

Design and Development of an Auxiliary Chickpea Second Sieving and Grading Machine

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Abstract. Sieving and grading are two final operations of high quality grain production. Farmers in Iran normally winnow chickpea by hand, which leaves a large amount of debris among the chickpea. To correct this problem, a machine was designed and developed at Tehran University to sieve and grade chickpea a second time. A low price, easy maintenance and usage, and technology appropriate for Iranian farmers were important considerations in the development of the machine. The following steps were taken during the design of the machine: Physical properties, terminal velocity, and coefficient of friction of five different varieties of Iranian chickpea: Jam, Philip, Bivanij, ILC-482 and ILC-12-60-31--were determined. The following parameters and factors affecting machine operation were determined. The arithmetic mean diameter was 6.7-9.7 mm with an average of 7.8 mm. The terminal velocity of a whole chickpea was 10-15 m/s, with an average of 12.6 m/s. For the dried leaves and stems, the averages were 3.0 m/s and 5.5 m/s, respectively. The minimum coefficient of friction occurred on galvanized steel and was 0.28, and the maximum coefficient of friction value of 0.33 occurred on fiberglass. The cleaning, grading, and overall efficiency of the machine were evaluated with 2 kg of hand-cleaned peas (debris-free) mixed with 15 grams chaff and stem and 100 grams of clods and stones. The cleaning efficiency of the whole chickpea was 93 % and the debris was 91 %. Overall, the machine efficiency was 84 %.

Keywords: chickpea, sieving, grading, cleaning efficiency, grain

Introduction

The world production of chickpea is about 7 million metric tons (MA, 1998). Average yield is about 610-710 kg per ha. Approximately 70-80% of chickpea production is used for human consumption, 14% for animal feed, 5-10% for seed, and 2-7% is lost during harvesting and processing.

Iran's major chickpea production areas are in the Kermanshah, Hamadan, Kordestan and Khorasan provinces. The average yield is 400-600 kg per ha (Koojakee and Avel, 1993). Chickpea plants are pulled out by hand, carried to a flat area, and piled into a conical stack (with a base diameter of 3-4 m and height of 1-2 m) called kharman. The pile is threshed by moving a

cow or tractor in a circle over it or by hitting a group of plants with a stick.

Afterward, the material is winnowed by hand, separating it into chickpea and material other than chickpea (MOP). This procedure is labor-intensive, and time-consuming and a lot of debris remains mixed with the chickpea. At the end of the process, the chickpea has not been graded and are not well cleaned. To prepare the chickpea for sale, a final cleaning is done by hand to separate the MOP from the chickpea, but there is still no grading done. From a marketing standpoint, it is necessary to grade the product according to quality and type of consumption.

Igbeka (1984) designed and constructed a machine to sieve rice and beans. This machine had sieve angle of 4-5° with a specific angular velocity of 300-350 rpm. The sieving efficiency was from 20-61% for different moisture content and varieties. Kachru and Sahay (1990) optimized a pedal-type sieving machine for chickpea, sorghum, and wheat. There has not been much study, however, on the design and development of chickpea sieving and grading machines (Aghagoolzadeh, 2001). Thus, it was necessary to study the physical properties of Iranian chickpeas in order to properly design a sieving and grading machine. This examination determined the physical properties of Iranian chickpea to facilitate the design and construction of a machine. The machine must be an affordable price (approximately US\$1200) for the Iranian farmer, do both grading and cleaning, and be less labor-intensive.

MATERIALS AND METHODS

Five varieties of Iranian chickpea- Jam, Philip, Bivanij, ILC-482 and ILC-12-60-31- were studied. Several two kg samples were randomly selected from different parts of Kermanshah province. The samples of one variety were mixed and a 0.5 kg sample was selected at random from the mix. From the sample 100 chickpea kernels were randomly selected. The steps were repeated for all five varieties.

A caliper was used to measure three perpendicular diameters for each chickpea with 0.05 mm accuracy (Tabatabaeefar, 2002). The average, standard deviation, maximum, and minimum diameter for each variety were determined. A relative frequency distribution for each size interval was calculated.

The coefficient of friction of the chickpea on different surfaces (glass, galvanized steel, fiberglass and plywood) was determined using a laboratory slope-meter apparatus. A topless box filled with 200 grams of chickpea with 5.7% moisture content d.b. was inverted onto a galvanized steel surface while the slope-meter was level (angle=0). The slope-meter was slowly pivoted until the box of material started to flow (Lorenzen, 1959). At that position, the angle was read off from the slope-meter compass and recorded. The experiment was repeated for each surface type.

The angle of repose of the chickpea was determined using a fixed wooden wall glued on a wooden surface as a rectangular shape. The box was filled with chickpea, leveled and the surface angle set at 0°. The surface was gradually tilted until the chickpea in the box started to move. The angle was then read off the compass next to the surface and recorded (Mohsenin, 1986).

The terminal velocity of Iranian chickpea was determined by Rabani (2001). The terminal velocity of chickpea leaves and stems were measured in a wind column. A 25-gram sample with 5.7% moisture content d.b. was placed on the screen in the column. The fan speed was increased and the material was allowed to float At which point the air velocity was recorded (Tabatabaeefar and Persson, 1995).

Design considerations

The followings are a list of design considerations for chickpea cleaning.

Particle movement on a sieve surface is by vibration. The resultant force on a particle must be higher than the friction force between the chickpea and the surface. Particle velocity on the sieve surface must not be too high, or the chickpea will pass by the sieve openings instead of falling through.

Farm machinery in Iran must be inexpensive and easy to repair and this machine must also be capable of producing 500-1500 kg/h of cleaned material.

The sieve may have openings of various shapes, but for materials of high sphericity (85%), a circular shape must be used.

Because the ratio of maximum diameter to minimum diameter is 1.4 (less than 2.0), there is no need for vertical motion; horizontal motion will suffice.

Sieves must be placed at an angle ($4-8^\circ$) less than the angle of friction of the chickpea on the surface. Sieve motion was adjusted from an eccentric with a radius of 30 mm. The throughput on the sieve was determined to be equal to $0.45 \text{ kg s}^{-1}\text{m}^{-2}$. The sieve surface area must be equal to 0.88 m^2 for a capacity of 500-1500 kg/h.

The mean diameter of Iranian chickpea was 6.7-9.7 mm, with the size of 70 % of the chickpea having diameters 7.3-8.5 mm. The chickpea were thus divided into three grades: large, medium, and small. Sieve openings with 6-7 - and 8 mm diameters were determined.

A relative movement between fluid and particle creates an aerodynamic force. Aerodynamic properties separate the stems, leaves, and chaff and light seed from the chickpea. Either a suction fan or blowing fan can be chosen to propel the air. A suction fan will interact with a particle.

There are two types of fans, axial and centrifugal. In the axial fan, air flows parallel to the axis. In a centrifugal fan, air enters parallel to the axis but exits perpendicular to the axis, creating a higher pressure more suitable for a sieving machine.

Fan selection depends upon terminal velocities of chickpea, chaff, leaves, and stem (Aghagoolzadeh, 2001). The air velocity needed to separate the unwanted material from chickpea was 6-9 m/s, greater than the terminal velocity of the stems and leaves and less than that for the chickpea. A centrifugal fan with straight blades was designed with an airflow rate of $1 \text{ m}^3/\text{s}$ to supply an airflow velocity of up to 11 m/s with an inlet area of 0.1 m^2 .

An airflow channel was needed to guide the air as well as undesirable material out of the machine. An inexpensive and easy-to-build airflow channel of rectangular shape was constructed.

Machine Construction

With design specifications and cost limitations in mind; an auxiliary sieving and grading machine (TAGmachine) was built in the Agricultural Machinery Engineering Department of Tehran University. Machine components and specifications included sieves, sieve frames, airflow systems, a power transmission system, and material input system and collection areas as shown in Figure 1.

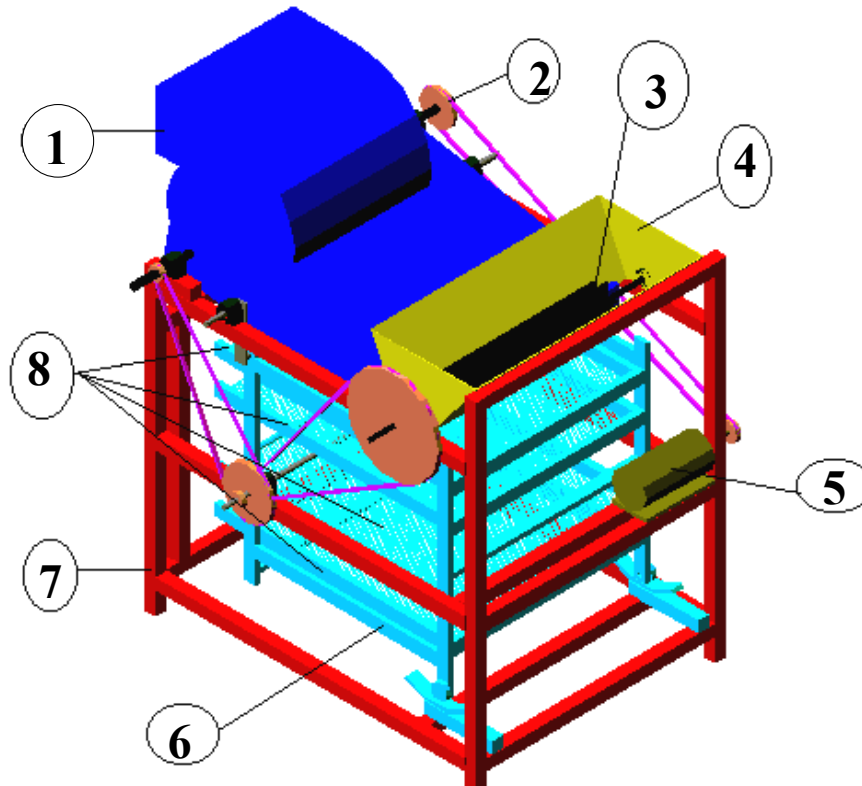


Figure 1. Sieving and grading machine.

1: Air-channel 2: Pulley and Belt 3: Metering device 4: Hopper
5: Electric-motor 6: Sieve Frame 7: Main Frame 8: Sieves

TAGmachine specifications

The specifications of the TAGmachine at the time of construction were as follows:

Length	1700 mm
Width	1500 mm
Height	1800 mm
Machine capacity	1000 kg/h
Power requirement	1.5 kW with 1440 rpm electric motor
Power transmission	V-belts and pulleys
Fan	Centrifugal with four blades
Airflow channel inlet size	140 x 700mm
Number of sieves	4
Sieve hole diameters	10, 8, 7, 6 mm
Sieves frame	Single
Sieve motion	Sieve frame was vibrated at 200 Hz with a crank shaft 150 mm long and a 30 mm eccentric radius.

The fan speed, sieve slope and opening sizes of the sieves can all be adjusted, making it suitable for cleaning other crops.

The parameters of fan speed, sieve size, and sieve slope of the TAGmachine were set at various position while it was running. A mixed material of known weight (2 kg) consisting of hand-cleaned chickpea (debris-free), 15 grams of known weight leaves and stems and 100 grams of clods and stones were fed into the machine. Degree of cleaning and separation, as well as overall efficiency was determined. The weight of the cleaned and graded chickpea, collected from sieve openings of 8-, 7- and 6- mm, was measured and the chickpea from 10- mm sieve were also sorted and weighed. The same procedure was used for the MOP. This procedure was repeated three times.

TAGmachine efficiency was determined using Igbeka (1984) method. The separation efficiency of the cleaned chickpea was determined from Equation 1:

$$EP = GP/(GP+GR), \quad (1)$$

Where EP = separation efficiency of cleaned chickpea, GP = weight of collected cleaned chickpea from sieve sizes 8-, 7-, 6- mm and GR = weight of cleaned chickpea not collected.

The separation efficiency of the MOP was determined from Equation 2.

$$EMOP = BR/(BR+BP), \quad (2)$$

Where EMOP = separation efficiency of materials other than chickpeas, BR = weight of collected MOP and BP = weight of MOP not collected.

Equation 3 determined the total efficiency of the machine:

$$\text{TAGmachine } E = EP * EMOP \quad (3)$$

Results and Discussion

The three perpendicular diameters, L1, L2, and L3, their averages and standard deviations and, the maximums and minimums of each variety were determined as shown in Table 1.

Table 1. Diameter (mm) of Iranian chickpeas by variety. Number of sample =100

	Statistical parameters	Variety				
		Jam	Bivanij	Phillip	Ilc-482	Ilc-12-60-31
L1 ^a	Mean	9.1	10.2	9.1	8.9	8.8
	Standard Deviation	0.46	0.92	0.38	0.44	0.4
	Maximum	10.7	11.75	10.5	10.05	10.5
	Minimum	7.9	8.3	7.7	7.9	7.15
L2	Mean	7.08	7.66	7.18	6.83	6.84
	Standard Deviation	0.48	0.52	0.36	0.30	0.42
	Maximum	7.95	8.55	8.1	7.4	8.15
	Minimum	5.85	6.5	6.05	6.15	6.05
L3	Mean	7.32	7.74	7.49	7.03	7.01
	Standard Deviation	0.44	0.5	0.53	0.45	0.42
	Maximum	8.4	9.15	8.5	8.15	8.3
	Minimum	6.25	6.55	6.5	6.05	5.95

a) L1 = longest diameter, L2 = longest diameter perpendicular to L1, L3 = longest diameter perpendicular to L1 and L2.

A frequency histogram of the arithmetic mean diameter for all varieties of chickpea and a fitted normal distribution curve was determined. The classification of frequency of the chickpea diameters is shown in Table 2.

Table 2. Classification of frequency of diameters of Iranian chickpea.

Range	Mean (mm)	Relative frequency, %	Cumulative relative frequency, %
6.6-7.4	7.0	17.6	17.6
7.4-8.2	7.8	59.6	77.2
8.2-9.0	8.6	16.2	93.4
9.0-9.8	9.4	6.6	100

The coefficient of friction of chickpea with a 5.7% d.b. moisture content was determined over different types of surfaces (galvanized steel, glass, fiberglass and plywood) as shown in Table 3. Galvanized steel material was used for the machine hopper.

Table 3. Coefficient of friction of chickpea over different surfaces

Surface type	Galvanized steel	Glass	Fiber glass	Plywood
Coefficient of friction	0.28	0.30	0.33	0.33

The terminal velocity for Iranian chickpea with a 7-8% moisture content d.b. was 10-15 m/s with an average of 12.6 m/s. For leaves and stems with 5.7% moisture content d.b. it was 3.5 m/s and 5 m/s, respectively.

Primary TAGmachine test

The TAGmachine was evaluated during its first test for its separation and grading capabilities. The separation of cleaned chickpea from stems, leaves, stones, clods, and other materials was observed. The effect of uniformity of air velocity, the angular velocity of the fan, sieve slope and sieve angular velocity on separation and grading chickpea were also determined.

Air velocity was measured at 10 different locations in the air channel inlet and outlet with a hotwire anemometer. The air velocity at the inlet had an average of 10.1 m/s with a standard deviation of 3.3 m/s and the outlet had an average air velocity of 6.5 m/s with a standard deviation of 0.71 m/s.

The fan speed was first set at 500 rpm and the material was fed through the TAGmachine onto the upper sieve. The velocity was then increased until some chickpea were observed to move along with other material into the air channel. Proper fan speed was determined to be 900 rpm for good quality separation and grading.

Eighty percent of debris came along with cleaned chickpea when the sieve slope was set at 10° for sieves 8, 7, 6 mm and 0° slope for the 10 mm sieve. Several slopes were tried to find one where the material would sit on the sieve openings at the lowest possible slope angle. The proper slope for sieve sizes 8, 7, and 6 mm was about 5°, and about 2° for the 10 mm sieve. The angular velocity of the sieve and sieve slope had an inverse relation. When the sieve frequency was set at 315 Hz, chickpeas were not going through the opening. The velocity then was reduced while the slope was kept constant. At a very low velocity, the material rested on the sieve openings and material flow toward the end of the sieve was reduced sharply. The proper sieve frequency was determined to be 200 Hz.

Cleaned chickpea and MOP were collected from the machine at different sieve outlets as well as MOP from the sieve pan at the bottom of the sieve frame. They were weighed and recorded for all three replications.

The separation efficiency of cleaned chickpea was determined from Equation 1 to be 93%. The separation efficiency of MOP was determined from Equation 2 to be 91%. The overall TAGmachine separating efficiency was 84% at 5.7 % moisture content, which is higher than reported by Igbeka (1984).

Conclusion

The designed and developed TAGmachine performed well with high separating efficiency and grading ability. The overall machine efficiency was 84 %.

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