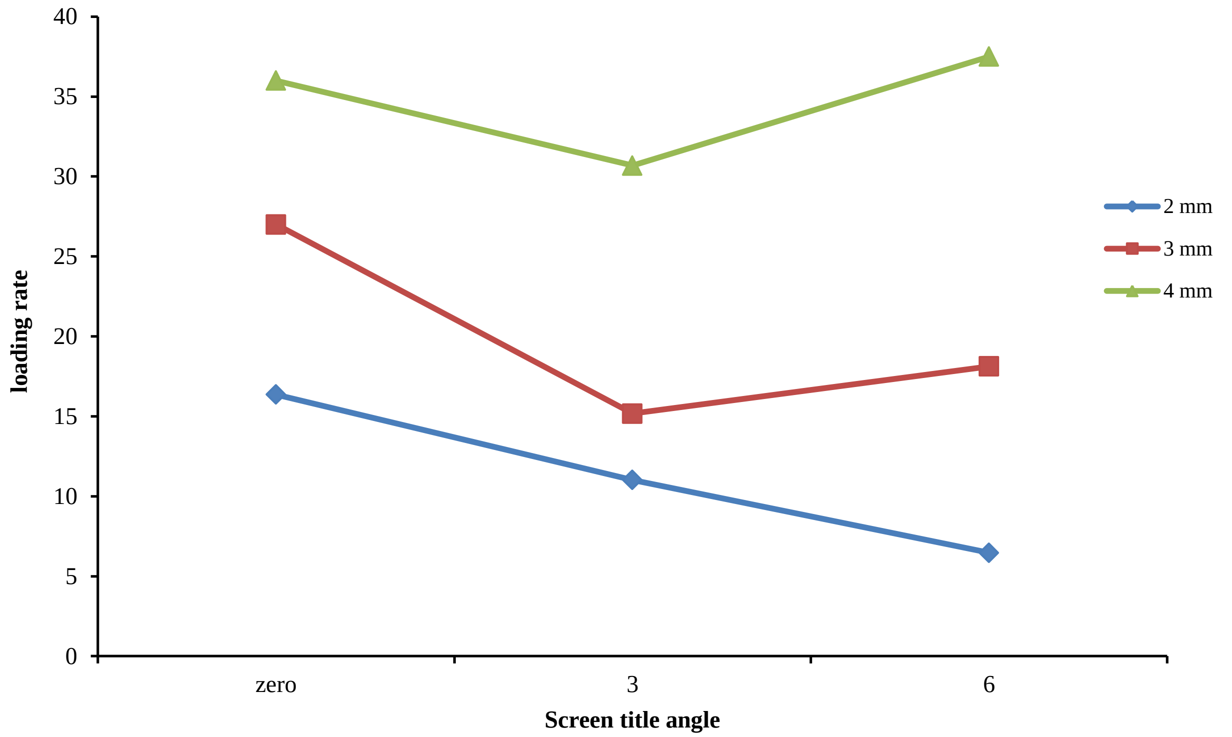

Figure 6 Effect of hole screen diameter and screen title angle on loading rate for clover seeds in sieve oscillation 1.27 m s^{-1}

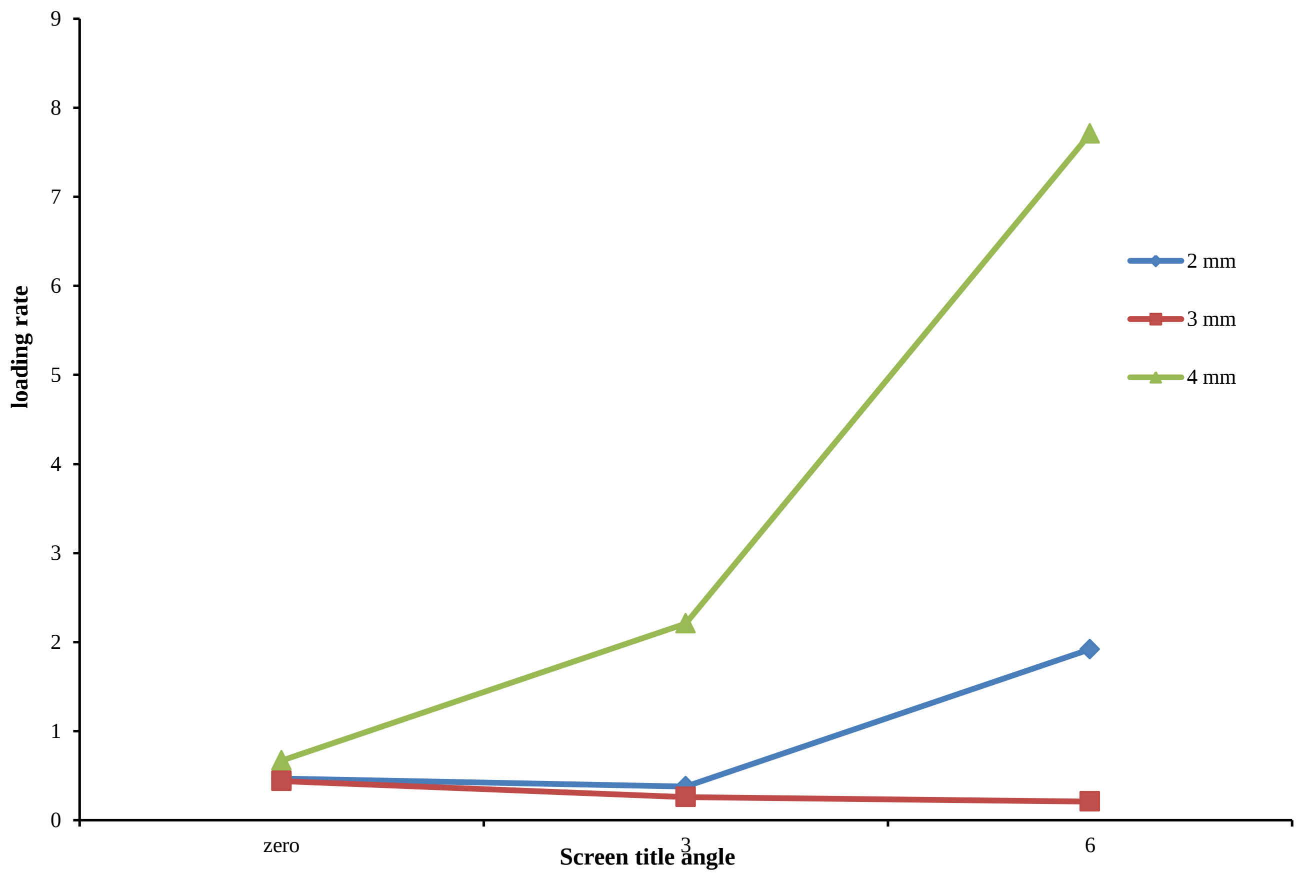

Figure 7 Effect of hole screen diameter and screen title angle on loading rate for clover seeds in sieve oscillation 0.53 m s^{-1}

3.2 Effect of hole screen diameter and screen title angle on machine efficiency

As shown in Figures 8, 9, and 10 results were: machine efficiency for sesame seeds increased by increasing sieve oscillations from 0.53 to 2.26 m s^{-1} because of the increased speed of locomotion of seeds inside the machine. Machine efficiency was reduced when the screen title angle was increased from 0 to 6 degrees in 2 and 3 mm hole diameters with 1.27 and 2.26 m s^{-1} sieve oscillation and 4mm hole diameter with 1.27 m s^{-1} sieve oscillation due to some seeds come out of the upper sieve hole. In 2.26 m s^{-1} sieve oscillation, machine efficiency increased with a 4 mm hole diameter. By raising screen tithe angle with 2 mm hole diameter, machine efficiency increased from 48.8% to 51.6%, then reduced to 6.93%. However, increasing screen tithe angle with 3 mm hole diameter decreased machine efficiency from 99.2% to 98.8%, then increased to 99.6%, and increasing screen tithe angle with 4 mm hole diameter with 0.53 m s^{-1} sieve oscillation decreased machine efficiency from 98.13% to 95.6%, then increased to 98.4%.

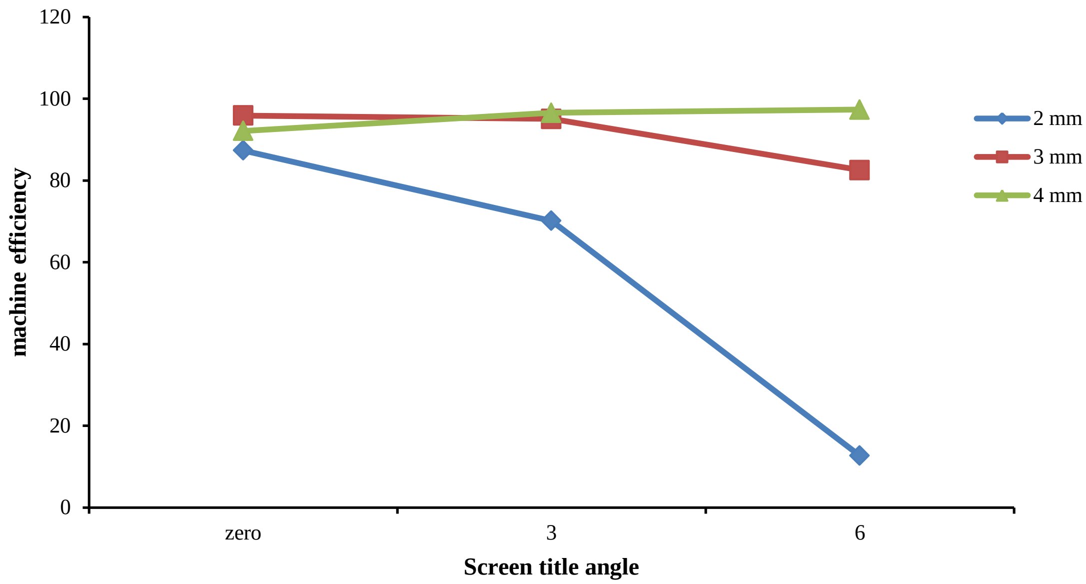

Figure 8 Effect of hole screen diameter and screen title angle on machine efficiency for sesame seeds in sieve oscillation 2.26 m s^{-1}

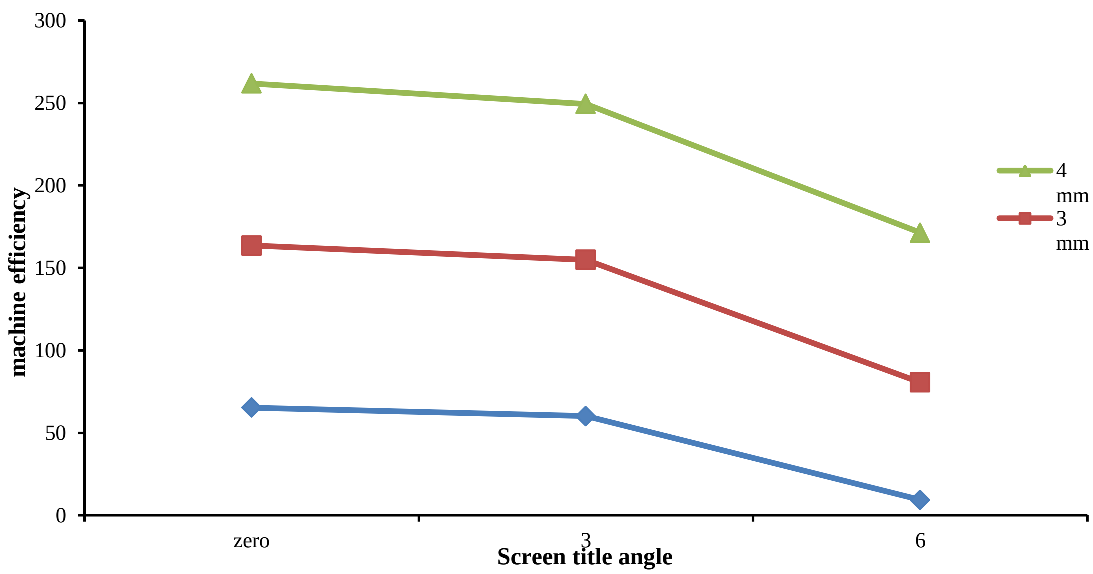

Figure 9 Effect of hole screen diameter and screen title angle on machine efficiency for sesame seeds in sieve oscillation 1.27 m s^{-1}

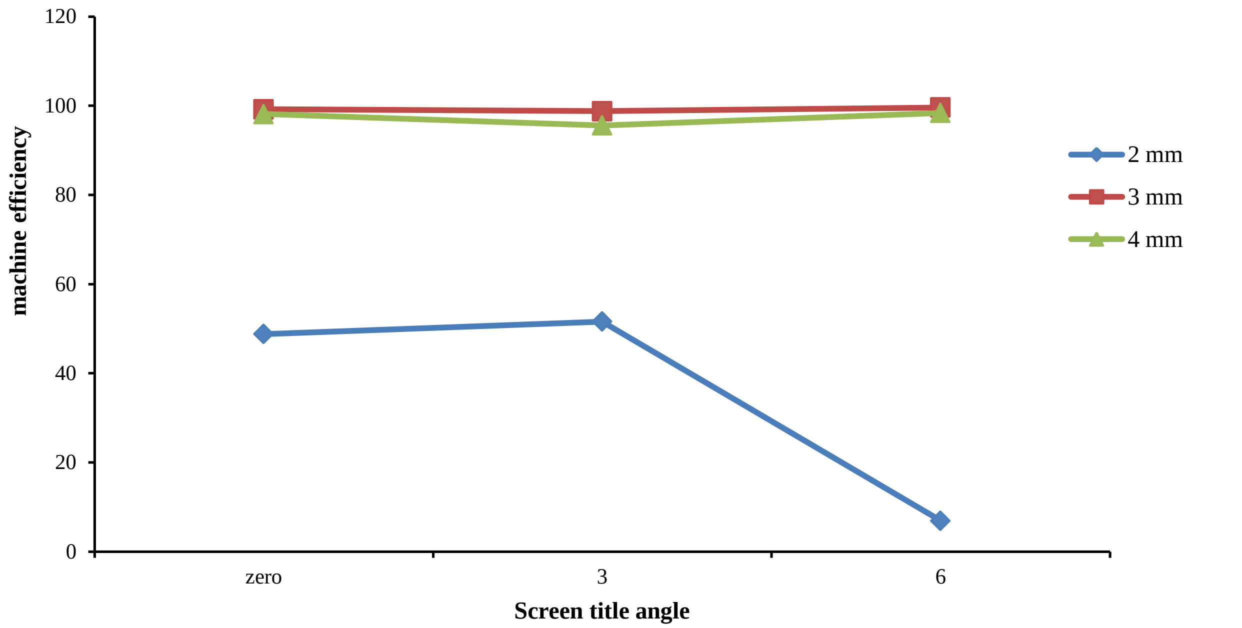

Figure 10 Effect of hole screen diameter and screen title angle on machine efficiency for sesame seeds in sieve oscillation 0.53 m s^{-1}

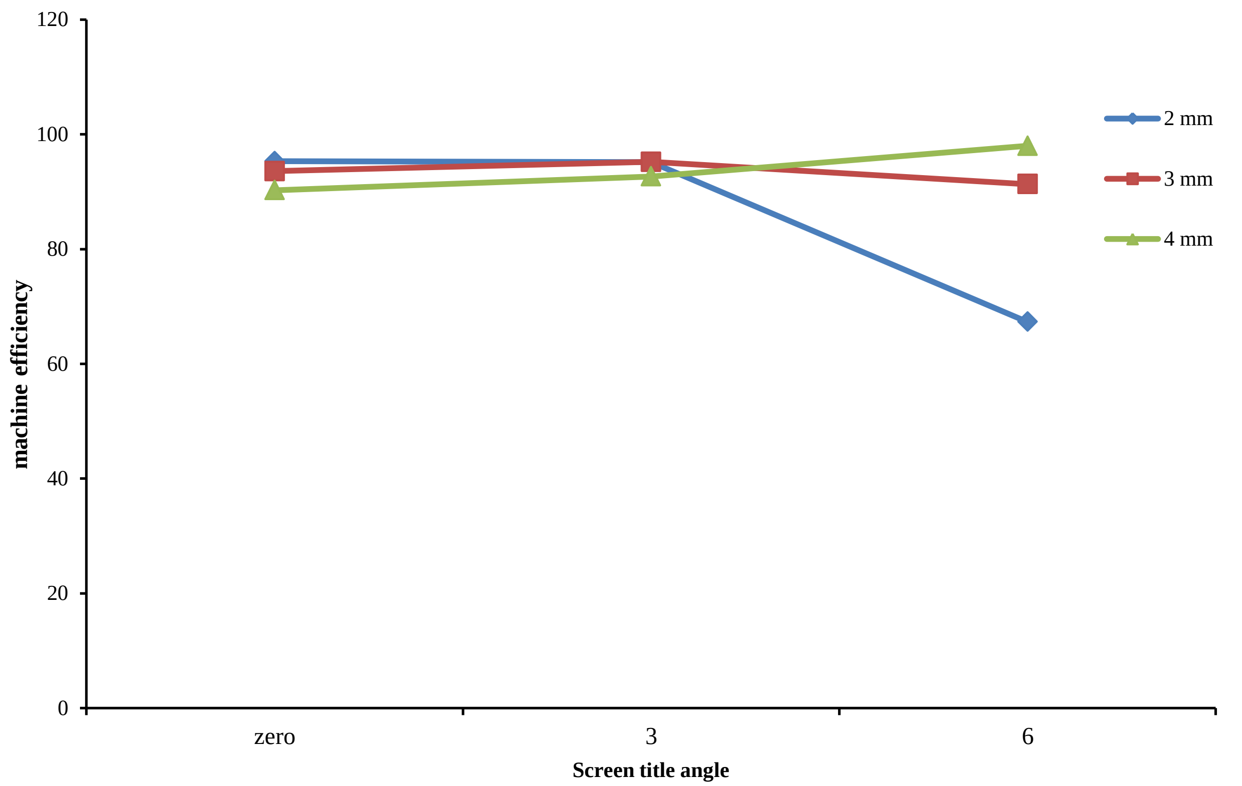

Figure 11 Effect of hole screen diameter and screen title angle on machine efficiency for clover seeds in sieve oscillation 2.26 m s^{-}

When using 2 mm hole diameter for sieve oscillations under research, machine efficiency decreased as the screen title angle increased for clover seeds because some seeds come out of the upper sieve hole. However, utilising a 3 mm hole diameter in a 0.53 m s^{-1} sieve oscillation and a 4 mm hole diameter in a 2.26 m s^{-1} sieve oscillation increased the results. Machine efficiency decreased from 97.07% to 96.93% after increasing screen tithe angle with 3 mm hole diameter, and decreased from 95.6% to 95.2% after increasing screen tithe angle with 4 mm hole diameter and 1.27 m s^{-1} sieve oscillation. Increased screen tithe angle with 3 mm hole diameter and 2.26 m s^{-1} sieve oscillation improved machine efficiency from 93.6% to 95.2 %, then reduced to 91.33% machine efficiency increased because of the increased title angle and due to the high percentage of sphericity and reduced machine efficiency because some seeds come out of the upper sieve hole as shown in Figures 11, 12, 13.

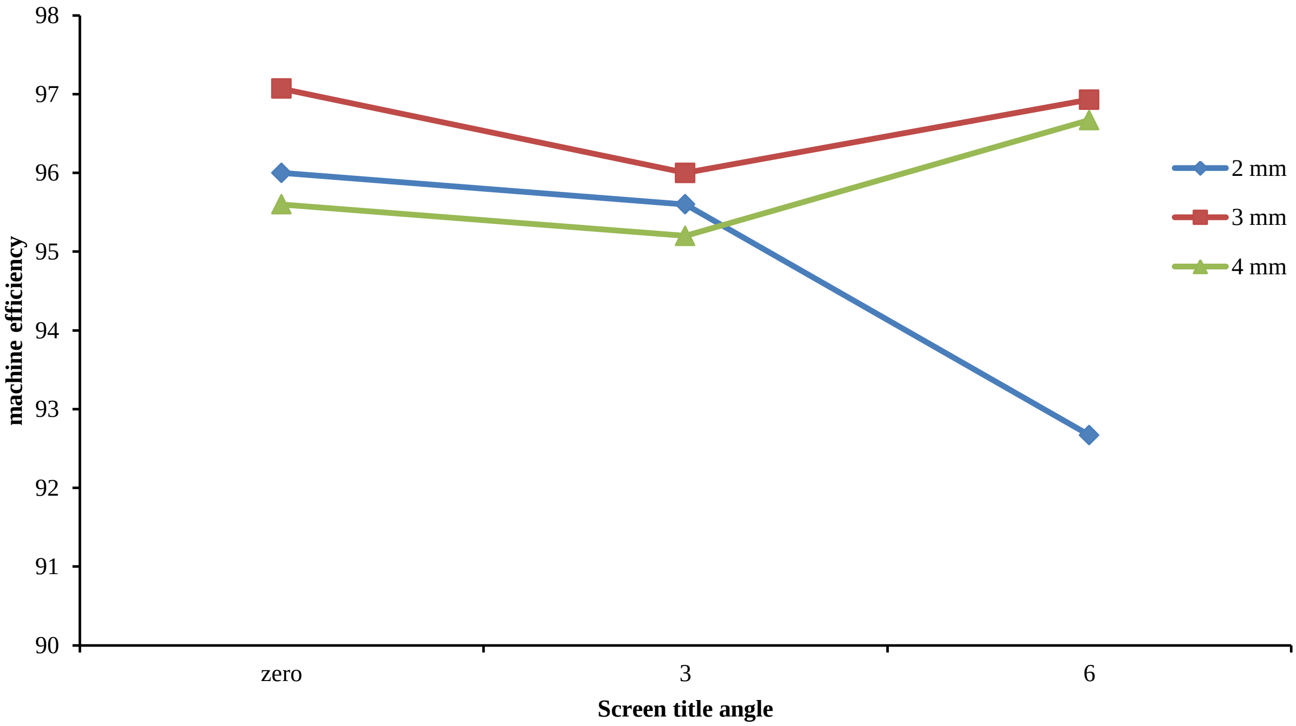

Figure 12 Effect of hole screen diameter and screen title angle on machine efficiency for clover seeds in sieve oscillation 1.27 m s^{-1}

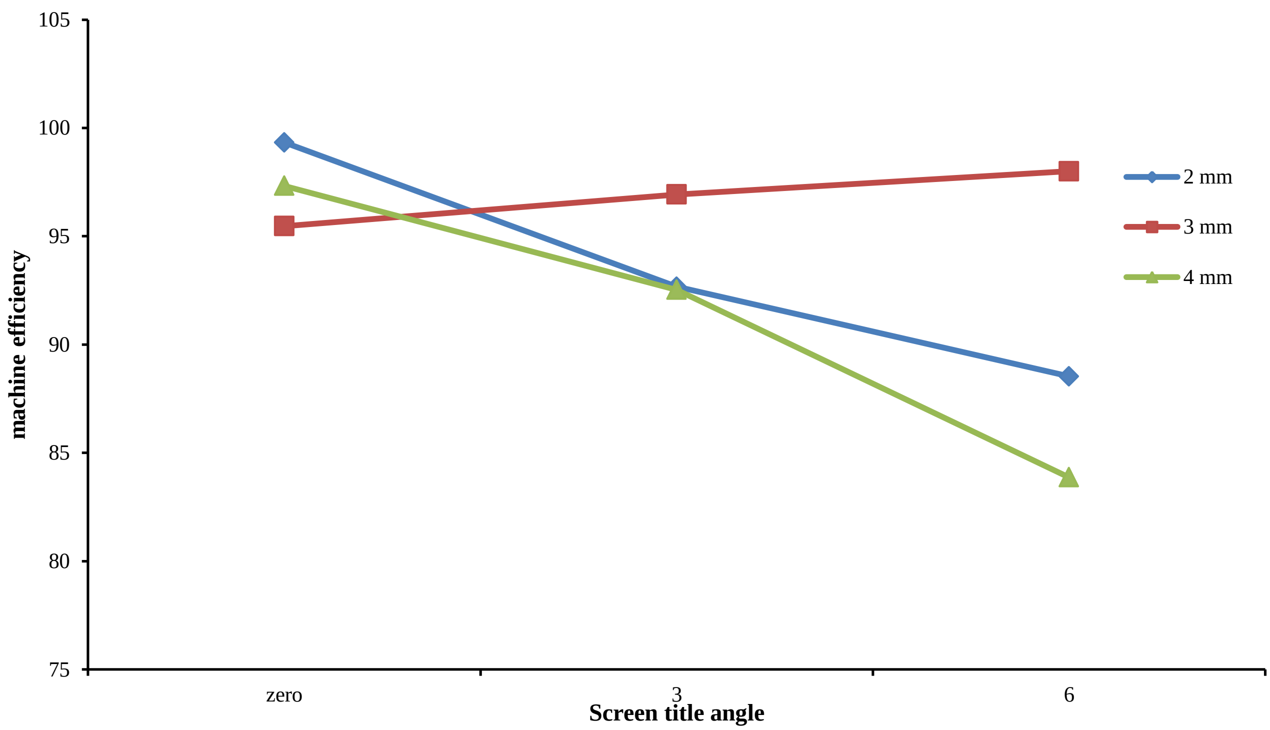

Figure 13 Effect of hole screen diameter and screen title angle on machine efficiency for clover seeds in sieve oscillation 0.53 m s^{-1}

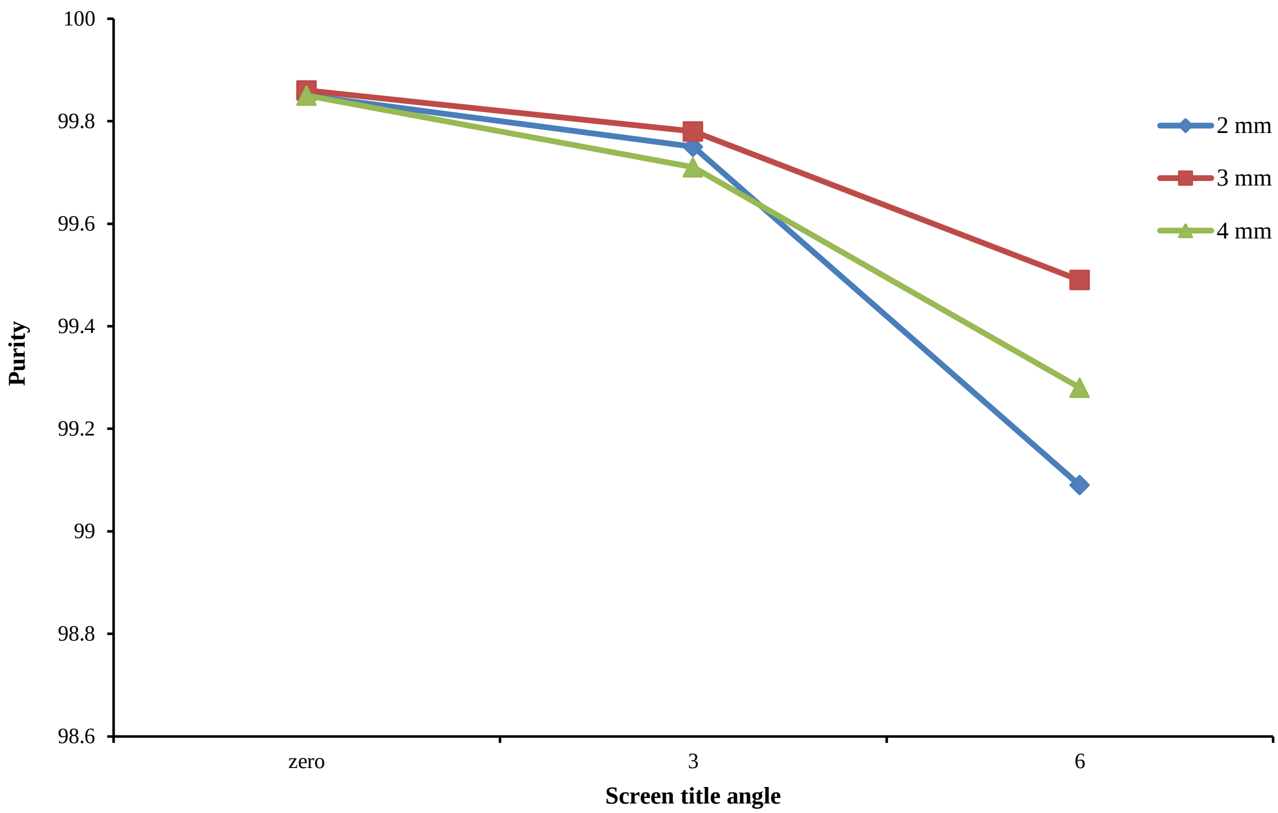

Figure 14 Effect of hole screen diameter and screen title angle on purity for sesame seeds in sieve oscillation 2.26 m s^{-1}

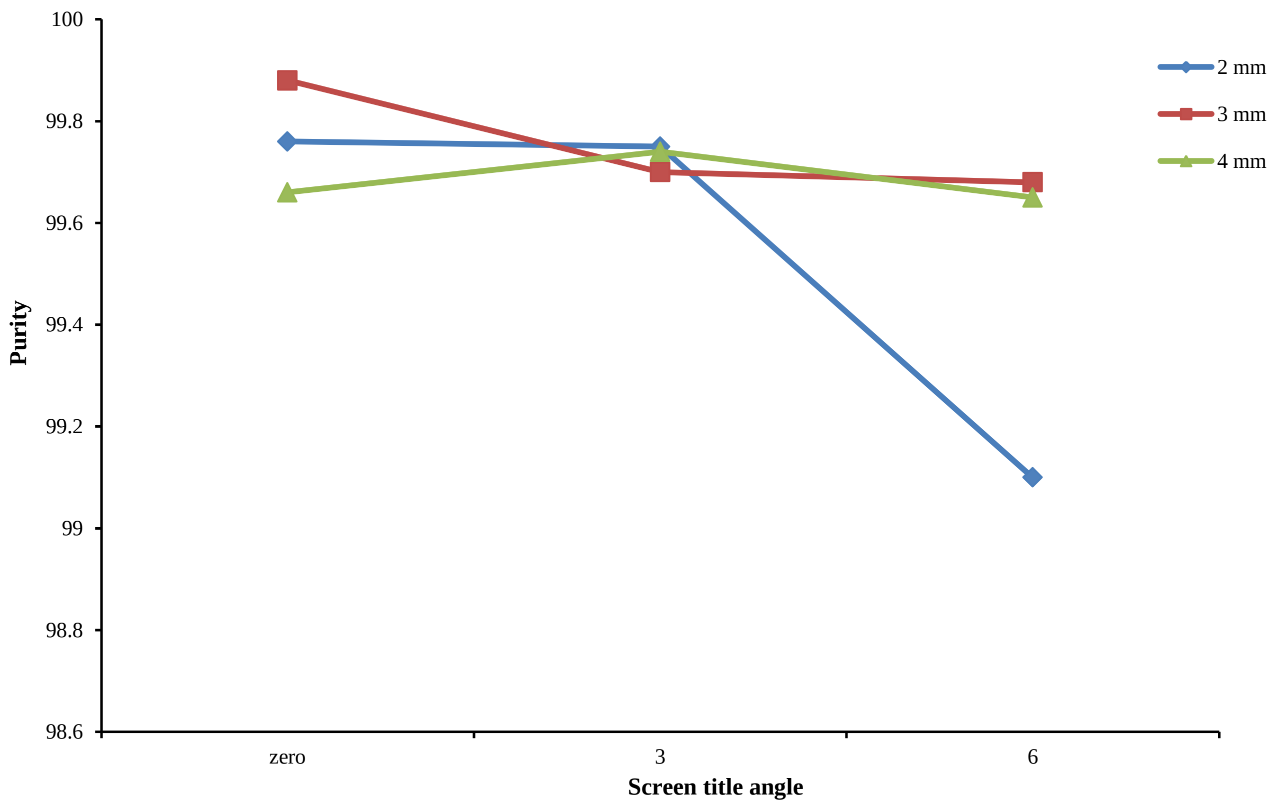

Figure 15 Effect of hole screen diameter and screen title angle on purity for sesame seeds in sieve oscillation 1.27 m s^{-1}

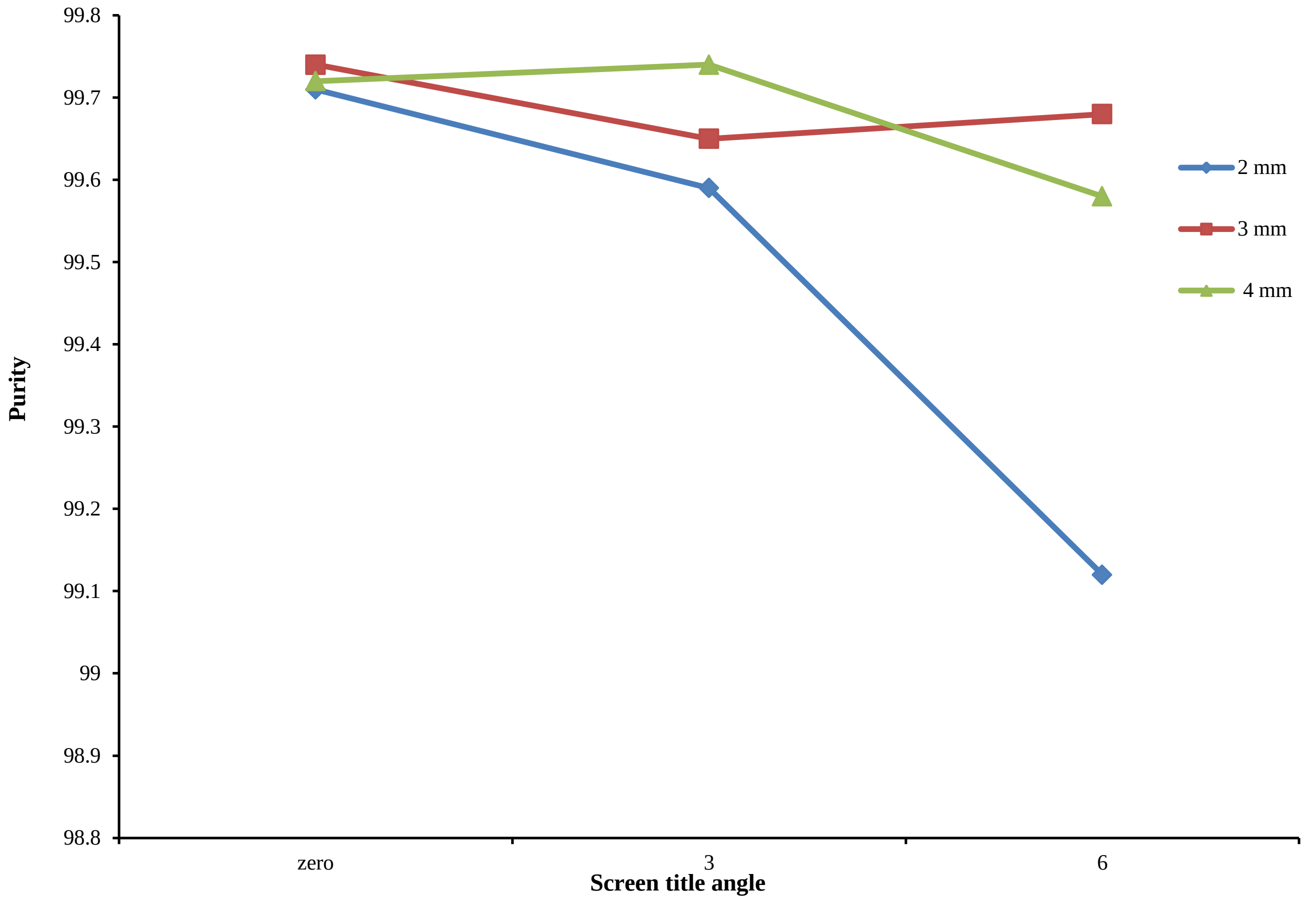

Figure 16 Effect of hole screen diameter and screen title angle on purity for sesame seeds in sieve oscillation 0.53 m s^{-1}

3.3 Effect of hole screen diameter and screen title angle on purity

As shown in Figures 14, 15, 16 results were: purity of sesame seeds decreased when sieve oscillations with a 2 mm hole diameter were used. Purity decreased due to the shorter sieving time when 3 and 4 mm hole diameters were used with 1.27 and 2.26 m s^{-1} sieve oscillations by increasing screen title angle. Purity decreased from 99.74% to 99.65% before improving to 99.68% by increasing the screen title angle for a 3 mm hole diameter in a 0.53 m s^{-1} sieve oscillation. However, raising screen title angle for 4 mm hole diameter in 0.53 m s^{-1} sieve oscillation increased from 99.72% to 99.74%, then reduced to 99.58%. The optimum purity was 99.78% at sieve oscillation of 2.26 m s^{-1}, screen tilt angle of 3 degrees and round shaped screen 3 mm.

By raising screen title angle, clover seed purity decreased when utilising 2 and 4 mm hole diameters in 2.26 m s^{-1} sieve oscillation and 3 and 4 mm hole diameters in 1.27 m s^{-1} sieve oscillation. Purity decreased due to the shorter sieving time. Increased screen title angle from 0 to 3 degrees for 0.53 m s^{-1} sieve oscillation purity, then dropped in on 6 degrees for hole screens under examination. Purity increased from 99.8% to 99.84% in 1.27 m s^{-1} sieve oscillation, then decreased to 99.73% by increasing screen title angle for 2 mm hole diameter, and increased from 99.6% to 99.76% in 2.26 m s^{-1} sieve oscillation, then decreased to 99.61% by increasing screen title angle for 3 mm hole diameter. The optimum purity was 99.78% at sieve oscillation of 2.26 m s^{-1}, screen tilt angle of 3 degrees and round shaped screen 3 mm as shown in Figures 17, 18, and 19.

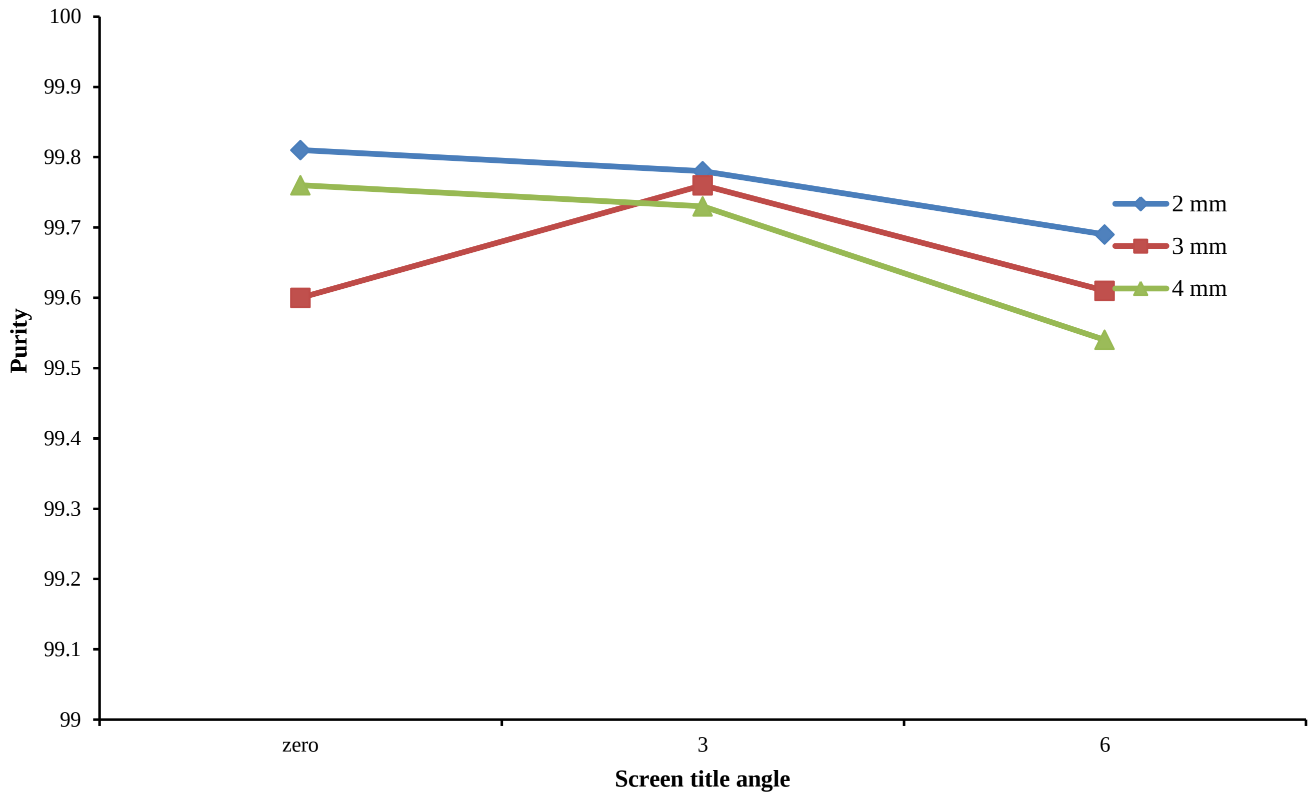

Figure 17 Effect of hole screen diameter and screen title angle on purity for clover seeds in sieve oscillation 2.26 m s^{-1}

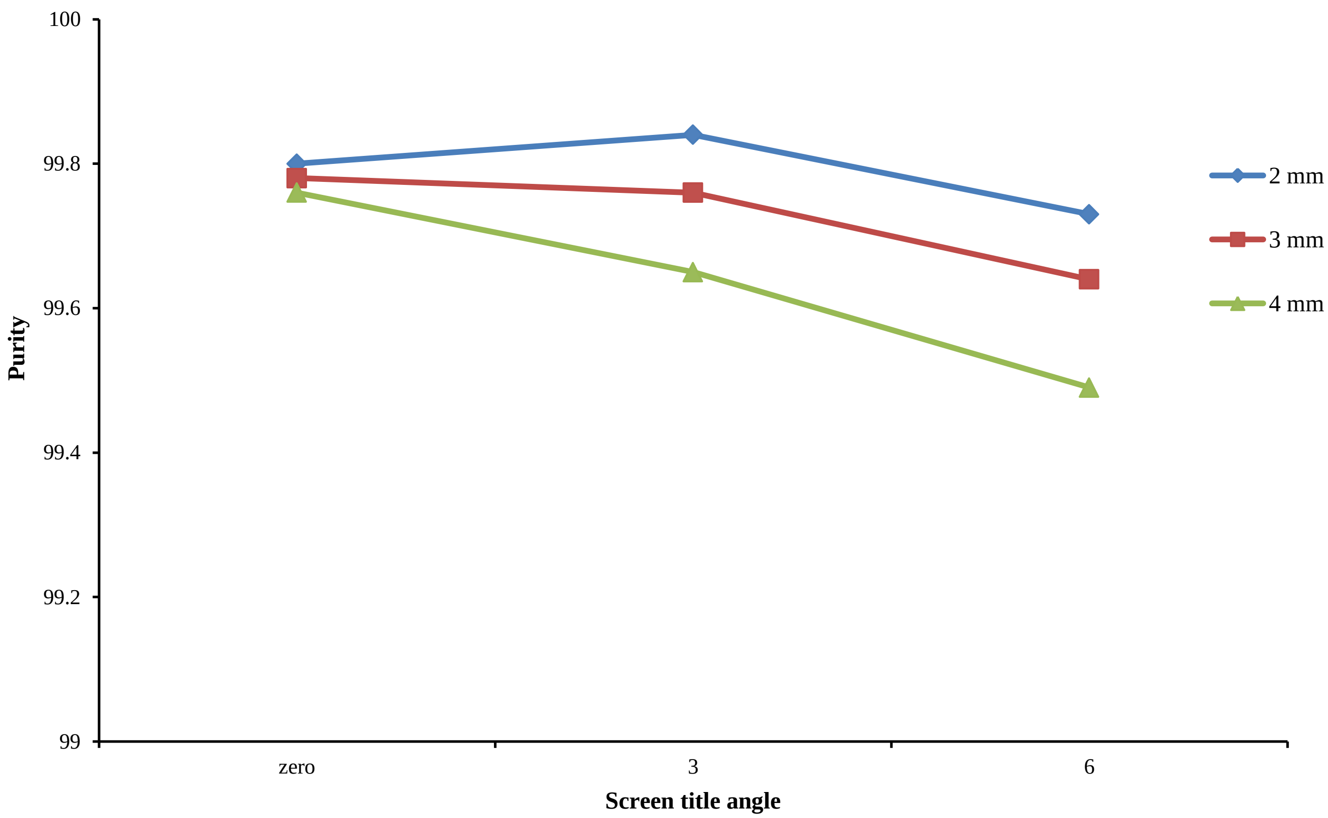

Figure 18 Effect of hole screen diameter and screen title angle on purity for clover seeds in sieve oscillation 1.27 m s^{-1}

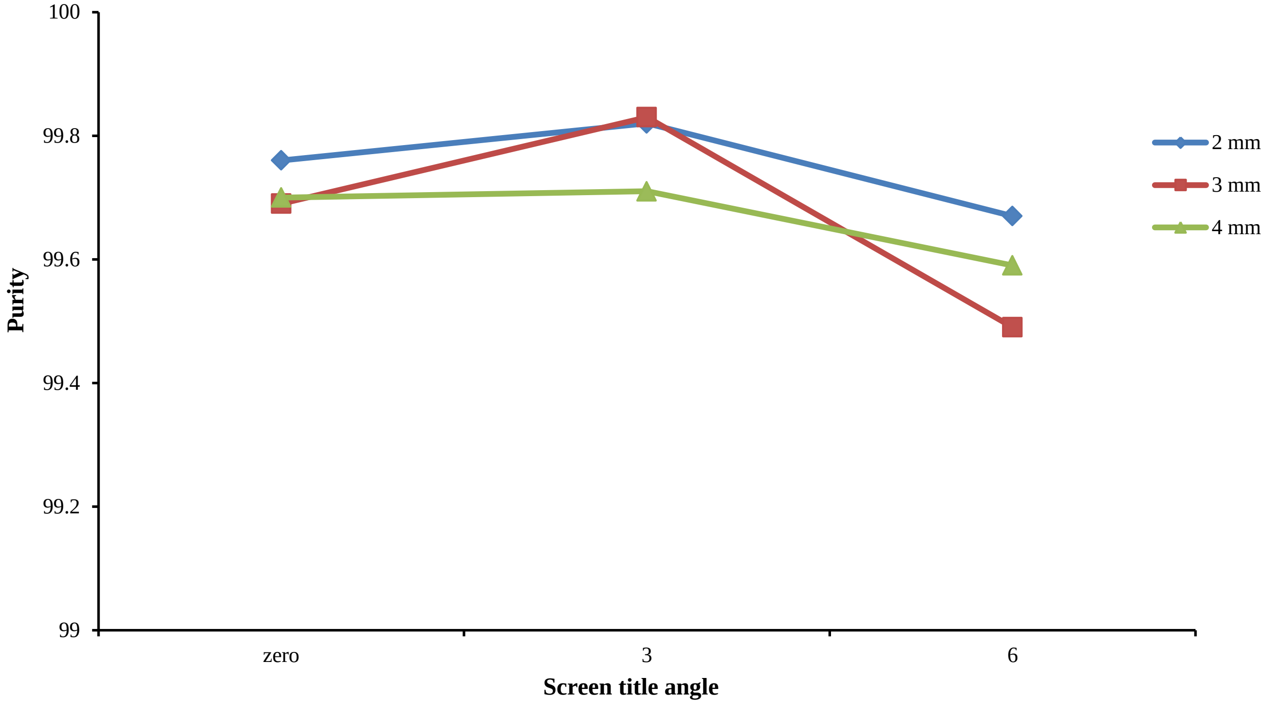

Figure 19 Effect of hole screen diameter and screen title angle on purity for clover seeds in sieve oscillation 0.53 m s^{-1}

4 Conclusion

From this investigation it is found that:

- Physical and engineering properties of sesame and clover seeds affected seeds cleaning.

- Screen title angles, hole diameters and sieve oscillation significant loading rate, machine efficiency and purity.

- The optimum performance was at sieve oscillation of 2.26 m s^{-1} and screen tilt angle of 3 degrees for sesame and clover seeds

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