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Properties of Soybean for Best Postharvest Options

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1. Introduction

Soybean is considered as one very important grain grown commercially in more than 35 countries of the world and the leading producer is the USA (41%) followed by Brazil (23%), Argentina (16%) and China (9%), (F A O 1988).
Soybean contains 40% protein, 35% total carbohydrate and 20% cholesterol-free oil (Deshpande et al., 1993). Mineral content of whole soybean is about 1.7% for potassium, 0.3% for Magnesium, 110 ppm iron, 50 ppm zinc and 20 ppm copper (Smith and Circle, 1972). Soybean is the world leading vegetable oil and accounts for about 20 to 24% of all fats and oil in the world. Soybean is becoming increasingly important in agriculture because it is a food source in human and animal nutrition
So many varieties have been developed around the world considering desired traits. The properties of the developed cultivars could be considered to vary from one cultivar to the other. Sometimes, such variations in properties (especially physical properties) are easily observable, especially in the size and shape of such cultivars. Other properties would have to be measured to know them or to see how they vary from one cultivar to another. By extension, the properties (physical, mechanical and chemical) of a cultivar affect the post harvest options to which a cultivar may be subjected. The challenge of post harvest processing of soybean into animal and human food is increasing by the day. This is so because, the world's population is increasing and the challenge of eradicating hunger and producing quality food on the surface of the earth is staring.
Manuwa (2000, 2007), Manuwa et al.(2004, 2005) reported on similar improved varieties of Soybean that were developed in Nigeria. The major improvements made on soybean varieties from 1987 through 1992 at IITA were to increase grain yield by about 20%, improve resistance to pod shattering and to maintain the level of all other traits constant. In order to design equipment for threshing, winnowing, separation, grading, sorting, size reduction, storage, and other secondary processing of soybean, especially the new improved cultivars, the physical properties should be determined.

2. Varieties of soybeans

So many varieties of soybean have been developed around the world so that it is a major task to know all of them. The main aim of developing varieties (cultivars) was to improve desired traits such as:

- Early maturity,
- Disease resistance e.g phytophthora root rot resistant
- High grain yield,
- Shattering and lodging resistant,
- Intact seed coat and some weathering tolerance,
- Seed quality that meets culinary market standards, for example a light hila culinary type.

A number of varieties have been reported in literature (Tables 1, 2, 3).

3. Harvesting and utilisation of soybean

Needless to say that before soybean can be utilised as food for either man or animal, it must first of all be harvested from the field. However, harvest management is a crucial skill for the specialty soybean producer, simply because the physical appearance of the beans is so important to the buyer. Small-seeded soybeans tend to thresh well, but air adjustments may have to be fine-tuned to remove chaff without blowing the small seeds out the back of the combine. Large-seeded soybeans are extremely prone to mechanical damage during threshing operations, which can knock off the seed coat and/or split the embryo into its cotyledonal halves. The combine's cylinder speeds will have to be slowed considerably to avoid this, and the crop may require harvesting at somewhat higher moisture content.

Prompt harvesting will always be a must, as field deterioration of the seed affecting appearance can commence soon after the moisture content of the physiologically mature seed drops to 14%.. If storage is necessary, the producer will have to ensure that storage facilities are clean, dry, and free from any materials that may be toxic to humans. The conditions under which beans are stored greatly influence the quality of the processed product. Moisture content of 13% or less will prevent mold growth. However, very dry beans tend to split when being transferred, and the splitting lowers the quality.

Soybeans can be used for oil, livestock feeds and for preparing various dishes. A number of traditional foods have been produced from soybeans: *Tofu. Miso, Natto, Tempeh, Soymilk, Soyflour, Soyoil, soy milk* (Bschmann, 2001). According to the report, the size of the seed is often crucial, and may be either smaller or larger than average soybean cultivars. For example, small seeds are sought out for *natto*, while large seeds are preferred for *tofu*. Perfectly round seeds are generally prized, while oblong or kidney-shaped soybeans are usually avoided

4. Post harvest options

Post harvest options are generally all the activities that can be carried out after the harvesting of crops in order to convert it to use by man and animal. It can be classified into primary and secondary processing.

Primary processing: This includes threshing, winnowing, cleaning, separation, grading, sorting, packaging, transportation, marketing, storage and so on.

Grains or seeds from harvesters are not directly suitable for its final use such as re-sowing, animal feed or human consumption. The standards of seeds in the three categories have risen in the last few decades to date. Reasons, especially for re-sowing seeds include the need to achieve international marketing standard, and secondly the uniform, high germination product required in precision drilling.

COUNTRY	VARIETY	YIELD (Kg/ha)	SOURCE
USA	Jim	-	www.ag.ndsu.nodak.edu/aginfo/variety/soybean.htm
	Traill	-	
	RG200RR	-	
	Walsh	-	
	MN0201	-	
	MN0302	-	
	Barnes	-	
	Normatto	-	
	Nannonatto	-	
	Norpro	-	
	SD1081RR	-	
	Sargent	-	
	Surge	-	
	SD1091RR	-	
AUSTRALIA	Arunta	3.81	Adapted from: www.ag.ndsu.nodak.edu/aginfo/variety/ Soybean.
	Stephens	3.80	
	Bowyer	3.55	
	Curringa	3.73	
	Djakal (BAF 212)	3.93	
SLOVENIA	Aldama	1791	Acko and Trdan (2009)
	Borostyan	1242	
	Essor	2757	
	Ika	3138	
	Kador	3702	
	Major	2342	
	Nawiko	2748	
	Olna	2272	
	Tarna	3381	
	Tisa	4216	
NIGERIA	Samsoy 2	1745	Manuwa, 2005; 2007
	TGx 923-2E	1736	
	TGx992-22E	1642	
	TGx 1440-1E	1629	
	TGx 1448-2E	1558	
	TGx 1660- 19F	2134	
	TGx 1489-1D	2071	
	TGx 1447-2D	1970	
	TGx 1437-1D	1877	
	TGx 1455- 2E	1660	
	TGx 849-313D	1524	

Table 1. Some Soybean cultivars from USA, Australia, Slovenia & Nigeria

COUNTRY	VARIETY	YIELD (Kg/ha)	OIL CONTENT (%)
INDIA	Alankar	2200	-
	Ankur	2300	-
	Clark - 63	1800	-
	PK-1042	3300	-
	PK-262	2800	-
	PK-308	2600	20-23
	PK-327	2300	-
	PK-416	3200-3800	41-56
	PK-564	3000	-
	Shilajeeth	2200	-
	Bragg	1800	-
	Calitur	1800	-
	Durga	2100	-
	Gaurav	2200	-
	Indira Soya -9	2300	-
	JS-2	1800	-
	JS-71-05	2000-2400	41
	JS-75-46	1600-3100	-
	JS-76-205	1600-2000	-
	JS-79-81	2800	-
	JS-80-21	2500-3000	-
	JS-90-41	2500-3000	-
	JS-335	2500-3000	17-19
	MACS-13	2700	15-22
	MACS-58	2000-2500	-
	MAUS-47 (Parbhani ona)	2500-3000	20
	MS-335	2800	-
	NRC-12(Ahilya-2)	2800	-
	NRC-2(Ahilya-1)	3500-4000	21
	NRC-7(Ahilya-3)	3200	-
	PK-472	3300	-
	PUSA-16	2800	-
	PUSA-22	2600	-
	PUSA-37	2800	-
	TYPE-49	2200	-
	MACS-57	2800	-
	MACS-450	2500	20
	MAUS-2	2450	-
	MAUS-1	2800	-
	MAUS-32(Prasad)	3000-3500	19
	KB-79(Sneha)	1700	-
	MACS-124	2500-3200	-
	PUSA-40	2600	-

Source: http://agmarknet.nic.in/soybean-profile.pdf

Table 2. Some Soybean cultivars from India

BR 16	BR 36	BRS 153	BRS 155	Embrapa 1
Embrapa 48	FT 106 I	FT 109 I	FT 2	FT 20 (Jau)
FT 4	FT 7 (Taroba)	FT 9 (Inae)	FT Manaca	FT Seriema
IAC 13	IAC 15	IAC 15-1	IAC 16	IAC 4
IAC Foscarin-31	IAC/Holambra twart-1	KI-S 601	KI-S 602 RCH	MS/BR 34 (Empaer 10)
Ocepar 10	Ocepar 16	Ocepar 4 (Iguaçu)	Ocepar 7 (Brilhante)	Ocepar 8
RB 502	RS 9 (Itaúba)	BRS 156	IAC 11	Paraná
BRS 157	BRSMS Apaiari	CEP 12 (Cambará)	Cobb	FT 103
FT 104	FT 2000	IAS 4	Ivorá	Ocepar 17
Ocepar 5 (Piquiri)	RS 5 (Esmeralda)	BRS 134	BRS 136	BRS 138
BRS 65	BRS 66	BRSMA Sambaíba	BRSMA Seridó RCH	BRSMG Confiança
BRSMS Piapara	BRSMS Piracanjuba	CEP 20 (Guajuvira)	DM Nobre	Embrapa 30 (V. R Doce)
Embrapa 62	Emgopa 313 (Anhang.)	Emgopa 316 (Rio Verde)	FT 101	FT 19 (Macacha)
GO/BR 25 (Aruanã)	IAC 100	IAC 12	MS/BR 19 (Pequi)	Ocepar 14
Santa Rosa	BR 28 (Seridó)	BR 38	BRS Carla	RB 603
RB 604	DM 247	DM 339	1 BR 6 (Nova Bragg) Bragg(3)	Bragg
BRS 137	BRS 154	BRS Celeste	BRSMG Garantia	BRSMG Robusta
BRSMG Segurança	BRSMG Virtuosa	BRSMS Mandi	Embrapa 20	(Doko RC)
Embrapa 63 (Mirador)	Emgopa 315 (R. Verm.)	FT 10 (Princesa)	FT 18 (Xavante	FT 6 (Veneza
FT Cometa	IAC 18	IAC 22	MG/BR48 (Gar. RCH)	
UFV 19 FT	UFV/ITM-1	BR 30	BRS 135	BRS Milena
BRSMS Carandá	BRSMS Lambari	BRSMS Piraputanga	BRSMS Taquari	BRSMS Tuiuiú
DM Soberana	Embrapa 64 (Ponta Porã)	Emgopa 301	FT 14 (Piracema)	FT 5 (Formosa)
FT Abyara	FT Maracajú	FT Saray	Fundacep 33	Ocepar 12
UFV 10 (Uberaba)	Bossier	BR IAC 21	BRSMA Parnaíba	BRSMG 68 (Vencedora)
BRSMG Liderança	BRSMG Renascença	BRSMS Bacuri	BRSMS Surubi	DM Vitória
FT 11 (Alvorada)	FT Guaira	IAC 17	IAC 8	IAC 8-2
KI-S 702	KI-S 801	MG/BR-46 (Conquista)	Ocepar 3 (Primavera)	UFV 18 (Patos de Minas)
BRSGO Goiatuba	BR 4	BR 9 (Savana)	BRSMA Pati	Embrapa 4
Embrapa 46	Embrapa 47	Emgopa 304 (Campeira)	Emgopa 309 (Goiana)	FT 8 (Araucária)
FT Bahia	FT Cristalina	FT Cristalina CH	FT Estrela	FT Iramaia
FT Líder	Ivaí	MT/BR 50 (Parecis)	MT/BR 51 (Xingu)	MT/BR 53 (Tucano)
Planalto	UFV 5	BRSMT Crixás	CAC-1	CS 301
CS 303	DM 118	Dourados	FEPAGRO-RS 10	FT 102
IAC 20	M-SOY 2002	BRSGO Catalão	Campos Gerais	Embrapa 9 (Bays)
Emgopa 308 (S.Dourada)	FT 100	FT 45263	FT Canarana	FT Eureka
IAC 14	Invicta	Ipagro 21	RS 7 (Jacuí)	Emgopa 303

Adapted from: Glass et al.(2006)

Table 3. Some Soybean cultivars from Alabama, USA

Requirements for seed cleaning:

- To obtain graded lots of seed which will meet home and international testing standards for the variety under consideration, in terms of purity, viability, vigour and size variation
- To remove completely any seeds, the sale of which in a batch may contravene the Noxious Weeds Act, of some countries.
- To avoid any loss of good seeds in the cleaning process.
- To avoid excessive wear that may be due to sorting machines.
- To remove all contaminants that is capable of damaging subsequent processing machinery such as size reduction machines. Typical contaminants include weed seeds, straws, leaves, stones and soil particles.

Principles of separation:

It is important to identify differences in the physical properties of the seeds and the contaminants that will enable the machine (to be designed) make them flow in different directions. Such properties include the following:

- Seed dimensions: length, width, thickness, geometric mean diameter
- Specific gravity
- Falling rate (float)
- Surface texture, friction
- Colour
- Resilience (ability to bounce)
- Electrical conductance

Typically, most processing machines identify differences in properties between good seeds and contaminants. For example a sieve identifies size while other machines identify a combination of properties such as specific gravity table. The shaking table for example identifies friction, size and density of the seeds. The air-screen cleaner for example make use of differences in size, shape and density of the seeds and such machine range from a small, one fan, single screen machine to the large multi-fan eight screen machine with several air columns. Other machines that are used for primary processing include threshing machine, from simple hand operated threshers to high capacity multi cop threshers, combine harvesters, winnowers, air-screen separators (oscillating or vibrating), graders (band, spiral), separators (spiral, table, magnetic, electrostatic, colour, pneumatic, and so on).

Secondary crop processing: It involves processing of food for direct consumption. This requires grinding, milling, oil extraction and so on. To accomplish these, machines are used such as size reduction machines such as milling machines, dehullers, grinding machines, oil press and so on.

5. Methodology for evaluating soybean properties

Sample preparation: Dry mature Soybeans [Glycine max.] are normally used for all the experiments. Before the experiments, the grains were further cleaned by removing those that were physically bad, unhealthy or broken. The moisture content of the grain would be determined using a standard method. Physical properties were determined at the initial moisture content. Thereafter, grain sample of the desired moisture levels were prepared by adding calculated amount of distilled water and sealed in separated polythene bags. The samples would be kept at about 278 ^{0}K in a refrigerator for 1 week to enable the moisture to distribute uniformly throughout the sample. Before the commencement of a test, the required quantity of the grain was taken out of the refrigerator (if kept there to cool), and allowed to warm up to room temperature at about 305 ^{0}K.

Physical properties: The physical properties of Soybean to be determined include linear dimensions, mass, bulk density, seed density, volume, surface area, sphericity, porosity, coefficient of static friction on structural surfaces and angle of repose, angle of internal friction, terminal velocity. Experiments were conducted at five levels of moisture content in the desired range and replicated five times. Average values were normally reported. The choice of the range of moisture content was due to the fact that the lower limit was the safe storage moisture content, and the upper range, the maximum moisture content obtainable after the seeds were soaked overnight.

Linear dimensions and geometric mean diameter: To determine the size of the grain, 10 sub samples each consisting of 100 grains were randomly taken. From each sub sample, 10 grains were taken and their three linear dimensions namely, length (L), width (W) and thickness (T) were measured with a venier calipers having accuracy of 0.01mm. The geometric mean diameter (D_{GM}) of the grain was calculated by using the following relationship (Sreenarayanan et al 1985, Sharma et al 1985).

$$D_{GM} = (LWT)^{1/3} \tag{1}$$

Test weight: Sub samples of One, one hundred and one thousand soybean grains from each sample were randomly selected and weighed. The averages of the replicated values are usually reported.

Bulk and seed density: A method similar to that reported by Shephered and Bhardwaj (1986) can be used to determine the bulk density at each moisture level: a 180 ml cylinder was filled continuously from a height of about 15 cm. Tapping during filling was done to obtain uniform packing and to minimize the wall effect, if any. The filled sample was weighed and the bulk density of the material filling the cylinder was computed (Shephered and Bhardwaj, 1986; Deshpande and Ali, 1988; Mohsenin, 1970). The seed density of the grain can be determined by the liquid displacement method to determine the seed volume similar to that reported (Shephered and Bhardwaj, 1986; Deshpande and Ali, 1988).

Sphericity and porosity: According to Mohsenin (1970), sphericity ф, was calculated using the formula.

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

Fractional porosity is defined as the fraction of space in the bulk grain which is not occupied by grain. Thompson and Isaacs (1967) gave the following relationship for fractional porosity.

$$\varepsilon = \frac{(1-\rho_b)}{\rho_s} x100 \tag{3}$$

where,

ε	=	fractional porosity
ρ_b	=	bulk density of the seed
ρ_S	=	Seed density

Angle of repose: The emptying angle of repose θ is normally determined at the moisture levels using the pipe method (Henderson 1982, Jha 1999). A pipe of 40 cm height and 106 mm internal diameter was kept on the floor vertically and filled with the sample, Tapping during filling was done to obtain uniform packing. The tube was slowly raised above the floor so that the whole material could slide and form a heap. The height above the floor H and the diameter of the heap D at its base were measured with a measuring scale and the angle of reposes θ of the soybean computer using the equation;

$$\theta = Arc\tan(2H / D) \tag{4}$$

Surface area: The surface area of the grain can be found by analogy with a sphere of geometric mean diameter for the different levels given by (McCabe et al., 1986)

$$S = \pi D_{GM}^2 \tag{5}$$

Coefficient of static friction: The coefficient of static friction for seed grain can be determined against structural surfaces such as plywood (with grain parallel to direction of motion and then with grain perpendicular to direction of motion), galvanized steel (GS), glass, concrete and so on. A bottom less wooden box of 150 mm x 150 mm x 40 mm was constructed for this purpose. This was similar to that reported by (Oje, 1994). The box shall be filled with soybean grains on an adjustable tilting surface. The surface would be raised gradually using a screw device until the box started to slide down and the angle of inclination read on a graduated scale.
Terminal velocity: The terminal velocity of soybean at different moisture content can be determined using an air column (Polat et al., 2006). For each test, a seed was dropped from the top of a 75 mm diameter, 1 m long glass tube. The air was made to flow upwards in the tube from bottom to the top and the air velocity at which the sample seed was suspended was noted with an anemometer having at least 0.1 m/s sensitivity.
Angle of internal friction: To determine the angle of internal friction of soybean at different moisture contents, the direct shear method can be used according to Uzuner (1996), Zou and Brucewitz (2001), Molenda et al.(2002) and Mani et al.(2004). Typical velocity to be used during the experiment is 0.7 mm/min (Kibar and Ozturk, 2008) and the angle of internal friction can be calculated using the following equations:

$$\sigma = \frac{N}{A}100 \tag{6}$$

Where: σ - normal stress (kPa), N - load applied over sample (kg), A - cellular area (cm2),

$$\tau = \frac{T_s}{A}100 \tag{7}$$

Where: τ – stress of cutting (kPa), Ts – strength of cutting (kg),

$$\tau = (C + \sigma tg\phi) \tag{8}$$

Where: C- cohesion

6. Rupture force and rupture energy

To determine the rupture force and rupture energy, a Universal Testing Machine (UTM) can be used such as Instron Universal Testing Machine reported by Tavakoli et al. (2009). It was equipped with a 500 kg compression load cell and integrator. The measurement accuracy was

0.001 N in force and 0.001 mm in deformation. The individual grain was loaded between two parallel plates of the machine and compressed along with thickness until rupture occurred as is denoted by a rupture point in the force-deformation curve. The rupture point is a point on the force-deformation curve at which the loaded specimen shows a visible or invisible failure in the form of breaks or cracks. According to them the point was detected by a continuous decrease of the load in the force-deformation diagram. The loading rate of 5 mm/min was used according to ASAE (2006a). The energy absorbed by the sample at rupture was determined by calculating the area under the force-deformation curve from the relationship:

$$E_a = \frac{F_r D_r}{2} \tag{9}$$

Where E_a is the rupture energy in mJ, F_r is the rupture force in N and D_r is the deformation at rupture point (Braga et al., 1999).

Cultivars	MC range %(db)	Dimensions (mm)	Mass (g)	Reference
JS- 7244	8.7- 25.0	L: 6.32 to 6.75 W: 5.23 to 5.55 T: 3.99 to 4.45 GMD: 5.09 to 5.51	- - 1000 grains: 110 to 127	Deshpande et al., 1993
TGX 1440-1E	10.5- 34.1	L: 8.58 to 10.02 W: 6.51 to 7.22 T: 5.43 to 5.69 GMD: 6.71 to 7.44	1 grain: 0.11 to 0.21 100 grains: 14.67 to 19.98 1000 grains: 139.18 to 190.6	Manuwa, 2000
TGX 1871- 5E	7.1- 43.7	L: 7.52- 9.11 W: 6.47- 7.05 T: 5.49- 5.05 GMD: 6.44- 7.29	1 grain: 0.136 to 0.206 100 grains: 12.3 to 16.59 1000 grains: 119.17 to 153.15	Manuwa and Afuye, 2004
TGX 1019-2EB	6.7- 47.1	L: 7.37 to 9.96 W: 6.48 to 7.45 T: 5.33 to 5.54 GMD: 6.33 to 7.39	1 grain: 0.178 to 0.218 100 grains: 13.78 to 18.79 1000 grains: 130.67 to 180.21	Manuwa and Odubanjo, 2005
Unspecified	6.7- 15.3	L: 7.41 to 9.57 W: 5.34 to 6.75 T: 4.5 to 5.17 GMD: 5.62 to 6.94	1000 grains: 121.76 to 223.65	Polat et al., 2006
TGX 1448- 2E	9.9 to 39.6	L: 8.3 to 10.4 W: 6.4 to 7.5 T: 5.4 to 5.8 GMD: 6.6 to 7.6	1 grain: 0.19 to 0.24 100 grains: 15.6 to 19.4 1000 grains: 154.2 to 185.6	Manuwa, 2007
Unspecified	8- 16	L: 7.24 to 8.19 W: 6.79 to 7.12 T: 5.78 to 6.23 GMD: 6.57 to 7.14	NAV	Kibar and Ozturk, 2008
Unspecified	6.92- 21.19	L: 7.27 to 8.23 W: 6.48 to 6.97 T: 5.41 to 5.94 GMD: 6.34 to 6.98	1000 grains: 171.5 to 219.04	Tavakoli et al., 2009

MC= moisture content, NAV= not available

Table 4. Effect of moisture content on mass and dimensional properties of some soybean cultivars

Cultivars	MC range %(db)	Seed density	Bulk density	Sphericity (%)	Porosity (%)	V_t (m/s)	Reference
JS- 7244	8.7- 25.0	1216 - 1124	735 - 708	80.6 – 81.6	40 - 37	NAV	Deshpande et al., 1993
TGX 1440-1E	10.5- 34.1	1184 - 1076	720 - 631	79 – 73.3	23.6 – 34.2	NAV	Manuwa, 2000
TGX 1871- 5E	7.1- 43.7	1222.3 – 935.7	686.5 – 616.7	85.87- 78.23	25.64 – 40.96	NAV	Manuwa and Afuye, 2004
TGX 1019-2EB	6.7- 47.1	1157 - 952	728.5 – 608.4	86 – 74.9	23.46 – 42.33	NAV	Manuwa and Odubanjo, 2005
Unspecified	6.7- 15.3	1062.6 to 1086.5	804.8 to 689.3	75 to 72	51 to 44.2	7.13 to 9.24	Polat et al., 2006
TGX 1448- 2E	9.9 to 39.6	1465 - 1074	714 - 638	79.1 – 72.7	19.5 – 33.7	NAV	Manuwa, 2007
Unspecified	8- 16	983.33 – 905.67	766.12 – 719.00	91- 87	22.58 – 20.61	NAV	Kibar and Ozturk, 2008
Unspecified	6.92-21.19	1147.86 to 1126.43	650.95 to 625.36	87.25 to 84.75	43.29-44.48	NAV	Tavakoli et al., 2009

MC= moisture content, NAV= not available
Vt = terminal velocity

Table 5. Effect of moisture content on density, sphericity, porosity and terminal velocity of some soybean cultivars

Cultivars	MC range %(db)	Angle of repose (degree)	Coefficient of static friction				Reference
			Galvanised steel	PWLG	PWDG	Glass	
JS- 7244	8.7- 25.0						Desshpande et al., 1993
TGX 1440-1E	10.5-34.1	24.1 – 31.5	0.344 – 0.509	0.446 – 0.600	0.481 – 0.653	-	Manuwa, 2000
TGX 1871- 5E	7.1- 43.7	23.43 – 32.23	0.434 – 0.679	0.4245 – 0.601	0.4243 – 0.6789	-	Manuwa and Afuye, 2004
TGX 1019-2EB	6.7- 47.1	25.87 – 32.45	0.3839 – 0.5774	0.4877 – 0.6249	0.4922 – 0.6876	NAV	Manuwa and Odubanjo, 2005
Unspecified	6.7- 15.3		0.21 – 0.34	0.22 – 0.35*		0.19 – 0.33	Polat et al., 2006
TGX 1448- 2E	9.9 to 39.6	24.2 – 30.2	0.391 – 0.510	0.466 – 0.601		-	Manuwa, 2007
Unspecified	8- 16		0.164 - 0.286				Kibar and Ozturk, 2008
Unspecified	6.92-21.19	24.56 – 29.93	0.28 – 0.326	0.287 – 0.361		0.262 – 0.307	Tavakoli et al., 2009

MC = moisture content, NAV= not available, PWLG = plywood parallel to grain, PWDG = plywood perpendicular to grain *PLWD = plywood

Table 6. Effect of moisture content on angle of repose and coefficient of static friction of some soybean cultivars

7. Estimated values of soybean properties

Some typical values and models of physical, mechanical and aerodynamic properties of soybean cultivars are reported in this section (Tables 4 to 6). Table 4 shows the effect of moisture content on mass and dimensional properties of some soybean cultivars**.** Table 5 shows the effect of moisture content on density, sphericity, porosity and terminal velocity of some soybean cultivars**.** Table 6 shows the effect of moisture content on angle of repose and coefficient of static friction of some soybean cultivars.

8. General comments

It can be seen that the number of soybean cultivars that have been developed around the world is numerous and can be better imagined. However, it appears that very little has been reported in literature concerning physical and engineering properties of such soybean cultivars. Nevertheless, it is obvious that post harvest options or technology are *sine qua non* in order to convert soybean seeds into quality food for human and animal in view of the quality of food nutrition available in the seeds.

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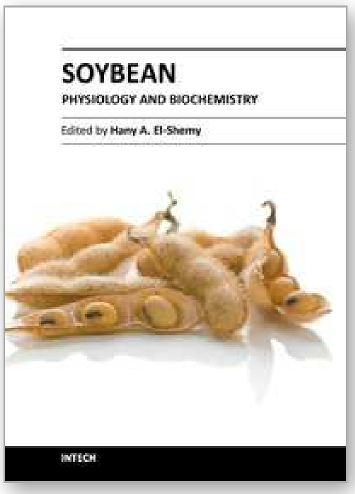

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Worldwide, soybean seed proteins represent a major source of amino acids for human and animal nutrition. Soybean seeds are an important and economical source of protein in the diet of many developed and developing countries. Soy is a complete protein and soyfoods are rich in vitamins and minerals.Soybean protein provides all the essential amino acids in the amounts needed for human health. Recent research suggests that soy may also lower risk of prostate, colon and breast cancers as well as osteoporosis and other bone health problems and alleviate hot flashes associated with menopause. This volume is expected to be useful for student, researchers and public who are interested in soybean.

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