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Porosity Rate of Some Kernel Crops

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Abstract: In this study, determination of porosity for some kernel crops was aimed. In addition, relationships were investigated between porosity values and some physical properties of these kernel crops. For this aim; wheat, canola, onion seed, corn, soybean and sunflower seeds were used as vegetal material. After determination of physical properties of kernel crops, a tube system was used which was designed for porosity measurements and operates according to ideal gas law. This measurement system can be filled easily with kernel crops. Pressure of 1.3 kp cm^{-2} was applied to kernel crops. In tests porosity values were measured at different moisture contents related with their physical properties. In the results, relationships between porosity values, moisture contents and physical properties were found. The effect of moisture content on porosity was significant at 99% confidence level for every seed bulk.

Key words: Porosity rate, kernel crops, physical properties

INTRODUCTION

Porosity value is one of the important factors that are used for system designing, in postharvest operations (drying, storage, aeration etc.). Also it is important to make pre-calculations and evaluations for the existent systems related with engineering. Important factors that determine the porosity in bulk are total volume and solid volume of one seed. Especially values of total solid volume and solid volume of one seed must be known to calculate the unit length of conveyor in pneumatic systems used for transportation of materials[1]. In addition void ratio among kernels is very important to control heat transfer[2].

Porosity values are also very important in storage process. Because of an increase in voids and consequently in the amount of air in voids, respiration velocity of materials, which are still actives, increase during storage. At the result, increase in heat happens. Finally, materials are affected negative from this increase.

An aparatus was developed to determine the porosity values of bean and chickpea[3]. In these tests, porosity increased with the increase in kernel size if seeds of bean and chickpea had spherical geometry. In a study on relationship between moisture content and porosity values; soybean, corn and lentil were tested. In the result, it was determined that porosity value increases with increasing moisture content. This relationship was highly important especially in corn (99%). Reason of this situation was attributed to the irregularity of dimensions of corn seeds[4].

Porosity value is also known as a packing factor[5]. Properties of the material in bulk should be known for mixing, transportation, storage and packaging processes. When granule material is put in a container, total volume includes air in it. Porosity of packed materials is the total volume which is occupied by air. In addition, solid density and bulk density are very important factors in designing transportation, storage and packaging processes. Solid density and bulk density of some materials can change related with their moisture content[6]. Paddy seeds were determined to gain a spherical shape and an elastic structure with increases in moisture content[7]. It was found that when the void volume of paddy bulk increases, its resistance to air decreases.

The objectives of this study were to determine porosity rate of six kernel crops that had different moisture contents and effects of moisture content on porosity rate. In addition, total solid volume and solid volume of one seed were calculated by using the porosity values determined.

MATERIALS AND METHODS

In this research, seeds of wheat, canola, onion, corn, soybean and sunflower were used as vegetal material.

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Table 1: Some physical properties of seeds used in tests

Seed	Moisture, %	1000 seed weight, g	Bulk density, kg l^{-1}	Average dimension, mm Length	Widht	Thickness	Sphericity, % Average	SD	CV
Wheat	27.22	45.33	0.675	6.97	3.85	3.24	63.62	0.83	0.68
	26.30	42.33	0.665	6.85	3.66	3.14	62.89		
	22.87	44.00	0.628	6.89	3.55	3.10	61.73		
	12.20	36.25	0.793	6.47	3.34	2.98	62.20		
Canola	24.42	4.66	0.670	1.72	1.60	-	93.00	0.50	0.25
	23.01	5.00	0.683	1.73	1.59	-	92.00		
	18.75	5.00	0.665	1.60	1.49	-	93.00		
	9.38	4.43	0.725	1.58	1.54	-	93.00		
Onion	33.18	6.00	0.570	3.06	2.08	1.55	69.95	3.05	9.29
	30.38	8.00	0.588	3.37	2.20	1.42	65.76		
	21.80	5.33	0.555	3.22	2.16	1.35	65.20		
	13.93	5.00	0.520	3.17	2.17	1.74	71.35		
Corn	16.09	321.33	0.727	12.38	8.69	4.60	63.98	1.74	3.02
	15.22	318.33	0.693	12.65	8.17	4.65	61.96		
	15.00	315.33	0.703	12.09	8.49	4.87	65.81		
	13.30	315.00	0.730	12.21	8.49	4.87	65.39		
Soybean	15.88	160.33	0.675	8.21	6.77	5.55	82.38	1.58	2.50
	14.00	155.50	0.726	7.77	6.41	5.13	81.63		
	13.38	153.00	0.689	7.68	6.63	5.50	85.22		
	12.04	151.00	0.709	7.56	6.41	5.20	83.75		
Sunflower	17.50	69.67	0.353	12.51	6.02	3.77	52.56	0.68	0.46
	15.36	61.00	0.350	11.74	5.83	3.50	52.99		
	11.20	58.50	0.380	11.55	5.77	3.37	52.67		
	7.53	57.00	0.365	11.72	5.48	3.40	51.44		

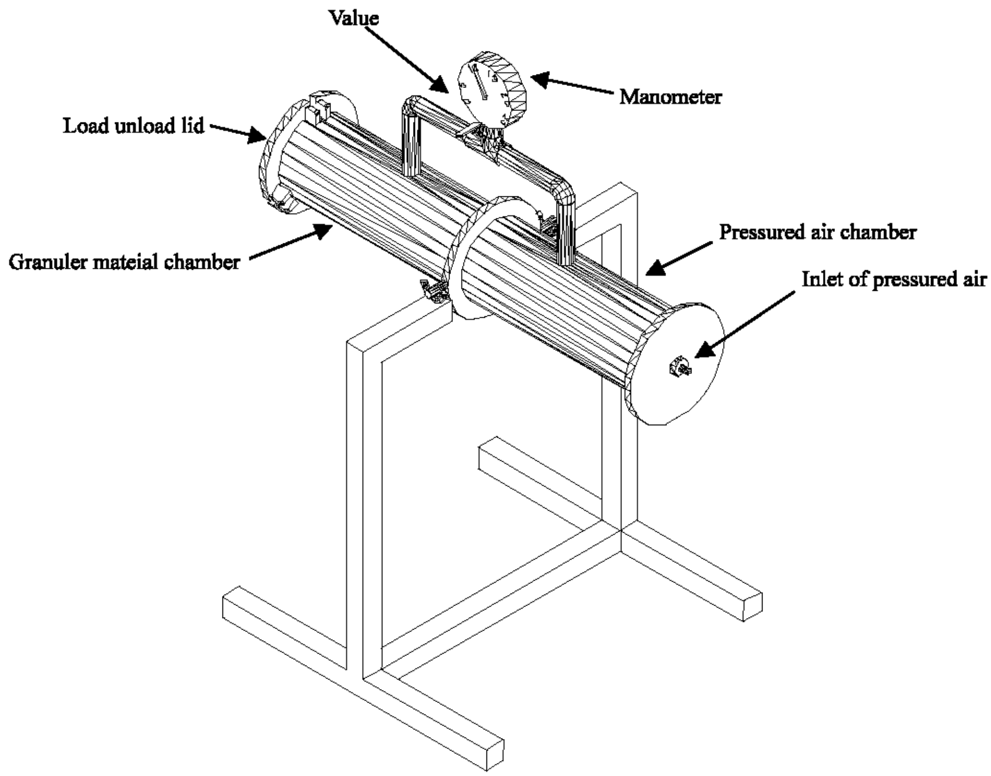

Fig.1: Porosity measurement apparatus

Some measured physical properties of these seeds were given in Table 1. An apparatus which is shown schematically in (Fig.1) was used to determine the porosity values. This apparatus consistsed of two steel chambers with the same volume. These chambers had the same axis and were seperated by divider to prevent volume contact. Connection of the two chambers was done by welding. One of these chambers was made with a lid to allow loading and unloading of seeds. A manometer and a valve were added to the apparatus to control pressured air between the chambers and to determine the air pressure value.

Determination of porosity values: For measurement of porosity, first, chamber of measurement apparatus was filled with pressured air. Desired air pressure was adjusted by a manometer and a valve which was located at the pressure air inlet. After seeds were filled into the material chamber, lid of the chamber was closed leak proof. Then the valve between two chambers was opened and filling of air in pressured air chambers to the voids among the seeds was supplied. Volume of material chamber was measured as 8.45 dm^3. Decrease in pressure of the pressured air that filled the voids among seeds was obtained by reading the manometer. Then porosity values according to ideal gas law were calculated using the pressure values obtained[3,4]. According to ideal gas law:

$$P_1\ V_1 = MR_1T_1 \quad (1)$$
$$R_1\ T_1 = R_2.T_2 = RT \quad (2)$$

Where P_1 is the absolute pressure, V_1 is the volume of pressured air chamber, M is air mass, R_1 is gas constant of air and T_1 is absolute temperature. Index of 2 for the same values represents values in material chamber.

Total air mass in apparatus (M) is divided into two parts that are air mass in pressured air chamber (M_1) and air mass in granular material chamber (M_2).

$$M = M_1 + M_2 \quad (3)$$
$$((P_1V_1) / RT) = (((P_2V_1) / RT) + (P_2V_2) / RT)) \quad (4)$$
$$(V_2 / V_1) = ((P_1 - P_2) / P_2) = \epsilon \quad (5)$$

As shown in Eqn. 5, porosity ratio (ϵ) is the rate of volume in material chamber to the volume in pressured air chamber. In tests, first measured pressure value was fixed as 1.3 kg cm^{-2}[3,4].

The effect of moisture content on porosity were evaluated by MSTAT statistics program according to t-test.

Determination of some physical properties: 20 seeds in every seed bulk that had different moisture levels were randomly selected to determine some physical properties with three repetitions. Dimensions of seeds were measured by using a caliper with an accuracy of ± 0.01. The largest of the three dimensions was designated as length, the second largest as width and the smallest as thickness. Sphericity coefficients of seeds were calculated using measured dimensions[8]. In addition, values of thousand seed weight and solid volume of bulk were measured at every moisture level. Moisture contents of seed bulk were determined according to ASAEs.352.2. Solid volume values of every seed bulk were calculated by subtraction of porosity values from the total volume. Standard ping-pong balls that had 28 mm diameter were used to calibrate the porosity measurement apparatus and to calculate solid volume. 24 balls were loaded into material chamber and porosity values of ball bulk were determined. Then total solid volume of balls was determined. Theoretical ball volume was calculated by dividing total volume of the solid ball bulk to ball number. Relationship between Theoretical Ball Volume (TBV) and Real Ball Volume (RBV) was given as below:

$$TBV = 0.992\ RBV \quad (6)$$

Seed bulk weights were weighed to determine theoretical seed solid volume by a digital balance. Seed number that was filled to the material chamber was calculated using with thousand seed weight. Then, total solid volume that was calculated using porosity value was divided to predicted total seed number. Finally, solid volume of one seed was calculated theoretically. Average real solid volume of one seed was calculated by using Eqn. 6 (Table 2).

The porosity will be affected by the geometry and size. In addition, if the container is tapped, the total volume and hence the porosity will decrease, until eventually the system reaches an equilibrium volume.

RESULTS AND DISCUSSION

The results of the measurements and calculations are summarized in Table 2 for six different kinds of seed that have different moisture contents. Porosity values change with changing moisture content. It was observed that these values also change related with geometrical, dimensional and surface properties of seeds. It was also observed that porosity decreased until reading equilibrium volume when the vane between two chambers was closed[6].

The effect of moisture contents on porosity were found highly significant at 99% confidence level for every seed bulk (t=57.731 for canola, t=67.989 for wheat, t=183.267 for onion seed, t=107.505 for corn, t=83.892 for soybean, t=238.503 for sunflower). According to data, obtained porosity values changed related with moisture content. It was determined that this change was different for every seed bulk. As seen in Fig.2., porosity values increased while moisture contents increased for wheat and canola bulks. However, porosity values decreased

Table 2: Results of porosity values and some physical properties

Seed	Moisture content,%	Porosity, %	Theoretical solid volume of one seed, mm^3	Real solid volume of one seed, mm^3
Wheat	27.22	39.33	41.16	41.49
	26.30	38.33	39.07	39.39
	22.87	38.00	40.83	41.16
	12.20	37.67	33.82	34.09
Canola	24.42	33.67	5.84	5.89
	23.01	33.50	6.29	6.34
	18.75	32.50	6.38	6.43
	9.38	32.23	5.68	5.72
Onion seed	33.18	40.00	7.29	7.35
	30.38	40.33	9.67	9.75
	21.80	40.50	6.42	6.48
	13.93	42.17	5.86	5.90
Corn	16.09	35.50	366.39	369.34
	15.22	35.17	364.80	367.74
	15.00	35.33	360.52	363.42
	13.30	35.50	359.17	362.07
Soybean	15.88	34.33	162.33	163.64
	14.00	34.33	157.44	158.71
	13.38	35.40	152.37	153.60
	12.04	35.50	150.16	151.37
Sunflower	17.50	42.33	156.10	157.36
	15.36	42.33	136.68	137.78
	11.20	44.50	126.15	127.16
	7.53	45.00	121.81	122.79

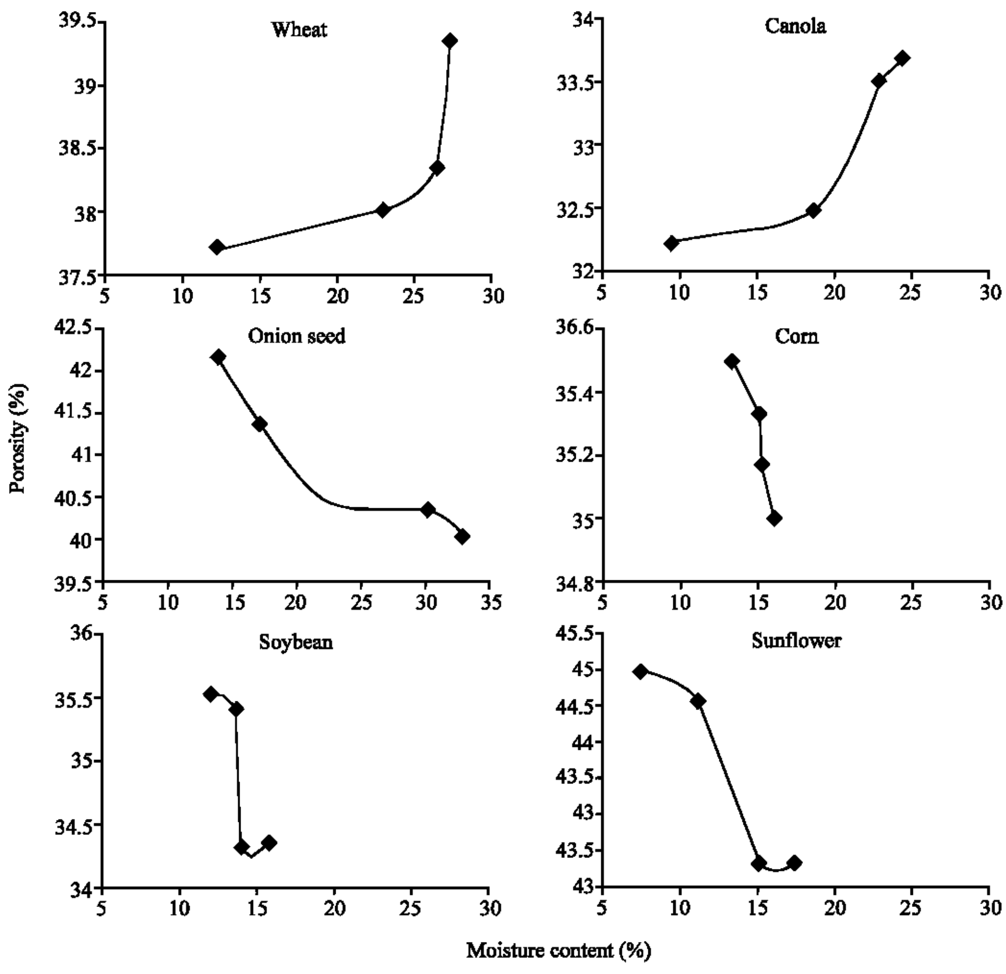

Fig. 2: Changing of porosity values related with different moisture content

while moisture contents increased for the bulks of soybean, corn, onion seed and sunflower. Reason for this difference is that dimensions of wheat and canola changed highly with increasing moisture content. However, their sphericity coefficient did not change despite the increase in moisture content. On the other hand, there were significant changes in sphericity coefficients of other seeds. Dimonsional change occurs along three axes for wheat and canola seeds. Therefore, their sphericity coefficient was the same. Average seed diameter increased as a result of the changes in three axes on wheat and canola. Therefore, contact diameters of seeds that were thouching each other and also void volume among them enlarged. It was reported by Dogantan and Tuncer[3] that for spherical kernels, amount of porosity increases when the kernel size increases. On the contrary, big differences appeared in sphericity coefficients of soybean, corn, onion and sunflower related with increases in moisture content. Consequently, it was determined that void volume among these seeds reduced. Similarly, irregularity in kernel size depending on moisture content is claimed to cause a change in porosity[4].

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