PHYSICAL PROPERTIES OF EGYPTIAN ROUGH RICE (SAKHA 102)

AS AFFECTED BY ITS MOISTURE CONTENT

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ABSTRACT

Egyptian rice variety Sakha 102which characterized byresistantto Blast diseases (Pyricularia grisea),high yield and grain quality, was used to investigate some physical and mechanical properties in order to determine needed designing parameters for handling and storage facilities and milling (dimensions, density, coefficient of friction, compressibility,and shear strength) at different levels of moisture content in the range of 10 - 30% d.b. The statistical equations relating each parameter to the moisture content were obtained.

The results of this study show that length, width, thickness, bulk density, particle density, coefficicient of friction are linear functions of moisture content, within the range of moisture content used. The least of the maximum compressive stress was found to take place at 15% moisture content (d.b). The shear strength and maximum compressive strength decreased with an increase of moisture content.

INTRODUCTION

Rice (Oryza sativa L.) is the second most importantcereal after wheat. Rice is an important crop in Egypt. The total rice production was about 7.5 million tons in 2009 **(Faostat, 2009)**.The marketing value of rice as an agricultural productdepends on its physical qualities after processing. One of the major problems of rice industry is breakage of grains during the course of mechanical handling and milling processing. Thepercentage of whole grain is the most important parameterfor the rice processing industry **(Marchezan, 1991)**.

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The main features of agro and food materials thatmake them different from mineral materials are stronginfluence of moisture content on mechanical behaviorand high deformability of granules. These differencesbring about certain peculiar behaviors and necessityof adjustments of models of material, experimentaltechniques and technological solutions **(Molenda and Horabik, 2005).**

Physical properties of granular agro-materialsare important in terms of the machines and storagefacilities designing. Bulk density, particle density, porosityand the static coefficient of friction can be useful in sizinggrain hoppers and storage facilities **(Varnamkhastia et al., 2007)**. The density of paddy rice was used in the design of storage bins and silos, separation of desirable materials from impurities, cleaning and grading and quality evaluation of the products (Solomon and Zewdu, 2009).These properties are important in the constructionof bulk storage facilities and the calculationof the dimensions of intermediate holding bins of agiven capacity. Problems associated with design shouldnot be attributed to disagreement among design philosophies,but rather to a serious lack of understandingof certain grain properties and how they relate to bindesign **(Thompson and Ross, 1983)**.Knowledge of the physical and mechanical propertiesof the agricultural products is of fundamental importancefor the appropriate storage procedure and fordesign, dimensioning, manufacturing and operatingdifferent equipments used in post harvest processingoperations of these products **(Corrêa et al., 2007).** To design equipments for application in harvesting, handling, storage and milling processes operations of rice, the knowledge of various physical and mechanical properties as a function of moisture content is important **(Molenda et al., 2004).** For rice grains and other commodities it can be seen that increased moisture content causes notable increases of pressure on silo walls. Because the increase of pressure requires an increase in the thickness of silo construction materials and costs of construction increase.Also, flow problems in silos such as arching, rat holing, irregular flow and segregation occur with increased moisture content. When arching or rat-holing occurs, much of the stored product flows at the center only, leaving some remaining behind in dead zones of the silo for long periods.

The present investigation was carried out to study the effect of moisture content on some physical and mechanical properties of Sakha 102 rice variety cultivated in Egypt.

MATERIALS AND METHODS

The selected short grain variety for this study Sakha which was characterized by its resistantto Blast diseases (Pyricularia grisea),high yield and grain quality, was obtained of the 2010 crop from the experimental farm of Rice Research Training Center at Sakha Kafer-Elsheikh Governorate. The properties were determined using paddy rice variety Sakha 102 which was cleaned and had initial moisture content about 20% (d.b.). The paddy samples were spread dried or rewetted to reach the required levels of moisture content. Calculated amount of water was added or removed with the test samples to reach the required moisture contentby equation ofCoÕkun et al., (2005).

$$\Delta w = \frac{D_i(M_f - M_i)}{100 - M_f} \qquad (1)$$

Where Δw is the mass of added or removed water (kg), D_i is the initialmass of the sample (kg), M_i is the initial moisture contentof the sample (%, d.b.) and M_f is the final moisturecontent of the sample (%, d.b.).

The samples were then stored as packed in polyethylene bagsfor one week at 4±1°C to allow the moisture content to distribute itself throughout the kernel grains. The samples were removed fromthe refrigerator andkept at room temperature (23 ± 2°C) before the experiment was started.The rewetting technique to attain the desiredmoisturecontent in kernel and grain has frequently been used(CoÕkun et al., 2005; Garnayak et al., 2008; Pradhanet al., 2008).Moisture content was determined by the oven method for the amount 20 gram for sample at 5 replicate which dried at 130 °C for 18 hr. The physical and mechanical propertiesof grain were investigated at each moisture levels.

1- <u>Dimensional properties:</u>

The kernel length, width, and thickness for one hundred grains sampled were measured from randomly selected sample at each moisture content levels. Length (L), width (W) and thickness (T)of the samples were measured using a platform type dial micrometer. Particle dimensions were measured at six moisture levels ranging from approximately10% to 30% (d.b.) using ten replicates.

2- <u>Density:</u>

Bulk and particle density of the experimentalsamples were determined at different moisture levels using the methoddefined by Mohsenin (1980), Boumans(1985), Singh and Goswami(1996) and Pradhan et al., (2008). Bulk density were determined by filling a known volume graduated cylinder (500ml) with the grains from a height of 15cm at constant rate, and the base of the cylinder was tapped a dozen (12) times on a table. Then, the cylinder was refilled again to its maximum reading (500ml). The grain in the cylinder was weighed and the bulk density was calculated (kg/m^3) by dividing the weight of quantity of seeds (kg) by its volume (m^3). The particle density was calculated using the mercury displacement technique (Amsler volume meter).The measurem- ents were repeated ten times for each level of moisture content.

3- <u>Static Friction Coefficient:</u>

An apparatus as shown in figure (1)was constructedto measure the static coefficient of friction of grain on different surfaces such as wood, steal, plastic and other.The apparatus consisted of a wooden base mounted on three adjustable legs for leveling. A wooden flat tray 35 x 21x8 cm. was hinged to the base at one end. The other end of the tray was attached by a long string to a wheel with a handle. By winding the handle, the wooden tray rotates around a hinge and making an angle with the horizontal. The test procedure started by leveling was the wooden base. A thin layer of one particle thick of the clean grain was placed on the testing material sheet inside the bottom ofhe tray. The wheel was the wound slowly and smoothly until at least 75% of the grains slide down the sheet surface. The angle of inclination of the tray with the horizontal was measured. The coefficient of friction of the paddy rice on the specified surface was defined as the tangent of the angle of inclination for each run (Ozarslan, 2002;Razavi and Milani, 2006; and Ghasemivarnamkhasti et al., 2007). The angle of the goniometry (**α**) was recorded. Then, the static coefficient of friction (**μ**) was calculated as follow:

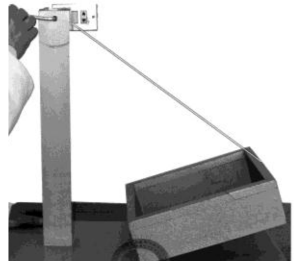


Figure (1): Static friction coefficientapparatus.

$$\mu = \tan(\alpha) \qquad (2)$$

The angle of friction (**α**) for each sheet of the selectedsheet materials at each level of paddy moisture content was repeated for ten replicates.

4- <u>Static Shear Stress:</u>

Static shear cell was designed by (Soliman, 1994)showing in figure (2). It was used to determine the shear stress of paddy rice for the investigated variety. A selected paddy rice grains from a randomly sample for each different levels of moisture content ranging from approximately 10%

Figure 2: Static shear cell.

to 30% (d.b.) was put inside the suitable hole of the tow discs.Then, the water was added slowly to thepailuntil the moving disc turned and the seed was cut. The pail with water was weighed and the shear force was calculated as follows:

$$F_2 = \frac{F_1 \times r_1}{r_2} \qquad (3)$$

Where:

F_2=shear force, kg

F_1=weight of the pail and water, kg

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:

$$A = (W \times T \times \pi)/4 \quad (4)$$

Where

A=cross section area of paddy rice, mm^2.

W=width of paddy rice, mm

T=thickness of paddy rice, mm

The static shear stress was calculated as follow:

$$Ss = \frac{F_2}{A} \quad (5)$$

Where: Ss=shear stress, kg/mm^2

F_2=shear force, kg

A=cross section area of the paddy rice, mm^2.

The static shear stress of the single kernel at each level of moisture content for paddy rice variety was conducted as ten replicates.

5- <u>Bulk and Particle Stress-Strain Test:</u>

Bulk and particle stress-strain tests were carried out by using an Instron Machine Cole Parmer model (G-08232-28) as shown in figure (3), with applied force ranges from 0 to 1818 kilograms and crosshead speed ranges from 5 to 100 mm/min. The system was provided with digital controller and documentation system model CEDM, which was connected with an automatic recording unit for each of time, force and velocity by computerized reading, operating and controlling system. The tests in this study were carried out at crosshead speed of 20 mm/min. Both the crosshead speed and the force transducer of the Instron machine were calibrated.

5-I- Bulk Stress-Strain Test:

The bulk stress-strain tests at each level of moisture content for investigated paddy rice grains variety were carried out by using cylindrical compression cell with a dimensions of 100mm in height and

70mm in diameter, with two circular parallel plates of 68mm diameter and 10mm thickness one for bottom and the other for top which was connected to the Instron crosshead using a steel bar of 2 cm diameter and 10 cm length figure (3). A randomly sample of about 300 cm^3 of grains was placed inside the cylinder between the two plates and the force was applied on the top plate by the press of the crosshead which was moved down at the selected speed (20mm/min) deforming the sample until the failure was achieved.

The deformation of the sample under the press was considered equal to the change in the sample height. The stress was calculated by dividing the force by thecircular cross-section area of the cylinder as follows:

$$Stress = \frac{4F}{\pi D^2} \qquad (6)$$

Where: F=the force, kg
D=cylinder diameter, cm

Figure (3): Instron machine

The strain was calculated by dividing the deformation of the sample by the initial height of the sample.

The experiment was repeated for different moisture contents from 10 to 25 % (d.b) compressive stress and volumetric strain (ΔV/V) relationship is recorded.

5-II- Particle Stress-Strain Tests

The particle stress-strain tests of rice grains were carried out by placing 25 grains in one layer,approximately, of the same thickness between two parallel plates and the force was applied on the top plate by the press of the crosshead which was moved down at the selected speed deforming the sample until failure was achieved. The force for one particle was calculated by dividing the total force by the number of the grains in the sample and the deformation of the particle under the press considered equals to the changing in the particle thickness. The average compressive stress was calculated from the applied force F and the instantaneous area of contact by dividing the force by the area of contact the particle as follows:

$$Stress = \frac{F}{A_P}$$

Where: F = force on one kernel, kg.

A_P= kernel contact area, cm^2.

This area was calculated for each load according to the compressive deformation(ΔT) assuming the grain to have an ellipsoidal shape in the two projections (plan and elevation). The area of contact was calculated theoretically using the following equation (Solimanand Korayem, 1983):

$$A_P = \pi \frac{WL}{4}\left[1 - \left(\frac{T - \Delta T}{4}\right)^2\right]$$

The compressive strain ($\Delta T/T$)was calculated by dividing the deformation of the particle (ΔT) by the initial particle average thickness (T)

For each stress-strain tests, the initial modulus of elasticity (E_o, MPa) was calculated as the initial slope of the stress strain curve before straight line. While, the modulus of elasticity (E, MPa) was calculated as the slope of the stress-strain curve at the stage appear to be straight line. Yield point, maximum compressive stress and rupture energy was calculated.

RESULTS AND DISCUSSION

1. DIMENSIONS

The three principal dimensions of paddy rice length (L), width (W), and thickness (T) mm shows in figure (4), at different moisture contents (M) (d.b.%) appeared to be linearity.The dimensions increased with increase of moisture content. The increase in the dimensions are attributed to expansion or swelling as a result of moisture uptake in the intracellular spaces within the seeds (Varnamkhasti *et al.* 2007).The relationships between the axial dimensions (L, W, and T,) and moisture content of grain were givenby following linear regressionequations:

L = 7.10931 + 0.00498 M R^2=0.99

W= 3.2078 + 0.00423 M R^2=0.98

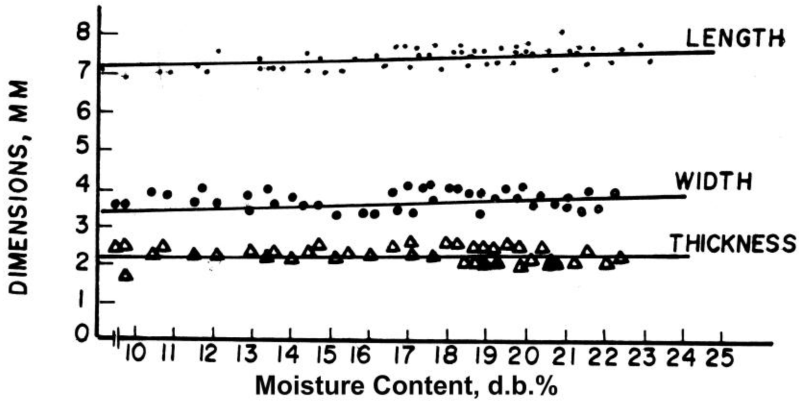


Figure (4) : Particle dimensions of paddy rice

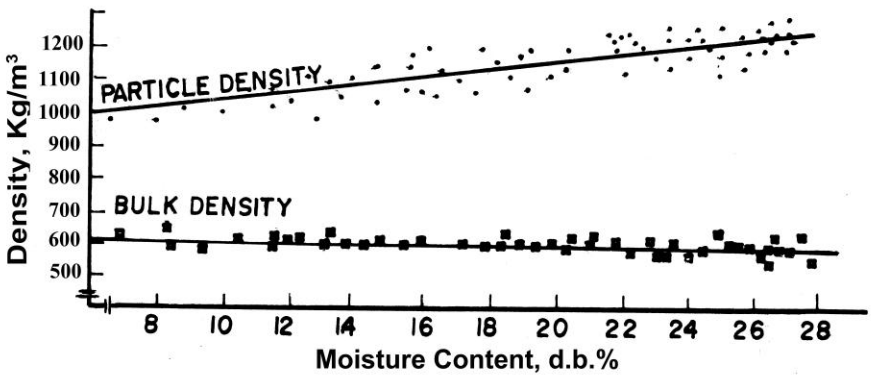


Figure (5) Bulk and Particle Density of Paddy rice

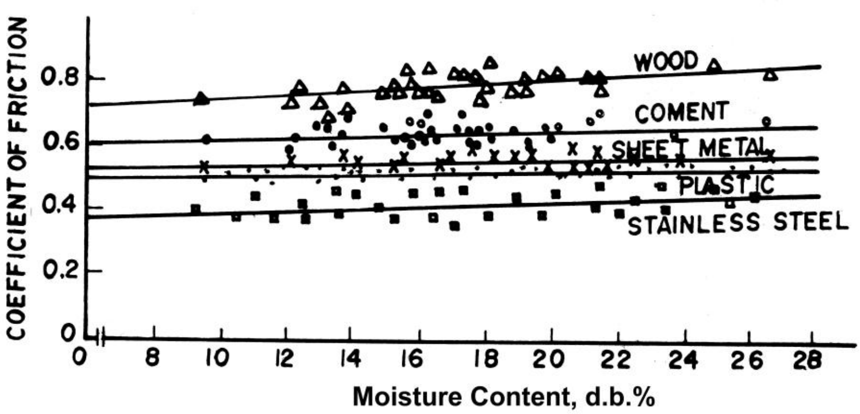


Figure (6): Coefficient of Fiction of Paddy Rice on Different Surfaces

This results show that there is an important and positive relationship between moisture content and principal dimensions of paddy rice.Results obtain in this study are in agreement with previous related studies which reported by Çalis, IR S.*et al.* (2005) ,Özgöz *et al.* (2005) and Karababa (2006).

2. DENSITY

The experimental results of the bulk density (B) and particle density (P) in kg/m^{3}for paddy grains at different moisture levels (M) are shown in figure (5). Increasing moisture content had a significant effect on each of bulk and particle density of paddy grains. Bulk density is inversely proportional with moisture content but particle density is directly proportional with moisture content. This was due to the fact that an increase in mass owing to moisture gain in the sample was lower than accompanying volumetric expansion of the bulk (Pradhan *et al.,* 2008; Solomon and Zewdu, 2009). The linear relationships between each of bulk and particle density with moisture content of paddy rice were described by the following regression equations:

$B = 0.599 - 0.0013\ M \qquad R^2 = 0.94$

$P = 0.916 + 0.0046\ M \qquad R^2 = 0.91$

3. COEFFICIENT OF FRICTION

The static coefficient of friction for paddy rice grains of the investigated variety on the selected materials surfaces including plywood, plastic, galvanized, concrete and stainless steel appeared to be linearly dependent on the moisture content. The coefficient of friction (μ) of paddy rice increased as moisture content was increased as shown in figure (6). It was observed that the static coefficient of friction increased linearly with the increase of the moisture content of grain on test surfaces.

For Plywood

$\mu = 0.676 +0.00699\ M \qquad R^2 = 0.82$

For Plastic

$\mu = 0.4614 + 0.0034\ M \qquad R^2 = 0.83$

For Galvanized Sheet

$\mu = 0.487 + 0.004\ M \qquad R^2 = 0.73$

For Concrete

$\mu =0.574 + 0.0042\ M \qquad R^2 = 0.77$

For Stainless Steel

$\mu = 0.333 + 0.0051\ M \qquad R^2 =0.91$

It wasobserved that the static coefficient of friction for paddygrains increased with increasingmoisture content on all surfaces. The reason for theincreased friction coefficient at higher moisture contentmay be owing to the water present in the grains, offeringa cohesive force on the surfaceof contact. As the moisturecontent of grains increases, the surface of the samplesbecomes stickier. Water tends to adhere to surfaces andthe water on the moist seed surface would be attracted tothe surface across which the sample is being moved (Baryeh and Mangope 2002; AltuntaÕ and Yildiz 2007;Pradhan *et al.,* 2008).

4. COMPRESSIBILITY

The mechanical properties data of compressive stress-strain for paddy rice variety under study at different levels of moisture content for bulk and particles case were analyzed to bio-yield strain point and maximum compressive stress (MPa).

For particlepaddy kernels, figure (7) illustrates the stress-strain behavior of paddy particlesin one layer at different moisture content. The modulus of elasticity, yield point and maximum compressive stress were determined from the curve.The results of paddy particle experimental showed the effect of moisture content on yield point and maximum compressive stress of paddy grains. The minimum compression stress of 6.1&8.9 MPa and maximum strain of 0.115 & 0.175 for each of yield point and maximum compressive stress respectively were at about 15 (M.C.d.b.%).

Figure (8) shows the variation in strain with moisture content at yield point and at maximum compressive stress. The values of strain-increase attain peak value and then decrease with increase in moisture content, the maximum strain occurs at 15% moisture content (d.b.). A similar result was given by Praseds, (1973).

Modulus of elasticity (E, MPa) of paddy rice variety was determined as a tangential slope of the initial part of the stress-strain curve before bio-yield point. The values of modulus of elasticity varied from 180 MPa as a minimum value at 15% moisture content (d.b.)to 600MPa at 12% moisture content (d.b.) for paddy rice.

For bulk paddy grain properties figure (9) shows the relation between compressive stress in (kpa) and the deformation ΔV/V at different moisture content. A linear regression technique was used to correlate the data with moisture content. The analyses yield the following equation:

$$\frac{\Delta V}{V} = 3.814\, P \log(M)$$

Where:

ΔV/V = volumetric strain.

P = compressive stress K.Pa.

M = moisture content (d.b.%).

5. SHEAR STRENGTH

Static particle shear stress of paddy rice grains of the investigated variety as shown in figure (10) which represent the relation between moisture content (M, d.b.%) and shear stress (S). A linear regression analysis yielded the following equation for paddy rice.

$$S = 8.023 - 0.16401\, M \qquad R^2 = 0.895$$

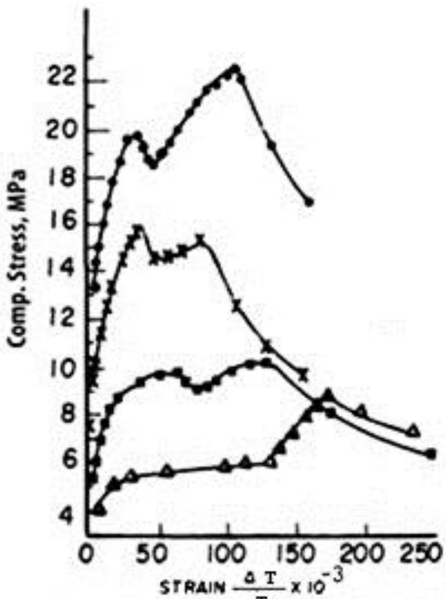
Where:

S = shear stress, MPa.

M = moisture content (d.b. %).

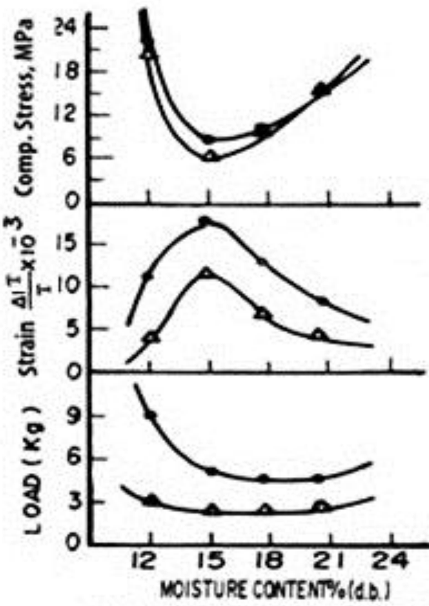
As shown from the above equation, the static particle shear stress decreased with increasing moisture content at the studied range.

Figure (10) clarify that the shear stress rapidly decreased with the increasing of moisture content until 15% (d.b.). Thevalues of shear stress be approximately constant during the moisture content range from 15 to 19 (d.b. %)and then rapidly decreased again.



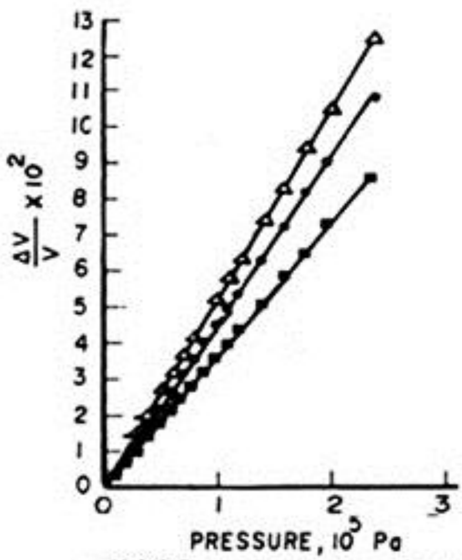
•12, ▲15, ■ 17.6 & x 20.5% M.C.d.b

Figure (7): Effect of moisture content on stress strain behavior for paddy rice



▲ YIELD POINT • MAX.COMP STRESS

Figure (8) : Effect of moisture content on stress - strain & load at yield point & maximum stress



▫ M.C. 8.7 • M.C.14.9 ▲M.C.21.5 % (d.b.)

Figure (9): Relation between pressure & volumetric strain at different moisture content (d.b. %)

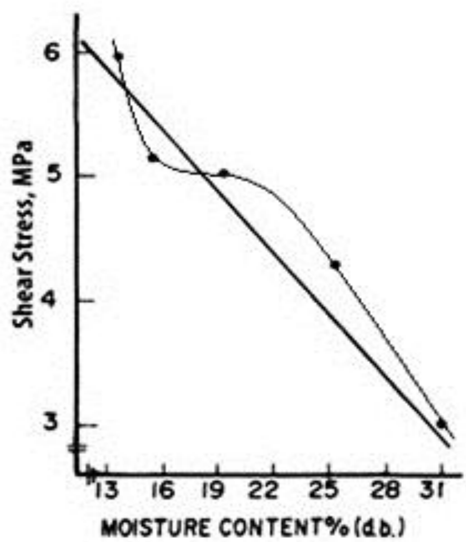


Figure (10) Relation between moisture content & shear stress for paddy rice.

SUMMARY AND CONCLUSIONS

In this study, some physical and mechanical propertiesof Sakha, 102 ricevariety cultivated in Egypt were investigated in the range ofmoisture contentsfrom 10 to 30 (d.b. %). The following conclusionsare drawn from this investigation:

1- The paddy dimensions increased with the increasing of moisture content.
2- Bulk density is inversely proportional with moisture content but particle density is directly proportional with moisture content.
3- The coefficient of friction of paddy rice was increased linearly with the increase of the moisture content of grain on all surfaces.The coefficient of friction was higher on wood followed by concrete surface, galvanizedsteel, plastic and stainless steel.
4- Compression stress of paddy particles were of 6.1 & 8.9 MPa and strain of 0.115 & 0.175 for each of yield point and breakage compressive stress respectively at about 15 (M.C.d.b.%).
5- Modulus of elasticity of paddy particle varied from 180 MPa as a minimum value at 15% moisture content (d.b.) to 600 MPa as amaximum values at 12% moisture content (d.b.).
6- For bulk paddy grain, volumetric strain of paddy directly increases with each of compressive stress and logarithm of moisture content (d.b. %).
7- Static particle shear stress of paddy rice grains rapidly decreased with the increasing of moisture content until 15% (d.b.). The values of shear stress be approximately constant during the moisture content range from 15 to 19 (d.b.%) and then rapidly decreased again.

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الملخص العربى

الخواص الطبيعية للأرز الشعير المصري (سخا ١٠٢) وعلاقتة بالمحتوي الرطوبي

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في هذة الدراسة تم استخدام الأرز الشعير المصري القصير الحبة صنف (سخا ١٠٢) الذي يتميز بمقاومتة لمرض اللفحةوعالي الإنتاجية والجودة لدراسة بعض الخواص الطبيعية والميكانيكية والمرتبطة بعمليات التداول والتخزين وعمليات الضرب والتبييض. والعوامل التى جرت دراستها هى تقدير الابعاد والحجوم وكل من كثافة الحبة والكثافة الكمية ومعامل الاحتكاك الإستاتيكي علي اسطح مختلفة واختبار اجهاد الضغط – الإنفعال على حبة واحدة خلال عدد ٢٥ حبة في صف واحد وكذلك في طبقة سميكة وكذلك اختبار اجهاد القص علي حبة واحدة وقد اجريت التجارب في مجال متغير من المحتوي الرطوبي من ١٠ الي ٣٠% (علي اساس الوزن الجاف) واوجدت المعادلات الاحصائية بين كل عامل من العوامل السابقة مع المحتوى الرطوبى.

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** باحث بمركز تدريب تكنولوجيا الأرز بالإسكندرية- معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية.

وكانت اهم الإستنتاجات المتحصل عليها كالأتي:

١ – زيادة أبعاد الأرز مع زيادة نسبة الرطوبة.

٢ - الكثافة الكمية تتناسب عكسيا مع المحتوي الرطوبي ولكن كثافة الحبة تتناسب طرديا مع نسبة الرطوبة.

٣ - معامل الاحتكاك الإستاتيكي للأرز الشعير يتناسب طردياً مع المحتوي الرطوبي. وكان أعلي معامل احتكاك على الخشب يليها الأسطح ألأسمنتية والحديد المجلفن والبلاستيك واللصلب المقاوم للصدأ.

٤- كان اقل اجهاد ضغط لحبة الأرز عند محتوي رطوبي ١٥% لتوتر في حدود ٦.١و٨.٩ ميجا باسكال وذلك عند انفعال ٠.١١٥و٠.١٧٥ لكل من مقطة الخضوع وأجهاد التحطيم على التوالي

٥ – كان أقل معامل مرونة لحبة الأرز الشعير في حدود ١٨٠ ميجا باسكال عند محتوي رطوبي ١٥٪ وكان اقصي معامل مرونة ٦٠٠ ميجا باسكال عند محتوي رطوبي ١٢٪.

٦ – يتناسب الإنفعال الحجمي للأرز الشعير في اختبار الإجهاد الإنفعال الكمي تناسبا طردياً مع كل من اجهاد الضغط ولوغاريتم المحتوي الرطوبي

٧ - إجهاد القص الإستاتيكي لحبة الأرز الشعير يقل بمعدل سريع مع زيادة المحتوى الرطوبي حتى ١٥ ٪ ثم تثبت تقريباً خلال الفترة من المحتوى الرطوبي من ١٥ الي ١٩% علي اساس الوزن الجاف ثم تنخفض بمعدل كبير مرة أخرى.