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Research Article

The determination of pneumatic conveying characteristics of chickpea

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Abstract: The pneumatic conveying characteristics of chickpea (*Cicer arietinum* L.) of the variety *Koçbasi* were determined. The length, width, thickness, arithmetic mean diameter, geometric mean diameter, sphericity, volume, 1000 seed mass, bulk density, true density, porosity, projected area, terminal velocity, drag coefficient, pressure drop, power consumption, and seed damage, namely mechanical damage, germination test, and seed vigour index, were investigated experimentally. The positive low pressure system was used for the conveying of chickpeas. The power requirement and pressure drop were boosted with increasing the revolution of the blower and conveying capacity decreased with increasing pipe diameter. The highest pressure drop and power requirement were obtained for 54.5 mm pipe diameter, while the lowest pressure drop was found for 70.3 mm pipe diameter. The mechanical damage to the chickpeas for both pipe diameters increased as the revolution of the blower increased.

Key words: Pneumatic conveying, positive low pressure system, chickpea, blower

Nohudun pnömatik iletim karakteristiklerinin belirlenmesi

Özet: Bu çalışmada, nohudun (*Cicer arietinum* L.) *Koçbaşı* çeşidinin pnömatik iletim karakteristikleri belirlenmiştir. Denemelerde, nohutların uzunluğu, genişliği, kalınlığı, aritmetik ortalama çapı, geometrik ortalama çapı, küreselliği, yoğunluğu, bin tane ağırlığı, kütlesel yoğunluğu, gerçek yoğunluğu, porozitesi, projeksiyon alanı, terminal hızı, sürüklenme katsayısı, basınç düşümü, güç tüketimi ve tohum zedelenmesini oluşturan mekanik zedelenme, çimlenme testi ve tohum vigor indeksi araştırılmıştır. Nohudun pnömatik iletimi için pozitif düşük basınçlı sistem kullanılmıştır. Üfleyici devrinin artmasıyla güç ihtiyacı ve basınç düşümü artmış, boru çapının büyümesiyle iletim kapasitesi azalmıştır. En yüksek basınç düşümü ve güç ihtiyacı 54.5 mm boru çapında tespit edilmiştir. 70.3 mm boru çapında ise en düşük basınç düşümü görülmüştür. Her iki boru çapı için üfleyici devri arttıkça nohudun mekanik zedelenmesinin arttığı belirlenmiştir.

Anahtar sözcükler: Pnömatik iletim, pozitif düşük basınçlı sistem, nohut, üfleyici

Introduction

Chickpea (*Cicer arietinum* L.) is one of the oldest and most widely consumed legumes in the world, particularly in tropical and subtropical areas. It has a high level of carbohydrate (41.1%-47.4%) and protein (21.7%-23.4%) and it contains 17.6% total dietary

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fibre, which increases to 49.5% after cooking (Chillo et al. 2008). Chickpea is a grain legume widely grown in Turkey for food. The grain forms an important source of protein in the Turkish diet (Konak et al. 2002). The world's total production of chickpeas was 9,400,000 t from 11,670,000 ha in 2007. Turkey has approximately 500,000 ha of chickpea harvesting area and produces 43,000 t per year (FAO 2007).

The pneumatic conveying characteristics of agricultural materials such as the length, width, thickness, arithmetic mean diameter, geometric mean diameter, sphericity, volume, thousand seed mass, bulk density, true density, porosity, projected area, terminal velocity, drag coefficient, pressure drop, power requirement, and seed damage are used in handling, processing, and designing equipment (Güner 2006; Kılıçkan and Güner 2006).

In order to optimize various factors, threshing efficiency, pneumatic conveying, and storage pertaining to chickpea seed, the physical properties are essential (Konak et al. 2002).

Aerodynamic properties of agricultural materials are used in the handling and processing of various agricultural products. Terminal velocity is one of the most important aerodynamic properties for the separation, the pneumatic transportation, and the cleaning of seed grains (Song and Litchfield 1991). Cleaning, automatic weighing, and hulling are among many operations that require certain pneumatic handling systems for conveying chickpeas. Pneumatic cleaners are used in the cleaning process, and they also describe the action of air and shakers in combination (Tabak and Wolf 1998). In order to design equipment for cleaning, handling, aerating, storing and processing of chickpeas, it is necessary to study their pneumatic conveying characteristics. Thus, the objective of this study was to determine the physical properties of chickpeas and air velocity, pressure drop, and power requirement in relation to pneumatic conveying characteristics.

Materials and methods

The experiments were conducted at the Department of Agricultural Machinery, Faculty of Agriculture, Ankara University. The conveying characteristics of the chickpea (*Cicer arietinum* L.) of the variety *Koçbasi*, widely grown in Turkey, were investigated in the tests. The chickpeas were produced in Konya, which is a city in the Central Anatolia region of Turkey.

Determination of physical properties

The chickpea seeds were cleaned manually to remove all foreign matter such as dust, dirt, stones, and chaff. To determine the size of the chickpeas, 10 groups of samples consisting of 100 segments were randomly selected. Ten seeds were taken from each group and their linear dimensions, namely length L, width W, and thickness T, were measured by using a micrometer to an accuracy of 0.01 mm (Yalçın and Özarslan 2004; Çalışır et al. 2005; Haciseferoğlu et al. 2005). The mass of 1000 seeds was measured by an electronic balance to an accuracy of 0.01 g. To evaluate 1000 bean mass, 1000 randomly selected beans from the bulk were weighed and their weights were averaged. The moisture contents of chickpea samples were determined by using standard methods such as an oven temperature of 103 °C and a heating time of approximately 4 h (ASAE 1992; Tabak and Wolf 1998).

Geometric mean diameter D_g, sphericity Ø, and arithmetic mean diameter D_a values were found by using the following formulae (Mohsenin 1970; Sitkei 1986; Güner et al. 2003):

$$D_g = (LWT)^{1/3} \quad (1)$$

$$\phi = \frac{(LWT)^{1/3}}{L} \quad (2)$$

$$D_a = \frac{L + W + T}{3} \quad (3)$$

where D_g is the geometric mean diameter in mm; *L* is the length in mm; *W* is the width in mm; *T* is the thickness in mm; ϕ is the sphericity in %; and D_a is the arithmetic mean diameter in mm.

The bulk density ρ_b was determined with a weight per hectolitre tester, which was calibrated in kg per hectolitre. The grains were not compacted during the test (Jain and Bal 1997; Çalışır et al. 2005b).

The true density ρ_t and volume V were determined by using the toluene displacement method. Toluene C_7H_8 was used instead of water because it is absorbed by the bean to a lesser extent. Moreover, its surface tension is low so that it can fill even shallow dips in a seed and its dissolution power is low (Mohsenin 1970; Sitkei 1986; Çalışır et al. 2005c).

The percent porosity was calculated by using the following equation (Mohsenin 1970; Singh and Goswami 1996):

$$\varepsilon = 100\left(1 - \frac{\rho_b}{\rho_t}\right) \quad (4)$$

where ε is the porosity in %; ρ_b is the bulk density in kg m^{-3}; and ρ_t is the true density in kg m^{-3}.

The projected area of a single kernel was measured by a scanner connected to a computer. A special computer program developed by Özarslan (2002) was used to estimate the area scanned.

The terminal velocities of the chickpeas were measured by using a wind column. An air stream was directed through a 70.3 mm inside diameter transparent tube positioned vertically. A roots blower (rotary positive displacement blower) was used to develop air flow. Air flow was regulated by adjusting the blower speed through a frequency inverter. For each test, a sample was released into the air stream from the top of the air column. Air was blown upward to suspend the bean in the air stream. The air velocity near the location of the seed suspension was measured by Lutron Am-4204 electronic anemometer having a least count of 0.1 m s^{-1} (Song and Litchfield 1991; Tabak and Wolf 1998; Çalışır et al. 2005b). The terminal velocity for each was measured 10 times and the average terminal velocity for each seed was determined.

The dimensionless drag coefficient characterizes the interaction between the chickpea and the airflow and is expressed by the formula (Tabak and Wolf 1998; Tabak et al. 2002).

$$C_d = \frac{2mg}{V_t^2 \rho_a A} \quad (5)$$

where C_d is the drag coefficient of the seed; m is the mass of the seed in kg; g is the acceleration of gravity in m s^{-2}; V_t is the terminal velocity in m s^{-1}; ρ_a is the air density of 1.223 kg m^{-3}; and A is the projection area in m^2.

Determination of conveying characteristics

Determination of pressure and pressure drop

In the tests, a positive low pressure pneumatic conveying system developed by Güner (2005) and approved by the Scientific and Technological Research Council of Turkey (TÜBİTAK) was used. The general arrangement of the pneumatic conveyor is shown in Figure 1. The pneumatic conveyor comprises a 20 m horizontal pipe and a 4 m vertical pipe and 3 bends of 90°. The roots blower (LT–65 type, max. 80 kPa, max. 2250 rpm produced by UKA in Konya, Turkey) was used to deliver air through the system. The seed hopper served as a storage container for the material. The chickpeas to be conveyed could be introduced into the system by using an airlock feeder. The speed of the airlock feeder could be adjusted to feed beans at different rates by a motor with a frequency inverter. The transparent tube provided a means to observe the transport phenomena in the horizontal flow. The cyclone separator was fixed at the discharged end to slow the particles flow and separate beans from the conveying air. The cyclone separator airlock was used. In the cyclone separator, the seeds fell downward by the cyclone separator airlock and the air containing dust and light foreign materials was exhausted out of the cyclone to the filter by the vacuum blower. The dust collector or exhaust air filter cleaned the conveying air.

The static pressure was measured at 5 points by the pressure transmitter (model: HUBA 0-1600 mb) and process screen to an accuracy of 1% (model: ESM-4900 48 × 96DIN ¼, produced by Emko Elektronik A.Ş. Bursa, Turkey). The pressure was measured at 5 locations throughout the conveyor by pressure transmitters (Figure 1). Therefore, pressure drop P across any 2 pressure tappings along the pipe length could be calculated; the total pressure drop was calculated by subtracting pressure at the cyclone inlet (atmospheric pressure) from which the first measurement point was divided by the pipe length. All of the measured pressures in the study were static pressure.

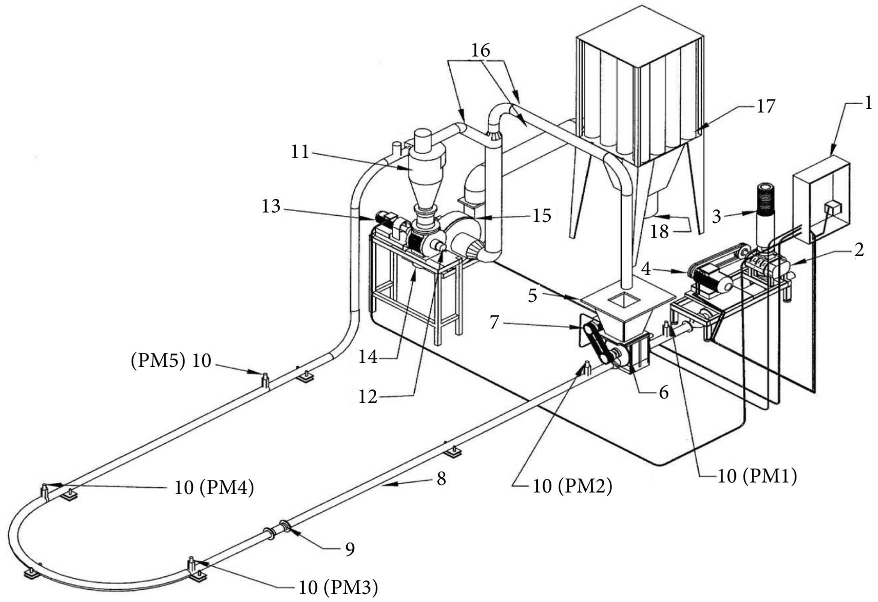

Figure 1. The general arrangement of the pneumatic conveyor: 1, control unit; 2, roots blower; 3, air inlet filter; 4, roots blower motor; 5, seed hopper; 6, rotary feeder or hopper airlock feeder; 7, rotary feeder motor; 8, seed pipe; 9, transparent tube; 10, pressure drop measurement (PM) tappings; 11, cyclone separator; 12, cyclone separator airlock; 13, cyclone separator airlock motor; 14, seed discharge; 15, vacuum blower; 16, dust pipes; 17, dust collector or exhaust air filter; 18, light foreign materials.

Determination of air velocity

The air velocity was calculated from the blower curve according to the pressure drop measured at the inlet of the pipe. To determine the air velocity, the volumetric air flow rate $m^3 s^{-1}$ of the roots blower (LT–65 type, max. 80 kPa, max. 2250 rpm produced by UKA in Konya, Turkey) corresponding to the according to pressure drop established throughout the entire conveyor was divided by the pipe cross section areas m^2 calculated according to the diameters of 54.1 mm and 70.3 mm (Hauch 2005).

To give the results of chickpea conveying for pipe diameters of 54.5 mm and 70.3 mm, the revolution of blower instead of air velocity was used in Figures 2-9. The air velocities for chickpea conveying at the different revolutions of blower are given in Table 1.

Determination of power requirement and capacity

To determine the conveying power requirement, the voltage, the current, and the power factor drawn by the electric motor (AGM 132 M4 type, 3-phase, 7.5 kW, produced by GAMAK in İstanbul, Turkey) for the roots blower were measured by using a voltmeter,

Table 1. Conveying velocities at different revolution of blower and both pipe diameters.

Revolution of blower (min^{-1})	Pipe diameters (mm)	Air velocities ($m\ s^{-1}$)
1150	54.5	18.16
	70.3	7.32
1300	54.5	20.85
	70.3	8.24
1450	54.5	29.06
	70.3	12.41
1600	54.5	32.50
	70.3	14.97
1750	54.5	36.33
	70.3	18.87
2000	54.5	42.17
	70.3	22.64

ampere meter, and power factor meter, respectively. Conveying capacity depended on the mass of the seed, air moved, and the physical characteristics of the seed (Hellevang 1985). In this study, conveying capacity was adjusted by the speed of the airlock feeder under the hopper.

Seed quality evaluation

Seed quality was evaluated in terms of mechanical damage, germination test, and seed vigour. The mechanical damage was determined by weight, comparing the mass of seeds damaged to a general sample of given mass (Segler 1951). Firstly, 3 replications of 100 seeds were weighed and then the damaged seeds conveyed one time through the conveyor were counted and weighed. The ratio of damaged seeds to the total seeds was termed as mechanical damage and expressed in mass percentage.

$$S_d = 100 \frac{M_d}{M_d + M_{ud}} \quad (6)$$

where S_d is the mechanical damage to the chickpea in %; M_d is the mass of damaged seeds in g; and M_{ud} is the mass of undamaged seeds in g.

Germination ability was determined according to the Association of Official Seed Analysts (AOSD 1981). Three replications of 100 seeds were placed in pre-soaked germination paper and were then placed in a seed germinator at 25 °C for 7 days. After 7 days, the number of seeds germinated normally was counted and used for calculating germination ability (Parde et al. 2002).

The seed vigour tests were conducted according to the International Seed Testing Association method (ISTA 1985). Sheets of paper towel with 3 × 50 seeds were kept in a seed germinator at 25 °C for 7 days. After 7 days, the lengths of germinated seedlings were measured in centimetres. The vigour index was calculated as

$$V_i = \frac{1}{N}\sum G_e \times S_l \quad (7)$$

where V_i is the vigour index; N is the number of seeds germinated; G_e is the germination rate in %; S_t is the seedling length in cm.

Results

Physical properties of chickpea

Table 2 shows physical properties of the chickpeas in the tests. In Table 2, the average values of length, width, and thickness of the chickpeas were 9.53 mm, 7.56 mm, and 7.48 mm at the moisture content of 8% d.b., respectively.

The average values of arithmetic and geometric mean diameter of the chickpeas were 8.19 and 8.13 mm, respectively. The average values, volumes, 1000 seed mass, bulk density, true density, porosity, and projected area of the chickpeas were 278.50 mm^3, 383.00 g, 741.50 kg m^{-3}, 1390 kg m^{-3}, 46.50%, and 43.00 mm^2 at the moisture content of 8% d.b., respectively.

Table 2. Physical properties of chickpea samples at 8.0% d.b.

Properties	Chickpea	
	Average Values	Standard Errors
Length, mm	9.53	± 0.218
Width, mm	7.56	± 0.191
Thickness, mm	7.48	± 0.085
Arithmetic mean diameter, mm	8.19	± 0.106
Geometric mean diameter, mm	8.13	± 0.078
Sphericity, %	85.59	± 0.417
Volume, mm^3	278.50	± 0.138
Thousand seed mass, g	383.00	± 0.325
Bulk density, kg m^{-3}	741.50	± 0.445
True density, kg m^{-3}	1390.00	± 0.128
Porosity, %	46.50	±0.392
Projected area, mm^2	43.00	± 0.467
Terminal velocity, m s^{-1}	17.20	± 0.291
Drag coefficient	0.764	± 0.451

The average terminal velocity values of the chickpeas determined in this study were also presented in Table 2. The terminal velocities were 17.20 m s^{-1}. The drag coefficients were 0.764.

Conveying characteristics of chickpea

Pressure and pressure drop in conveying pipe

The air flow (without materials) generates friction in the pipe, which must be overcome. The effect of revolution of the blower (without seeds) on the pressure depending on the measurement points at the pipe of inside diameter *70.3 mm* is presented in Figure 2. The trends in this figure are clear. When the pipe diameter is kept constant, the pressure rises directly with the revolution of the blower. The rate of pressure increase varies with the revolution of the blower. The rate of pressure rise increases as the revolution of the blower increases. The effect of the pipe length is also clear. At any constant revolution of the blower, the pressure decreases as the length of the pipe increases, namely, from the feeder point to the exit of the pipe.

The effect of chickpea on pressure drop at a conveying capacity (seeds throughput) of 5.0 t h^{-1} for both pipe diameters (*54.5 mm, 70.3 mm*) can be seen in Figure 3. At all revolutions of the blower of 1150, 1300, 1450, 1600, 1750, and 2000 min^{-1}, the highest pressure drop was obtained for chickpea at *54.5 mm* pipe diameter, while the lowest pressure drop was seen for *70.3 mm* pipe diameter. In addition, the increase in pressure drop with increasing air velocity can be seen in Figure 3. The pressure drops for chickpea increased from 233 Pa m^{-1} to 479 Pa m^{-1} at 1150 min^{-1} and from 416 Pa m^{-1} to 874 Pa m^{-1} at 2000 min^{-1}, respectively.

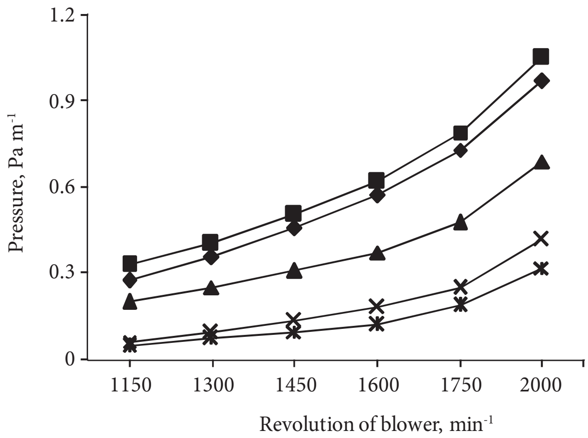

Figure 2. The effect of at revolution of blower on pressure drop for air only at the pipe of inside diameter of 70.3 mm at different pressure measurements (PM) locations: ─■─, PM_1; ─◆─, PM_2; ─▲─, PM_3; ✕, PM_4; ✳, PM_5.

Figure 3. The effect of chickpea on pressure drop at a conveying capacity of 5.0 t h^{-1} for different pipe diameters: ─◆─, 54.5 mm; ─■─,70.3 mm.

Figure 4 shows the effect of pipe diameter on the pressure drop at the revolution of the blower of 1450 min^{-1} and at a conveying capacity of 5 t h^{-1} for chickpea.

Figure 5 shows that at constant revolution of the blower of 1450 min^{-1}, the pressure drop rises directly with the conveying capacity. It is true for both of the pipe diameters studied. The maximum pressure drop was obtained for *54.5 mm* pipe diameter, while the minimum pressure drop was for *70.3 mm* pipe diameter. The maximum pressure drop for *54.5 mm* pipe diameter may be caused by its air velocities that are higher than the *70.3 mm* pipe diameter's air velocities.

Power requirement and conveying capacity

The rate of power requirement increase rises with the revolution of the blower (Figure 6). The *54.5 mm*

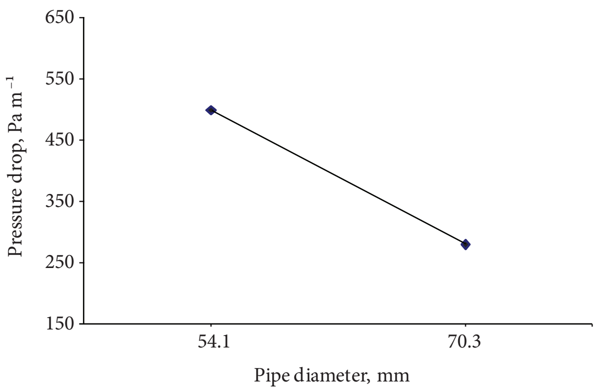

Figure 4. The effect of pipe diameter on the pressure drop at revolution of blower of 1450 min^{-1} and at a conveying capacity of 5 t h^{-1} for chickpea.

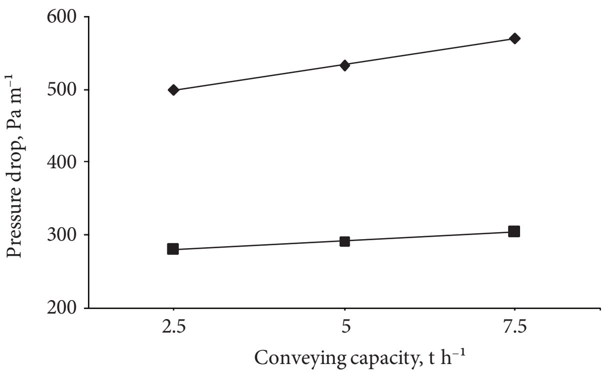

Figure 5. The effect of conveying capacity on the pressure drop at revolution of blower of 1450 min^{-1} of chickpea for different pipe diameters: ◆, 54.5 mm; ■, 70.3 mm

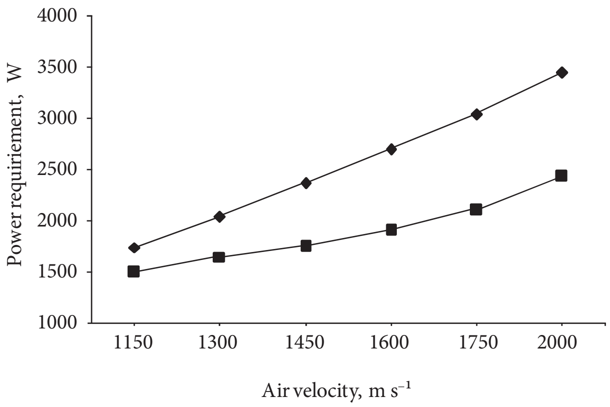

Figure 6. The effect of at revolution of blower on the power requirement at the conveying capacity of 5.0 t h^{-1} of chickpea for different pipe diameters: ◆, 54.5 mm; ■, 70.3 mm.

pipe diameter has a higher power requirement because of high air velocity.

The effect of pipe diameters on the power requirement for chickpea at constant revolution of the blower of 1450 min^{-1} and capacity of 5 t h^{-1} can be seen in Figure 7. The power requirement decreases as pipe diameter increases for chickpea. With respect to pipe diameter, the wide pipes, therefore, can be chosen for less power requirement. At a constant revolution of blower *54.5 mm* pipe diameter led to higher power requirement than *70.3 mm* pipe diameter.

The power requirement of pneumatic conveyors is greatly influenced by the choice of revolution of the

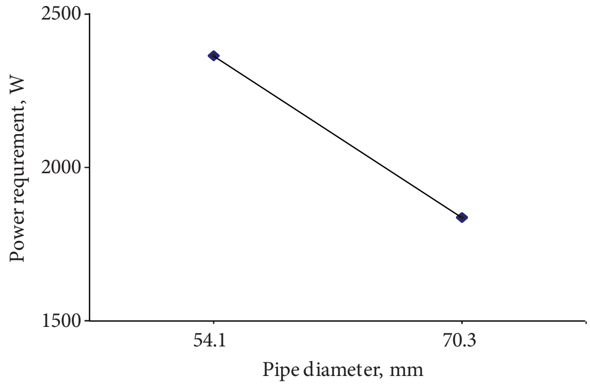

Figure 7. The effect of pipe diameter on the power requirement at constant at revolution of blower of 1450 min^{-1} and capacity of 5 t h^{-1} for chickpea.

blower. Power requirements as a function of conveying capacity are given in Figure 8. For a revolution of the blower the power requirement increases with increasing conveying capacity for both pipe diameters. The highest power requirement was obtained for *54.5 mm* pipe diameter, while the lowest was for the *70.3 mm* pipe diameter. The power requirements of *54.5 mm* pipe diameter for conveying capacities of 2.5 t h^{-1} and 7.5 t h^{-1} increased from 2037 W to 2300 W, respectively.

The effect of revolution of the blower on power requirement for air only at the pipe of inside diameter of *54.5 mm* is shown in Figure 9. As can be seen, power requirement increases with the revolution of the blower i.e. air velocity.

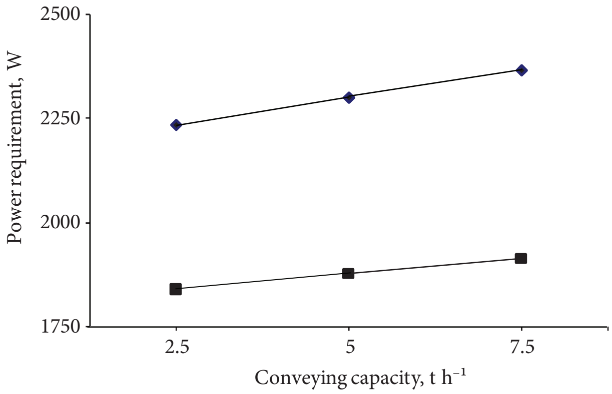

Figure 8. The effect of conveying capacity on the power requirement at constant at revolution of blower of 1450 min^{-1} of chickpea for different pipe diameters: ◆, 54.5 mm; ◆, 70.3 mm.

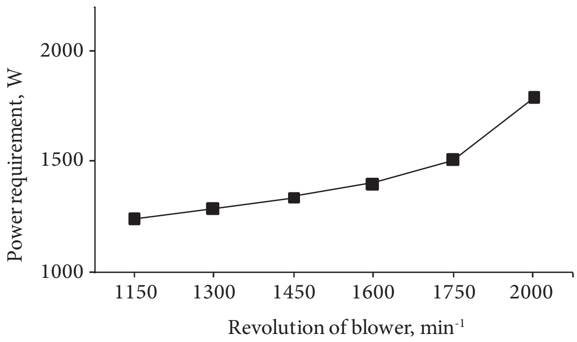

Figure 9. The effect of at revolution of blower on the power requirement at the pipe of inside diameter of 54.5 mm.

Chickpea seed quality evaluation

The effect of pneumatic conveying on mechanical damage is given in Table 3. The data show that mechanical damage to the chickpeas increases as the revolution of the blower increases at the inside diameters of *54.5* and *70.3 mm*. The maximum mechanical damage was obtained as the values of 27.13% for the revolution of the blower of 2000 min^{-1} and pipe diameter of *54.5 mm*.

The effects of pneumatic conveying on seed germination and vigour index for the inside pipe diameters of *54.5 mm* and *70.3 mm* can be seen in Table 2. Although the germination and the vigour index did not show any dependence on revolution of the blower, the germination and vigour index of *54.5 mm* and *70.3 mm* pipe diameters at the all revolutions of the blower dropped significantly after conveying. Before conveying, the germination and vigour index of *54.5 mm* pipe diameter for the revolution of the blower of 1150, 1450, 1750, and 2000 min^{-1} were 96% and 7.09 cm, 85% and 8.34 cm, 94% and 8.23 cm, and 92% and 6.44 cm, respectively. After conveying, the germination and vigour index of *54.5 mm* pipe diameter for the revolution of blower of 1150, 1450, 1750, and 2000 min^{-1} were 74% and 5.08 cm, 56% and 1.13 cm, 47% and 4.96 cm, and 44% and 4.33 cm for all revolutions of the blower, respectively.

Discussion

The length, width, thickness, arithmetic mean diameter, geometric mean diameter, sphericity, volume, 1000 seed mass, bulk density, true density, porosity, projected area, terminal velocity and drag coefficient of chickpea ranged from 6.93 to 10.08 mm, 6.10 to 7.90 mm, 4.55 to 6.50 mm, 6.05 to 7.66 mm, 5.86 to 7.55 mm, 78.36% to 85.71%, 127.00 to 138.00 mm^3, 133.60 to 147.00 g, 424 to 705 kg m^{-3}, 864 to 1280 kg m^{-3}, 45.00% to 51%, 37.60 to 58.60 mm^2, 14.60 to 16.40 m s^{-1}, and 0.333-0.509, respectively. The average sphericity of chickpea was 85.59%. Konak et al. (2002) determined geometric mean diameter and

Table 3. Mechanical damage, seed germination, and vigour index of chickpea in percentage at different inside pipe diameters and air velocities.

Inside pipe diameter, mm	Revolution of blower, min^{-1}	Mechanical damage, %	Before conveying		After conveying	
			G_e, %	V_i, cm	G_e, %	V_i, cm
	1150	14.47 ± 1.4	98 ± 1.0	28.04 ± 4.3	83 ± 5.8	20.87 ± 10.9
54.5	1450	17.82 ± 13.3	97 ± 2.1	23.34 ± 9.8	73 ± 2.3	19.03 ± 5.2
	1750	19.78 ± 3.5	84 ± 3.2	18.73 ± 14.6	59 ± 4.7	14.51 ± 7.7
	2000	26.34 ± 9.7	91 ± 7.9	16.94 ± 11.3	51 ± 10.9	1.74 ± 10.3
	1150	11.32 ± 2.6	98 ± 2.1	19.98 ± 12.0	84 ± 4.75	11.9 ± 6.5
70.3	1450	16.48 ± 6.1	96 ± 2.0	17.73 ± 9.3	69 ± 3.34	5.7 ± 7.9
	1750	18.89 ± 1.8	84 ± 3.9	15.48 ± 0.5	61 ± 6.42	6.8 ± 7.4
	2000	24.77 ± 1.1	96 ± 2.0	19.94 ± 6.5	52 ± 5.72	8.1 ± 2.0

G_e, germination; V_i, vigour index

sphericity of chickpea as 8.358 mm and 87.58% at the moisture content of 5.24% d.b., respectively. In addition, Kural and Çarman (1997) reported the sphericity of chickpea as 83.2%. Similar results have been reported by Konak et al. (2002). Volumes and 1000 seed mass of chickpea were found to be 238.00 mm^3 and 324 g, respectively.

The highest pressure drop was obtained for chickpea at *54.5 mm* pipe diameter, while the lower pressure drop was seen for *70.3 mm* pipe diameter at all revolutions of the blower of 1150, 1300, 1450, 1600, 1750 and 2000 min^{-1}, i.e. at all air velocities.

The pressure drop decreases as the pipe diameter increases at a constant conveying capacity and revolution of the blower. At a given conveying capacity and the revolution of the blower, the pressure drop decreases as the pipe diameter increases. If the decision has been made to work with low or medium pressure, then pipes with low diameter should not be used. Conversely, the pipe size available for a given duty may determine whether the pneumatic conveyor is to be of the high, medium, or low pressure type. Similar results were reported by Kılıçkan and Güner (2006)

The power requirement rises with the revolution of the blower. The power requirement decreases as the pipe diameter increases at a constant conveying capacity and revolution of the blower. It is desirable, therefore, to work with the lowest possible revolution of blower to keep the power requirement as low as possible. However, the danger of blockage should be taken into consideration because blockages can occur when the energy of air flow is insufficient to keep up the conveying process. Similar results were reported by Segler (1951), and Kılıçkan and Güner (2006).

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