RICE CHARACTERISTICS EFFECT ON PROCESSING

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ABSTRACT

Egyptian paddy rice Sakha 105 as a short variety and Jasmine local aromatic as a long variety were used to discuss the physical and engineering properties of agricultural grains. This is to relate the importance of these properties in storage, handling and processing equipment. In this study, it is possible to draw attention of riceindustry producersin Egypt on the need to select the most appropriate transactions according to rice varieties.

Some physical and mechanical properties were evaluated at moisture content around13% (wet basis) for the two selected varieties. The average grain length, width and thickness were measured. The equivalent diameter and the weight of 1000 grains were also determined. The kernels sphericity was calculated. The aspect ratio which is used as an indicator of a tendency toward an oblong shape was founded. The surface areaand the volume were determined. The particle density, bulk density, porosity and angle of reposewere measured.The measured values of static shear stress and hardness of a single kernel was determined. Nonlinear model for describing the mass of paddy rice was investigated, too. In this regard mass was estimated with aspect ratio of single variable of kernel dimensions with a very high coefficient of determination for each of short grains (Sakha 105) and for long grains (Jasmine Egyptian) varieties.

INTRODUCTION

Rice (Oryza Sativa L.) is one of the leading food crops of the world and is second only to wheat in terms of annual production for food use. The world's rice production increased from 520 million tones in 1990 to 685 million tones in 2009, while the Egyptian's rice production increasing from 2.2 million tones in 1981 to 7.5 million tones in 2009 (FAOSTAT, 2009). The increasing economic

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importance of food materials, together with the complexity of modern technology for their production, handling, storage processing, preservation, quality valuation, distribution and marketing and utilization demands comprehensive information on physical properties of these materials. For this purpose, size, volume, surface area, thousand grain weights, density, porosity, angle of repose, coefficient of friction are of prime importance. These properties influence the design and evaluation of rice processing including drying, husking, whitening and polishing as well as grading machines, storage and grain moving equipment. Forexample the knowledge of the coefficient of friction of paddy on the equipment wall and on the silo wall surfaces are necessaries and fundamentals for a rational and safe design of grain moving handling equipment, processing and storage (Lawton, 1980; Mohsenin, 1986; Milani, 1993; Suthar& Das, 1996).

Also friction between an un-consolidated material and a conveyor belt affects the maximum angle with the horizontal, which the conveyor can assume when transporting the solid. Husking characteristics of paddy are dependent upon its shape and size (Shitanda et al., 2001). Some physical characteristics of rice such as grain thickness has a major effect on the volume expansion ratio of the cooked rice followed by degree of milling and then by apparent amylase content of the grain (Mohapatra&Bal, 2007). To obtain better quality-milled rice, the knowledge of physical properties of paddy grain is necessary for modeling of dynamic abrasion in rice milling operation as well as, fordesigning of suitable polishing systems (Mohapatra&Bal, 2004). The knowledge of physical properties such as dimension characteristics and determination of milled rice quality parameters by image processing techniques will enable regular monitoring of milling operation in an objective manner and thus the operator to quickly react within a few minutes to changes in material properties (Yadav& Jindal, 2001).

Thousand weight of paddy grains is one of a limited factors for grain quality and price, and is used for calculating the head rice yield. Data on actual milling output were obtained from the millers and were expressed in percentage of paddy fed for milling. Expected milling output was determined at the laboratory by taking the 1000 grain weights of milled head rice and the corresponding weight of thousand grain of paddy and then expressing the weight of milled head rice as a percentage of the weight of the paddy. Any shortfall in actual milling output was considered as the milling loss due to breakage of grain (Sarker& Farouk, 1989). Ehsanullah et al. (2000) conducted a study to evaluate the effect of direct seeding versus transplanting on yield and quality of fine rice. They used 1000-grain weight of rice as a physical property to determine the highest yield and quality of fine rice Basmati- 370. Also, using of the latter property as a characteristic affecting grain yield was reported by Mahmood et al.(2003). Gravitational and frictional properties of grain can be useful in analyzing harvesting operation performance. Based on investigation performed by Srivastava et al. (1990), grain bulk density and angle of repose are related to separator performance, while harvesting grain, such that increasing grain density increases separator capacity, while increasing the grain angle of repose has the opposite effect.

Dynamic angle of repose determines the maximum angle of a pile of grain in the horizontal plane (Mohsenin, 1986).

Physical properties of paddy have been investigated and reported by several researchers (Wratten et al., 1969; Morita & Singh, 1979; Steffe& Singh, 1980; Arora, 1991; Kachru et al., 1994; Reddy &Chakraverty, 2004; Correa et al., 2007). However, a comprehensive study of the physical properties of paddy grain is still needed.

The present study was conducted to determine some of the paddy physical properties such as linear dimensions, sphericity, equivalent diameter, surface area, volume, bulk and particle density, hardness,shear stress and angle of repose and throw some lights on their effects in relation to rice operations.

MATERIALS AND METHODS

Two varieties of the most spreading paddy rice in Egypt were selected, Sakha 105 as a short variety, and Jasmine local aromatic as a long variety. Paddy rice varieties were obtained of the 2010 crop from the experimental farm of Rice Research Training Center (RRTC) at SakhaKafer-Elsheikhgovernorate. The grains were cleaned and the foreign matter, as stones, straw and dirt was removed in the laboratory of rice technology training center (RTTC), Alexandria.

The moisture content of the grains was determined using a standard moisture oven. Three principle dimensions length (L), width (W), and thickness (T) of one hundred grains of each variety were randomly selected and measured usingdigital venire caliber model YATO No.YT203 with an accuracy of 0.01mm in three replicates.

The equivalent diameter D_P in mm considering a prolate spheroid shape for a paddy rice grain was calculated through the following expression (Mohsenin, 1986).

$$D_p = \left[4L\left(\frac{W+T}{4}\right)^2\right]^{\frac{1}{3}} \quad (1)$$

The sphericity (φ) expresses the characteristics shape of a solid object relative to that of a sphere of the same volume and defined as the ratio or the surface area of the sphere having the same volume as that of the grain to the surface area of the grain, was determined as (Mohsenin, 1986).

$$\boldsymbol{\varphi} = \frac{(LWT)^{\frac{1}{3}}}{L} \quad (2)$$

The aspect ratio (Ra) is used in classification of grain shape and it was calculated as:

$$R_a = \frac{W}{L} \quad (3)$$

The weight of one thousand grains (m, g)sample was determined by counting 100 kernels using grain counter model KY-130 and weighing them in an electronic digital balance with accuracy 0.001 g and then multiplied by 10 to give the mass of 1000 grains, the weight was repeated ten replicates.

The paddy grains volume (V, mm^3) of a single grainwere measured using toluene (C7H8) displacement technique of one thousand randomized grains and the average values for single grain were determined, in ten replicates. Toluene was used in place of the water, because it is absorbed by grains to a lesser extent. The volume of toluene displaced was found by immersing a weighted quantity of paddy in the toluene (Mohsenin, 1986; Singh &Goswami, 1996; Demir et al., 2002; Selvi et al., 2006). The measured volume of one grain was verified using Jain and Bal (1997) equation as follow:

$$V = 0.25\left[\left(\frac{\pi}{6}\right)L(W+T)^2\right] \quad (4)$$

The grain surface area, S, mm^{2}was evaluated using Jain and Bal (1997) equations as follow:

$$S = \frac{\pi B L^2}{2L - B} \quad (5)$$

Where:$B = \sqrt{W\,T}$ (6)

The particle density defined as the ratio between the weight of a paddy and the actual volume of the grain.Knowing the weight and volume of one thousand randomized grains, the particle density were calculated. The particle density for each paddy varieties was determined including ten replicate. The particle density was calculated using the following formula:

$$\boldsymbol{P_t} = \frac{m}{V} * 1000 \quad (7)$$

Where:- P_t =particle density of the paddy rice, kg/m^3
m =weight of the one thousand paddy rice, g
V=volume of one thousand randomized grains by toluene, ml.

The bulk density (P_b, kg/m^3)is the mass of a group of individual particles divided by the space occupied by the entire mass, including the air space and was determined using bulk density tester apparatus model (MK-50A). The grains placed into the hopper and the liter cup below, the grain was poured into the cup from a controlled height, to ensure even bulk density. Then draw the apparatus plate across the edge of the cup to level the top of the grain. Finally the weight of the liter cup was determined by the weighing balance. Each test was done in ten replicates.

The Porosity (ε) is defined as the percentage of air between particles compared to a unit volume of grains and it was computed by the following equations (Jain &Bal, 1997) as:

$$\varepsilon = \frac{(P_t - P_b)}{P_t} * 100 \quad (8)$$

Angle of repose is the angle with the horizontal at which the material will stand when piled. The angle of repose of the paddy was determined by using the apparatus developed by (Soliman, 1994). In this apparatus the angle of repose was the measured angle between the horizontal and the natural slope of the seeds heap. Theapparatus platform was adjusted on

the horizontal level and the height above the platform was measured by sliding measuring scale. The lid with the sliding scale was removed, and the control gate was closed. Then, the paddy rice was poured into the container from the open top until it fills, and left a while for rest, then the control gate was opened and the paddy rice was discharged under gravity through the funnel. Then, the lid with sliding scale was mounted again and the measuring scale was lowered until its flat disc touches the apex of the heap of the paddy rice remaining on the platform, and the height was read on the graduated scale. The height of the heap was calculated by discount the height above the heap apex from the height above the platform (the height before pouring the seeds).
The dynamic angle of repose was calculated by the following relation (Soliman, 1994)

$$\theta = tan^{-1}\left(\frac{2H}{D_p}\right) \qquad (9)$$

Where: θ =the dynamic angle of repose, degree
H= height of the heap, cm.
D_P=platform diameter, cm.
The dynamic angle of repose for each paddy rice variety was determined as an average of ten replicates.
Static shear cell as shown in figures (1) was designed by (Soliman, 1994). It was used to determine the shear stress of paddy rice for the investigated varieties. A selected paddy rice grains from a randomly sample was put inside the suitable hole of the tow discs. Then, the water was added slowly to the pail until the moving disc turned and the seed was cut. The pail with water was weighed and the shear force was calculated as follows:

$$F_2 = \frac{F_1 * r_1}{r_2} \qquad (10)$$

Where: F_2=shear force, N
F_1=weight of the pail and water, N
r_1=the radius from disc center to groove bottom, cm
r_2=the radius from disc center to hole center, cm
The cross section area (A) of the seed was calculated as follows:

$$A= W * T * \pi/4 \qquad (11)$$

Where:-A =cross section area of paddy rice, m^2.

W =width of paddy rice, m

T=thickness of paddy rice, m

The shear stress was calculated as follow:

$$S_s = \frac{F_2}{A} \qquad (12)$$

Where:-S_s=shear stress, Pa

F_2=shear force, N

The particle shear stress at each paddy rice variety was including twenty replicates.

Hardness of paddy rice kernels has a close relationship with quality; kernels with less hardness give alowerreturn of milling recovery. Kernel hardness were determined using the Japonichardness tester model (Kiyo Seisakasho, KY-140), with a maximum reading of 20kg and an accuracy of 200grams. Selected paddy rice from a randomly sample was put on the platform of the hardness tester in thickness direction, and pressed by the needle end which turned by hand; meanwhile the graduated circular scale reading was increased with the increasing of the pressure on the paddy rice until the paddy rice has been cracked. At this point the reading of the scale pointer means the seed hardness.The particle hardness for each investigated variety was including twenty replicates.

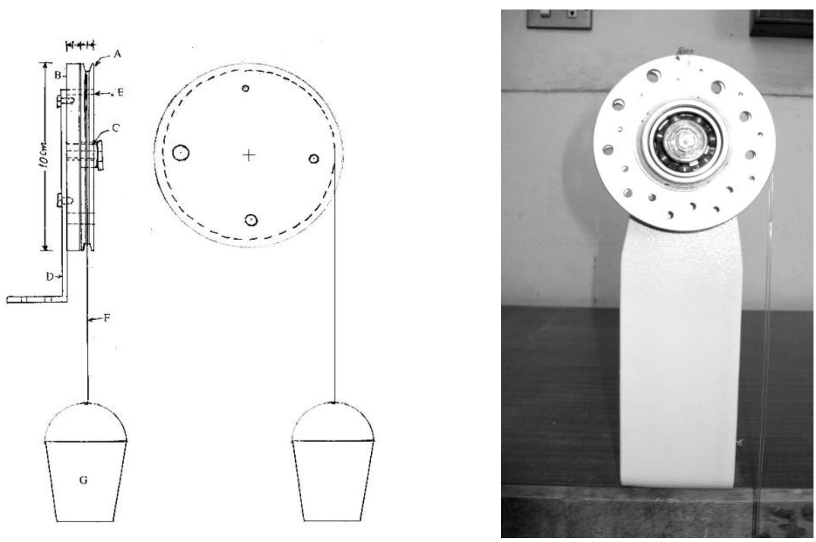

Figure (1): Static Shear CellApparatus.(A-Moving Disc B- Fixed Disc C- Ball Bearing D- HolderE- HoleF- Rope G- Water Bucket)

RESULTS AND DISCUSSION

The results of measured physical characteristics of the two selected paddy rice varieties Sakha105 as a short grains and Jasmine local aromatic as long grains are clarified as follows:

1-Dimensions:

The average paddy rice of the three principal dimensions (Sakha 105 as a short variety) length, width and thickness were found to be 8.077± 0.31, 3.395± 0.15and 2.198± 0.12 mm, respectively. Corresponding value for the average paddy (Jasmine local aromatic as a long variety) were 10.063±0.62, 2.755±0.21 and 2.020±0.16 mm respectively.

The results show that Jasmine variety was smaller than Sakha 105in width and thickness dimension but longer in the length. If an over look to these characteristics and was not taken into account in the rice-milling industry, this will cause loss and increasedbroken rates. The importance of dimensional characteristics of paddy rice in determining aperture sizes and other adjusted parameters of machine operations have discussed by Mohsenin (1986) and highlighted lately by Omobuwajo et al. (1999).

Equivalent diametersconfirmed the interest in the rice-milling industry about the differences in the dimensions of paddy rice grains.The values of equivalent diameter (D_P)were obtained mathematically using equation (1). The equivalent diameter (D_P) ofSakha 105 as a short variety was 3.981± 0.032 mm, while the equivalent diameter (D_P) of Jasmine local aromatic as a long variety was3.856 ± 0.021 mm.

2- Sphericity (φ):

The sphericity (φ)of sakha 105varietywas 0.485 ± 0.011 andwas 0.380 ± 0.008 for Jasmine local aromatic variety which indicated that the shape of the grainsmakes it difficult to roll on the surface.These values should be given a sign to the riceindustry producers on the sensitivity of handling with these differences, also gives a lot of meaning for dimensions studies.

3- Aspect Ratio (Ra):

The aspect ratios (Ra) were calculated for each varietyasan indicator of a tendency toward an oblong shape, for Sakha 105variety was 0.420 ± 0.035and a corresponding value of Jasmine local aromatic varietywas 0.295± 0.015.

The relationship between kernel mass and aspect ratio (W/L) was obtained by stepwise statistical regression analysis, which produced the pest fit third degree polynomial equation with a high coefficient of determination (R^2) for each of Sakha 105 and Jasmine Egyptian aromatic varieties respectively, as shown in figures 2 and 3.

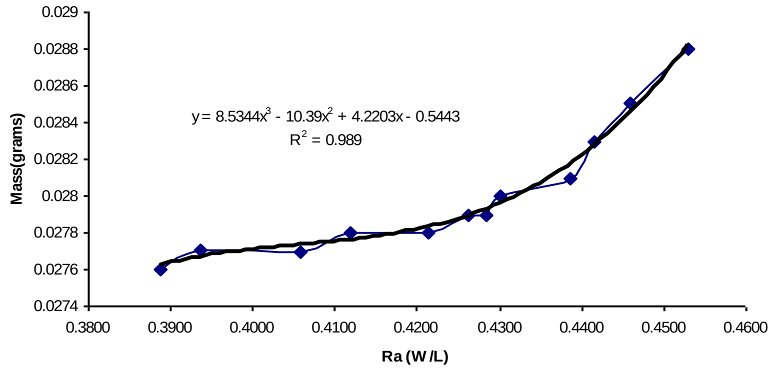

Figure (2) Relationship between kernel mass and aspect ratio (W/L) for (Sakha105) of paddy rice variety.

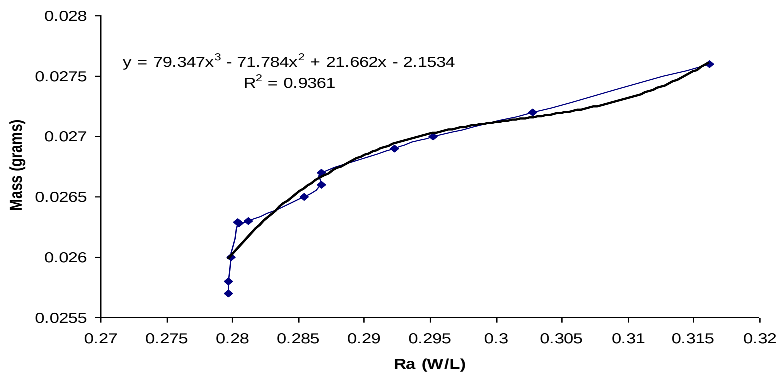

Figure (3) Relationship between kernel mass and aspect ratio (W/L) for (Jasmine Egyptian aromatic) of paddy rice variety.

4- Volume and Surface area:

The volumes of paddy grains of the two varieties were conducted using toluene displacement technique and verified by equation (4). The volume of single grain of Sakha 105 was $33.019 \pm 2.31\ mm^3$ and the volume of Jasmine local aromatic variety was $30.027 \pm 1.51\ mm^3$.

The surface area of paddy grains were evaluated by equation (5), and were ranged from 41.654 ± 2.51 for Sakha 105variety to 42.225 ± 3.82 mm^2 for Jasmine local aromatic variety.

The values of surface areas give rice industry producersa good indicatorfor the highest rice husk percentage of long variety than short varieties.This affects all thermal treatments and heat and mass transfer through drying process and play an important role in parboiling rice processing, fordetermining the required time of stepping and dryingstage.

5 - Weight of one thousand grains:

The weight of one thousand grains is a useful parameter to "milling quality" in measuring the relative amount of quality and full grain and the amount of immature in lot of paddy kernels (Luh, 1980), also good indication of paddy rice prices. The measurements of weight of one thousand paddy rice grains of different varieties at the certain moisture content under study were conducted, and the weight of 1000 paddy grains for Sakha 105varietywas28 ± 0.51 g and 26.72 ± 0.47g for Jasmine local aromatic. It is worth noticing that the increase of moisture content increases the value of weight of a one thousand grains and this was confirmed by (Korayem and Soliman, 1983, &Kibar et al. 2010).So one should refer to the best moisture content when deal with rice on the industry level.

6- Density:

The particle density, bulk density and porosity were determined for each variety of paddy rice. For Sakha 105variety were1151.865±3.31 kg/m^3, 540.335± 2.18 $kg/m^3$and 48.631±0.61%, and for Jasmine local aromatic were1198.77±4.22kg/m^3,469.154± 3.15kg/m^3,60.863±1.71% respectively.The bulk density and the porosity, for each variety differ significantly, but the particle density values, practically did not present significant differences among the varieties. This characteristic can be used inair separation and cleaning processes for grains since lighter fractions will float. These values can help in the design of storage, warehouse,handling and transport operations.

7- Angle of repose:

The angle of repose of paddy for Sakha 105variety was 39.003±0.61^{o}, and 36.966±1.31^{o}for Jasmine local aromatic variety which was suggested by that reported for Iran's paddy varieties (Zareiforush et al.,2009) but higher than that reported for wheat grains (Solimanetal., 2009).

Dynamic angle of repose is very important parameters for determinationof the handling belt types, dimensions and capacity and in the filling of hopper, storage bins and flat storage facility when grain is not piled at a uniform bed depth rather is peaked. As the moisture content increased, the angle of repose of paddy rice grain was found to increase linearly, this was confirmed by (Korayem and Soliman, 1983, & H. Kibar et al. 2010). For this pay attention carefully drying to reach the most suitable moisture content of paddy rice , which was to prove its effect on post-harvest processing.

7- Static shear stress& hardness:

Static shear stress of paddy rice for the investigated varieties, were determined according to Soliman, 1994 technique. The calculated values of static shear stress for Sakha 105variety was12.754±2.352 (MPa) and 9.084±1.177 (MPa) for Jasmine local aromatic variety.

The hardness of a single paddy grain for each investigated variety was determined as an average value of twenty replicates, whichwas ranged for Sakha 105variety6.90±0.4 kg and 5.8±0.3 kg for Jasmine local aromatic variety.These results clarify the difference between the two paddy varieties long-grain and short grain varieties. So these values should be referenced in the post-harvest rice processing. It appears clear in husking operation processthat the pressure between the two rubber rules adjusting according to this values. Also in the process of milling, inside the machine of friction or in abrasive machine the pressure on the grain surface must be known according to these values.

A summary of the results of the some physical properties of two varieties Sakha 105 as a short grains and Jasmine local aromatic as long grains are shown in Table 1.

Table 1. Some physical propertiesof two Egyptianpaddy

PhysicalParameters	Sakha 105	Jasmine
1- Average grain length, mm	8.077± 0.31	10.063± 0.62
2- Average grain width, mm	3.395± 0.15	2.755± 0.21
3- Average grain thickness,mm	2.198± 0.12	2.020± 0.16
4- Equivalent diameter, mm	3.981± 0.032	3.856± 0.021
5- Sphericity, decimal.	0.485± 0.011	0.380± 0.008
6- Aspect ratio, decimal.	0.420± 0.035	0.295± 0.015
7- Surface area, mm^2.	41.654± 2.51	42.225± 3.82
8- Volume grain, mm^3.	33.019± 2.31	30.027±1.51
9- Weight of 1000 grains, g.	28± 0.51	26.72± 0.47
10- Particle density, kg/m^3.	1151.865± 3.31	1198.77± 4.22
11- Bulk density, kg/m^3.	540.335± 2.18	469.154± 2.31
12- Porosity, %.	48.631± 0.61	60.863± 1.71
13- Angle of repose, degree.	39.003± 0.61	36.966± 1.31
14- Static shear, MPa.	12.754± 2.352	9.084±1.177
15- Hardness, kg.	6.90±0.4	5.80±0.3

CONCLUSION

In conclusion, the information on engineering properties of paddy rice varieties Sakha 105 as a short variety and Jasmine local aromatic as a long variety, which can be useful for designingequipment used for paddy processing. Rice makers can adjust machines according to these values, which gives them higher quality and productivity of whole grains and therefore high economic profits.

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الملخص العربى

الخصائص الطبيعية للأرز الشعير وارتباطها بالعمليات التصنيعية

*سليمان نصيف سليمان **محمد السيد عمر يحي

تم استخدام الأرزالشعير المصري من الصنف سخا١٠٥ قصير الحبة، والصنف العطرى المحلى ياسمين طويل الحبة لدراسة الخصائص الفيزيائية وارتباطها بالعمليات التصنيعية وهي تعتبر ذات أهمية كبيرة في تصميم وتشغيل معدات التخزين والتداول و التدريج والفرز والتقشير وتبييض الأرز.

وتهتم الدراسة بتوفير قاعدة البيانات لمنتجى الأرز على المستوى الصناعى لإستخدامها في تحديد انسب المعاملات واختيار الغرابيل المناسبة للصنف واختيار سرعة الهواء المناسبة في الفصل علي اساس الكثافة كما انها تؤثر في ضبط وتحديد المعدلات لأجهزة التداول المختلفة وضبط الخلوصات والضغوط في درافيل التقشير واجهزة التبييض وفقاً لهذه المعايير.

تم تقييم بعض الخصائص الفيزيائية عند محتوى رطوبي١٣ ٪ (أساس رطب) وقد جد ان متوسط القيم لأبعاد الطول والعرض والسمك للصنف (سخا١٠٥) ٨.٠٧٧ ±٠.٣١و٣.٣٩٥ ±٠.١٥ ٢.١٩٨ ± ٠.١٢مم على التوالي وللصنف العطرى المحلى ياسمين ١٠.٠٦٣±٠.٦٢ و ٢.٧٥٥٥± ٠.٢١ و٢.٠٢٠± ٠.١٦مم على التوالي بينما كان القطر المكافىء للصنف سخا ١٠٥هو ٣.٩٨١ ± ٠.٠٣٢مم ، ووزن ١٠٠٠حبة ٢٨ ± ٠.٥١ جرام في حين أن القطر المكافىء للصنف العطرى المحلى ياسمين كان ٣.٨٥٦ ±٠.٠٢١ مم ووزن١٠٠٠ حبة ٢٦.٧٢ ± ٠.٤٧ جرام ولقد تم تقدير درجة كروية الحبوب و كانت ٠.٤٨٥ ±٠.٠١١ للصنف سخا ١٠٥ و٠.٣٨٠± ٠.٠٠٨ للصنف العطرى المحلى ياسمين.

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تم احتساب نسبة العرض الي الطول لمجموعة عشوائية من الحبوب للصنف سخا ١٠٥، وهو مؤشر على الأتجاه نحو استطالة الشكل وكانت ٠.٤٢ ± ٠.٠٣٥ والقيمة المقابلة هى٠.٢٩٥ ± ٠.٠١٥ لنوع ياسمين العطرى المحلي. وتراوحت المساحة السطحية للصنف سخا ١٠١ من ٤١.٦٥٤ ± ٢.٥١ مم^{٢} إلى ٤٢.٢٢٥ ± ٣.٨٢ مم^{٢} للصنف ياسمين العطري المحلي. في حين أن متوسط حجم حبوب الصنف سخا ١٠٥هى ٣٣.٠١٩ ± ٢.٣١ مم^{٣} وكان متوسط حجم الحبوب للصنف ياسمين العطري ٣٠.٠٢٧ ± ١.٥١مم^{٣} وكانت كثافة الحبة، والكثافة الكمية والمسامية وزاوية الراحة ١١٥١.٨٦٥ ± ٣.٣١كجم/م^{٣} ، ٥٤٠.٣٣٥ ± ٢.١٨ كجم/م^{٣}،٤٨.٦٣١ ± ٠.٦١٪، و ٣٩.٠٠٣ ± ٠.٦١^{o} على التوالي للصنف سخا ١٠٥ بينما ١١٩٨.٧٧± ٤.٢٢ كجم/ م^{٣}، ٤٦٩.١٥٤ ± ٢.٣١ كجم/م^{٣}، ٦٠.٨٦٣ ± ١.٧١٪ ، ٣٦.٩٦٦ ± ١.٣١^{o} على التوالي للصنف ياسمين العطري المحلي. ومتوسط القيم المحسوبة لأجهاد القص للصنف سخا ١٠٥ ومتوسط قيمة صلابة الحبوب ١٢.٧٥٤ ± ٢.٣٥٢ ميجا باسكال و ٦.٩٠± ٠.٤ كجم على التوالي في حين كان ٩.٠٨٤ ± ١.١٧٧ ميجا باسكال و ٥.٨ ± ٠.٣ كجم على التوالي للصنف ياسمين العطري المحلى. تم استخدام نموذج غير خطى لوصف علاقة كتلة الأرزالشعير كدالة لنسبة العرض الي الطول من متغير واحد واستنتجت العلاقة الرياضية التى تحقق هذا الوصف بمعامل ارتباط كبير.