J. Agric. Sci. Mansoura Univ., 33 (1): 273 - 282, 2008

SOME PHYSICAL AND ENGINEERING PROPERTIES OF SUGAR BEET SEEDS IN RELATION WITH SOME AGRICULTURAL MECHANICAL

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ABSTRACT

Some properties of sugar beet seed species were determined to utilize for design and develop the precision planter, handling process and cleaning systems. The main dimensions (length, width and thickness), spherisity, geometric mean diameter, arithmetic mean diameter, surface area, bulk density and true density were identified as physical parameters. Meanwhile, the terminal velocity, and hardness were measured as engineering properties. Results of the above investigated parameters showed that the mean of sugar beet seed properties data were 6.12 mm, 5.30 mm, 4.08 mm, 7.22, 44.59 mm, 5.17 mm, 204.97 mm^2, 0.277 g/cm^3, 4.62 g/cm^3, 1.66 m/sec and 17.64 N respectively for multi-germ species. But, the same data at mono-germ were 4.34 mm, 4.14 mm, 3.82 mm, 5.28, 22.94 mm, 4.10 mm, 112.96 mm^2, 0.439 g/cm^3, 0.747 g/cm^3, 3.049 m/sec and 23.29 N respectively.

The mean values for the coefficient of friction were 0.4765, 0.5108, 0.5704 and 0.7276 on stainless steel, iron sheet galvanized, plastic and rubber matrials respectively for multi-germ seeds. Furthermore, the mean values for the coefficient of friction were 0.2609, 0.2894, 0.3027 and 0.3537 on stainless steel, iron sheet galvanized, plastic and rubber matrials respectively for mono-germ seeds.

Keywords*:* Sugar beet, spherisity, geometric diameter, arithmetic diameter, surface area, bulk density and true density terminal velocity, coefficient of friction and hardness.

INTRODUCTION

In Egypt, the sugar beet is considered one of the most important crops, not only for sugar producing but also for its secondary productions, fodder, molasses and fertilizer as organic matter. The total cultivated area of sugar beet were about 446 $\times$ 10^3 feddans (Ministry of agricultural 2005), with an annual production of 0.5 million tones sugar.

El-Nakib, *et al.* (1996) reported that, are considered the very important guide to design the machinery components for planters and harvesters. To design equipment and facilities for handling, processing and storage, the physical properties must be known (Nimkar and Chattopadhyay, (2001); Aviara *et al.*, (2005) and Seyed and Elnaz, (2006)). These properties including principle dimensions (L, W and T), shape, mass, volume, roundness, sphericity, true and bulk densities, coefficient of friction, repose angle, terminal velocity, drag coefficient, Reynold’s number, projected area, and mechanical damage.

The physical properties of sugar beet seeds varying with the cultivars. In order to optimize various factors, threshing efficiency, pneumatic conveying and storage of sugar beet seeds, better understanding of the physical properties are also essential. Some physical properties length, width, thickness, geometric mean diameter, sphericity, mass, volume, bulk density, true density, porosity and static coefficient of friction of squash seeds at 6.4% moisture content were evaluated by Paksoy and Aydin (2004).

Knowledge of seeds physical properties is essential for controlling damage during storage, also are necessary in mathematical models for the design of equipment (Pérez, *et al.*, 2001). But, seed mechanical properties is important to the feed manufacture, handling, processing material and storage. Change in these properties can lead to abnormal high of low levels of active ingredients in finished feed, thus decreasing its quality (Molenda *et al.*, 2002). The methods of handling, processing and storing the seeds are needs to develop, improved these methods using suitable machines and equipment. Therefore to develop such methods and equipment, the physical and mechanical properties need to be known (Aviara, *et al.*, 1999).

Increasing economic importance of food materials, together with complexity of modern technology for their production, handling, storage, processing, preservation, quality, evaluation, distribution and marketing demands a better knowledge of the significant physical properties of these materials (El-Sahrigi, 1997). Chakraverty (1987) reported that the knowledge of important physical properties such as: size, shape, volume, surface area, density, porosity, color, etc., of different grains is necessary for the design of various separating, handling, storing and drying systems. The density and specific gravity values are also used for the calculation of thermal diffusivity and Renold's number. Some of the physical properties include 1000-grain weight, sphericity, roundness, size, volume, shape, surface area, bulk density, true density, static coefficient of friction against different materials and angle of repose. Some engineering properties of sugar beet seeds, such as density, terminal velocity and coefficient of drag, were reported by Kural and Carman (1997).

The grain hardnss had an opposite linier dpendence on moisture content. The hardness values of rice, corn, wheat and barely crops ranging from 21.76 to 37.50, 71.07 to 173.2, 24.01 to 50.44 and 37.35 to 81.4 N rspectively (Matouk *et al.*, 2005).

The physical and engineering properties of sugar beet seeds are very important in many problems associated with design of specific machine dealing with handling, grading, conveying, crushing and mixing. Also, it may be very important in analyzing and describing the behavior of planting and processing operation precision the sugar beet seed in field.

From this point of view, the main objective of this study is to determine the main relationships among the physical and engineering properties of sugar beet seeds.

MATERIALS AND METHODS

Sugar beet seeds (mono and multi-germ) were obtained from El-Gmiza Research Station. The seeds sampled for experiments were randomly selected, the initial moisture content of the seeds was determined using the oven method (AOAC, 1970). The seeds moisture content were about 12.5 and 13.4 % w.b. for sugar beet seed species mono and multi-germ respectively.

Methods for determination of each properties were selected on the basis of simplicity, accuracy of results and wide acceptability as follow:

- Seed main dimensions were determined: measuring the dimensions of three principal axes of 100 randomly selected seeds, using an digital vernier caliper with an accuracy of 0.05 mm.
- Sphericity "ϕ" was calculated according to Mohsenin (1970) as the following equation:

$$\phi = \frac{Dg}{L} = \frac{(L.W.T)^{1/3}}{L}$$

Where:

Dg = Geometric mean diameter, mm
L = Seed length, mm
W = Seed Width, mm
T = Seed thickness, mm

- Geometric mean diameter (Dg, mm) and the arithmetic mean diameter (Da, mm) of the sugar beet seed were calculated using the following equation (c.t. Seyed and Elnaz, (2006)):

$$Dg = (L.W.T)^{1/3}$$

$$Da = \frac{L + W + T}{3}$$

- Seeds surface area (A_s) was calculated by using the following equation (Mohsenin, 1970):

$$A_s = 2\pi (L.W)$$

- To determine seed mass and thousand seed mass the electric digital balance was used with an accuracy of 0.1 g.
- Bulk density was determined using graduated cylinder for measuring volume of seeds and mass it.
- The true density was determined using the water with a known mass of seeds displacement method. The 20 seeds in sample were used for each sugar beet species.
- The terminal velocity of seeds sample were measured using the constructed instrument by El-Fawal and Ismail (2007). The experiments were carried out on investigated instrument at El-Gemmiza Station Research Institute. Its components are:
  - PVC elbow tube 50 mm diameter; Horizontal links rubber and plastic, 240 mm long and 70 mm diameter; vertical plastic square tube, 200 mm height and cross section 80 × 40 mm; vertical conical trapezoid tube 750 mm height, cross section 80 × 40 lower open and 150 × 150 mm upper open; plastic pipe nine, 160 mm height and 8 mm diameter; two wire screen one to cover the nine pipe and the other to cover the upper open of the vertical tube.
  - The PVC elbow connected with the electric blower 600 W, 220 V, 50-60 Hz and 16000 rpm made in China.

The 20 seeds in sample were used for each sugar beet species. The sample was dropped in air apparatus, then air flow rate was gradually increased till the seed mass gets suspended in the air stream. At the location of seed suspension the seed terminal velocity (Tv) was measured using the following equation:

$$Q = A_1 V_1 = A_2 V_2 = A_3 V_3 = \ldots\ldots$$

Where:

Q = The air discharge, m^3/s

A = Cross-section aria of the vertical tube, m^2

V = Air velocity, m/s

- Static coefficient of friction of seeds was measured using digital inclined instrument with four surface stainless steel, iron sheet galvanized, plastic and rubber. The measured sample was about 10g sugar beet seeds for each species with three replicates.
- The 20 seeds in each sample were used to measure the seeds hardness in N by digital force gauge with an accuracy of ±0.01 N.

RESULTS AND DISCUSSION

1- Sugar beet physical properties

a- The main seeds dimensions

The mean of the sugar beet seeds length, width and thickness (Table 1) were 6.12, 5.30 and 4.08 mm respectively for sugar beet species multi-germ. While, the corresponding dimensions were 4.34, 4.14 and 3.82 mm respectively for sugar beet species of mono-germ.

The normal distribution curve of the sugar beet seeds length was illustrated in Fig. (1) for the two types of sugar beet species. The Fig. shows that the highest frequency of the sugar beet seed length ranging from 5.70 to 6.72 were 66 % for the sugar beet species multi-germ, and from 4.08 to 4.56 mm were 71 % for the sugar beet species of mono-germ.

Fig. (2) shows that the distribution curve of the sugar beet seed width for multi and mono-germ seed species. The highest frequency of the sugar beet seed width were 60 % and 66 % respectively for multi and mono germ seed species. Therefore, the range of sugar beet seed width at the high frequencies were 4.98 to 5.91 and 3.90 to 4.38 respectively for the sugar beet species of multi and mono-germ.

The frequency of sugar beet seeds thickness were illustrated in Fig. (3) for multi and mono-germ sugar beet species. The highest frequency was 58 % for multi-germ species at seed thickness ranged from 3.44 to 4.28 mm. However, the highest frequency was 77 % for multi-germ species recorded at seed thickness ranged from 3.66 to 4.02 mm.

b- The calculated physical properties

The calculated physical sugar beet seeds properties are sphericity, geometric mean diameter, arithmetic mean diameter and surface area. Table (1) shows that mean, maximum, minimum, standard deviation and cv %. The mean of the above properties were 7.22 %, 44.59 mm, 5.17 mm and 204.97

mm^2 for multi-germ species. But, there were 5.28 %, 22.94 mm, 4.10 mm, 112.96 mm^2 for mono-germ species.

Table 1: The sugar beet physical properties

Seed species	Physical properties	Mean	Maximum	Minimum	SD	CV, %
Multi-germ	Length	6.123	7.730	5.020	±0.597	9.747
	Width	5.299	6.560	4.050	±0.514	9.698
	Thickness	4.081	5.570	2.180	±0.551	13.503
	Sphericity	7.225	10.702	3.924	±1.312	18.161
	Geometric mean diameter, mm	44.587	76.304	22.406	±10.757	24.126
	Arithmetic mean diameter, mm	5.167	6.177	4.280	±0.411	7.962
	Surface area, mm^2	204.97	296.04	134.25	±35.91	17.52
	Bulk density, g/cm^3	0.277	0.289	0.267	±0.009	3.372
	True density, g/cm^3	0.462	0.773	0.271	±0.153	33.114
Mono-germ	Length	4.335	5.290	3.360	±0.267	6.168
	Width	4.145	4.600	3.660	±0.173	4.180
	Thickness	3.821	4.130	3.390	±0.156	4.095
	Sphericity	5.282	6.162	4.249	±0.356	6.735
	Geometric mean diameter, mm	22.937	29.532	17.510	±2.501	10.903
	Arithmetic mean diameter, mm	4.100	4.503	3.763	±0.151	3.673
	Surface area, mm^2	112.96	149.16	89.89	±10.22	9.05
	Bulk density, g/cm^3	0.439	0.445	0.436	±0.003	0.763
	True density, g/cm^3	0.747	1.018	0.579	±0.139	18.666

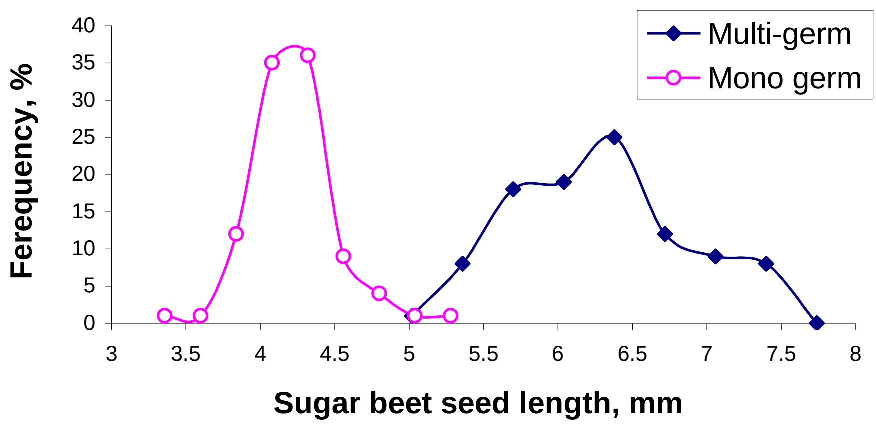

Fig. 1: The sugar beet seed length frequency.

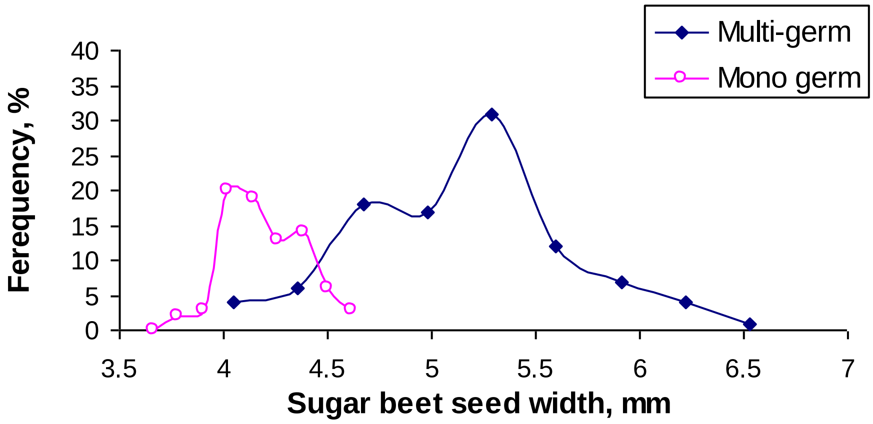

Fig. 2: The sugar beet seed width frequency.

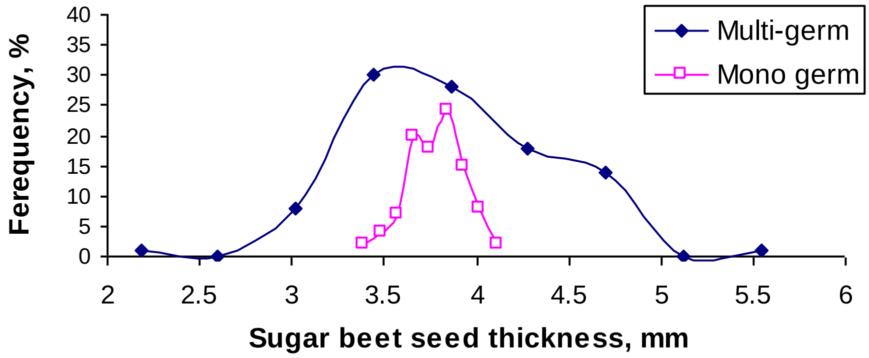

Fig. 3: The sugar beet seed thickness frequency.

Using the multiple regression analysis, the analysis of variance showed that the main sugar beet seed dimensions (L, W and T) had a high significant linear relationship with the sugar beet seed sphericity (ϕ), geometric mean diameter (Dg), arithmetic mean diameter (Da), seed surface area (As) and seed terminal velocity (Tv) for the two sugar beet seed species.

The best fit equation to explain the correlation between the sugar beet seed sphericity (ϕ), geometric mean diameter (Dg), arithmetic mean diameter (Da), surface area (As) and terminal velocity (Tv) and each of the main sugar beet seed dimensions (L, W and T) could be indicated as follows:

At multi-germ species

ϕ = -0.435 L + 0.829 W + 1.358 T $\quad R^2 = 0.9938$

Dg = 1.764 L + 2.13 W + 5.65 T $\quad R^2 = 0.9764$

Da = 0.33L + 0.33 W + 0.33 T $\quad R^2 = 1.0000$

As = 20.43 L + 25.14 W - 12.77 T $\quad R^2 = 0.9941$

Tv = 0.1086 L + 0.1115 W + 0.0960 T $\quad R^2 = 0.9837$

At mono-germ species

ϕ = -0.117 L + 0.754 W + 0.700 T R^2 = 0.9989
Dg = 4.321 L + 1.041 W - 0.016 T R^2 = 0.9956
Da = 0.33L + 0.33 w + 0.33 T R^2 = 1.0000
As = 24.145 L + 15.99 W - 15.15 T R^2 = 0.9989
Tv = 0.1364 L + 0.3402 W + 0.2734 T R^2 = 0.9918

Moreover, the regression analysis showed that the sphericity (ϕ), of sugar beet seed was inversely proportional to seed length (L) and directly proportion to seed width (W) and seed thickness (T) for both sugar beet species tested. While, it showed that the surface area (As) was inversely proportional to seed thickness (T) for sugar beet seeds species and directly proportion to seed length (L) and seed width (W) for both sugar beet species.

c- Bulk and true densities

The bulk and true densities of sugar beet seed were presented in table (1). The mean of seed bulk densities were about 0.277 $^{\pm}$ 0.009 and 0.439 $^{\pm}$ 0.003 g/cm^3 at seed species of multi and mono-germ respectively. However, the mean true density were 0.462 $^{\pm}$ 0.153 and 0.747 $^{\pm}$ 0.139 g/cm^3 espectively. for the above sugar beet seed species.

On the other hand, the bulk density were ranged from 0.267 to 0.289 and 0.436 to 0.445 g/cm^3 respectively for multi and mono-germ species.

2- Sugar beet engineering properties

Some engineering properties of sugar beet seed such as seed terminal velocity, static coefficient of friction and seed hardness were determined. Fig. (4) shows that the mean and standard deviation values for the previous sugar beet engineering properties at the two sugar beet seed species. From figure the sugar beet seed multi-germ species cleared that, the mean of its static coefficient of friction at four surfaces (stainless steel, iron sheet galvanized, plastic and rubber) and seed hardness were 0.4765 $^{\pm}$ 0.415, 0.5108 $^{\pm}$ 0.559, 0.5704 $^{\pm}$ 0.336 and 0.7276 $^{\pm}$ 0.532 respectively. While, the corresponding data of the sugar beet seed mono-germ were 0.2609 $^{\pm}$ 0.572, 0.2894 $^{\pm}$ 0.378, 0.3027 $^{\pm}$ 0.336 and 0.3537 $^{\pm}$ 0.736 respectively.

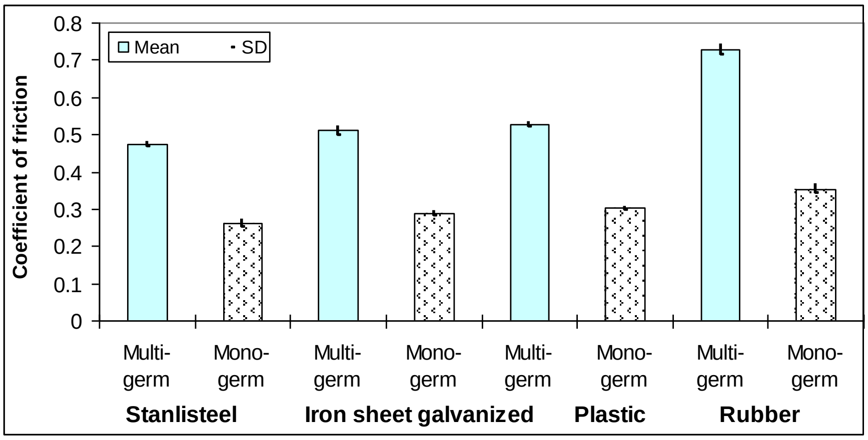

Fig. 4: The coefficient of sugar beet seed thickness frequency.

Table (2) shows that the mean, maximum, minimum, SD and cv % for the terminal velocity (Tv) and seed hardness values. The data cleared that the mean of terminal velocity and seed hardness for multi-germ species were 1.658 ± 0.163 m/sec and 17.64 ± 1.67 N respectively. While the corresponding data of the sugar beet seed mono-germ were 3.0489 ± 0.263 m/sec and 23.29 ± 2.42 N respectively.

Table 2: Sugar beet engineering properties

Seed species	Engineering properties	Mean	Max.	Min.	SD	CV %
Multi-germ	Terminal velocity	1.658	2.270	1.480	±0.163	9.858
	Hardness	17.64	20.4	15.1	±1.673	9.483
Mono-germ	Terminal velocity	3.049	3.830	2.350	±0.263	8.632
	Hardness	23.29	27.7	20.1	±2.417	10.378

The maximum values of terminal velocity, seed hardness and static coefficient of friction at four surfaces (stainless steel, iron sheet galvanized, plastic and rubber) were 2.27 m/s, 20.40 N and 0.488, 0.527, 0.536, 0.748 respectively for multi-germ seed species, while at mono-germ were 3.83 m/s, 27.70 N and 0.274, 0.300, 0.294, 0.370 respectively. Therefore, the minimum values at the corresponding measurements were 1.48m/s, 15.10 N and 0.466, 0.494, 0.516, 0.711 respectively for multi-germ seed species, while mono-germ species were 2.35 m/s, 20.10 N and 0.248, 0.281, 0.128, 0.335 respectively.

Conclusions

From the data of some physical properties of two sugar beet seed species, the following conclusions could be summarize:

1. The mean physical properties of the sugar beet seed, main dimensions (L, W and T), spherisity, geometric mean diameter, arithmetic mean diameter, surface area, bulk density and true density were 6.12 mm, 5.30 mm, 4.08 mm, 7.22 %, 44.59 mm, 5.17 mm, 204.97 mm^2, 0.277 g/cm^3, 4.62 g/cm^3 and 4.34 mm, 4.14 mm, 3.82 mm, 5.28 %, 22.94 mm, 4.10 mm, 112.96 mm^2, 0.439 g/cm^3, 0.747 g/cm^3 respectively for sugar beet seed species multi and mono-germ.
2. The mean engineering properties of sugar beet seed terminal velocity, hardness and coefficient of friction at four surfaces (stainless steel, ten galvanized, plastic and rubber) were 1.66 m/sec, 17.64 N and 0.4765, 0.5108, 0.5704, 0.7276 and 3.049 m/sec, 23.29 N and 0.2609, 0.2894, 0.3027, 0.3537 respectively for the multi-germ sugar beet seed species and sugar beet seed species mono-germ.
3. The regression analysis showed that the sphericity (ϕ), of sugar beet seed was inversely proportional to seed length (L) and directly proportion to seed width (W) and seed thickness (T) for both sugar beet species tested. While, it showed that the surface area (As) of sugar beet seed was inversely proportional to seed thickness (T) and directly proportion to seed length (L) and seed width (W) for both sugar beet species.

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بعض الصفات الطبيعية والهندسية لبذور بنجر السكر ذات العلاقة بميكنة بعض العمليات الزراعية

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معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية

يهدف البحث إلى دراسة بعض الخواص الفيزيائية والهندسية لصنفين من بذور بنجر السكر (عديد – وحيد الأجنة) للإستفادة منها أثناء تصميم وتطوير آلات الزراعة، التداول، التنظيف حيث تم تحديد الخواص الطبيعية وتشمل الأبعاد الرئيسية للبذور (الطول – العرض – السمك)، معامل التكور ، متوسط القطر الهندسى، متوسط القطر الحسابى، مساحة سطح البذرة، الكثافة الظاهرية، الكثافة الحقيقية. كما تم تحديد بعض الخواص الهندسية ومنها السرعة الحرجة، معامل الإحتكاك مع لأربع أسطح مختلفة (ستانلس ستيل، صاج مجلفن، بلاستيك، مطاط)، درجة صلابة البذور.

وكانت أهم النتائج التى توصل إليها البحث:

متوسط قيم الخصائص الطبيعية والهندسية الأبعاد الرئيسية للبذور (الطول – العرض – السمك)، معامل التكور ، متوسط القطر الهندسى، متوسط القطر الحسابى، مساحة سطح البذرة، الكثافة الظاهرية، الكثافة الحقيقية، السرعة الحرجة، درجة صلابة البذور على الترتيب ٦,١٢ مم، ٥,٣٠ مم، ٤,٠٨ مم، ٧,٢٢، ٤٤,٥٩ مم، ٥,١٧ مم، ٢٠٤,٩٧ مم^{٢}، ٠,٢٧٧ جم/سم^{٣}، ٤,٦٢ جم/سم^{٣}، ١,٦٦ م/ث، ١٧,٦٤ نيوتن لبذور بنجر السكر صنف عديد الأجنة. بينما كانت القيم المناظرة لبذور بنجر السكر صنف وحيد الأجنة على التوالى ٤,٣٤ مم، ٤,١٤ مم، ٣,٨٢ مم، ٥,٢٨، ٢٢,٩٤ مم، ٤,١٠ مم، ١١٢,٩٦ مم٢، ٠,٤٣٩ ج/سم٣، ٠,٧٤٧ جم/سم٣، ٣,٠٤٩ م/ث، ٢٣,٢٩ نيوتن.

نتج من قياس معامل الإحتكاك مع أربع أسطح مختلفة (ستانلس ستيل، صاج مجلفن، بلاستيك، مطاط) أن معامل الإحتكاك لها على الترتيب ٠,٤٧٦٥، ٠,٥١٠٨، ٠,٥٧٠٤، ٠,٧٢٧٦، مع صنف بنجر عديد الأجنة. بينما كانت القيم المناظره لصنف البنجر وحيد الأجنة ٠,٢٦٠٩، ٠,٢٨٩٤، ٠,٣٠٢٧، ٠,٣٥٣٧ على التوالى.

كما ظهر من نتائج التحليل الإحصائى أن طول البذرة على علاقة عكسية مع معامل التكور لكلا صنفى بذور بنجر السكر وكذلك سمك البذرة على علاقة عكسية مع متوسط مساحة السطح فى حين أن كل الأبعاد الرئيسية الباقية لبذور بنجر السكر كانت على علاقة طردية مع كل من معامل التكور، متوسط القطر الهندسى، متوسط القطر الحسابى، السرعة الحرجة للبذور فى كلا صنفى بذور البنجر تحت الدراسة. وبالتالى عند تحديد زوايا خروج البذور من جهاز التغذية فإن قطر فتحات القرص يجب أن تتوافق مع تلك الأبعاد.