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Influence of Harvest and Post-Harvest Conditions on the Physiology and Germination of Peanut Kernels

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ABSTRACT

Harvesting, storage, and shelling procedures can greatly affect seed vigor. In regions where mechanical harvesting and drying procedures are not standard, seeds are often damaged and germination is poor. The objective of this research was to study the effects of different drying procedures on seed quality. Germination of peanut kernel (*Arachis hypogaea* L., cv. J-11) was significantly affected by harvesting and post-harvest handling and operations. Harvesting at or around 110 d after emergence showed higher numbers of matured kernels, with high quality and better storability. Pods after harvest were dried in the field following different methods. Field drying of pods with haulms, in heaps to avoid direct exposure to sunlight following the DOR method, was found to be highly suitable in reducing mechanical injury during shelling and also in maintaining higher germinability of seeds in storage. Effects of shelling were assessed in terms of physical damage. Only sound mature kernels (SMK) were used for drying and storage tests, which involved temperatures ranging from 20-50 C (in an air velocity 0.61 to 1.0 m/sec) and ambient to 50% RH conditions. Effects of drying on occurrence of physical damage like % split kernel, bold kernel, and skin slip then were assessed. Both shelling and drying had shown significant effects on germinability, seedling vigor, membrane integrity, dehydrogenase activity, and lipid peroxidation when tested under ambient or accelerated aging conditions. Slow drying or low temperature/low humidity drying reduced physical damage and maintained high vigor and viability during storage.

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Seed quality can be affected by environmental conditions that occur while they are maturing on the plant, during harvest and processing, or in post-harvest storage (Heydecker, 1977). In the case of peanut (*Arachis hypogaea* L.), seed management during harvesting and seed processing frequently increases mechanical seed injury (McLean and Sullivan, 1981). This problem has been directly correlated to loss of seed viability in other crops such as soybean (Popingis, 1972). Baudet *et al.* (1978) showed that deep or superficial injuries during soybean seed processing either directly affect seed germination or cause latent effects which ultimately reduce seed vigor and storage potential. The latent effects caused by bruised tissue are more severe than those caused by breaking because injured tissues can host pathogens. According to Carvalho and Nakagawa (1988), injury during germination utilizes the energy reserves to heal the bruised tissue; therefore, the germination process may be either delayed or impaired.

Drying of seeds to a safe moisture content before storage is essential to minimize deterioration due to microorganisms and endogenous respiration during storage. In India, sun drying is the conventional method for reducing moisture level in the seed. Apart from being weather-dependant and slow, sun drying often results in nonuniform drying. Slow drying in the windrow or in the method described by the Directorate of Oil Seed Research, Hyderabad, India (DOR), which involves bundling plants and inverting them over other bundles to cover pods from direct sunlight and then exposing all pods to open air during the night, is conducive to mold proliferation which subsequently degrades seed germinability. On the other hand, artificial drying in an elevated temperature (up to 50 C) and low relative humidity ensure quicker and more uniform drying of seeds. Unless carefully controlled, artificial drying may cause a detrimental effect with respect to physical damage and germination parameters (Woodward and Hutchinson, 1972; McPhee, 1991).

The present study was conducted to evaluate (a) the effect of seed maturity and seed moisture content at harvest on storability, (b) the impact of mechanical damage during shelling and drying on seed viability; and (c) changes in physiological and biochemical parameters of peanut kernels.

Materials and Methods

Peanut (cv. J-11) pods were collected at 5-d intervals from 85 to 120 d after emergence (DAE) from the experimental farm of the Agric. and Food Eng. Dept., I.I.T., Kharagpur, India. Ten plants from the interior rows of each plot were randomly collected, and the number and weight of mature and immature pods were recorded. Mature pods were determined by visual characteristics as described by Pickett (1950). Pods that possessed white inner pericarp, white seed coat, and white hulls were classified as immature. Seed maturity also was studied following the method of Holaday *et al.* (1979) using a methanolic extract of freshly harvested seeds.

Immediately after harvest, pods were dried by one of the following three methods until the kernel moisture content was approximately 8%: (a) Windrow drying - after digging, plants with pods were left in rows in the field and dried for 7 d, (b) Shade drying - pods in the plants were dried in the test shed of a PHTC Rice Mill in rows for 1 wk, (c) DOR method - plants were bundled in heaps approx. 0.5 m high and 1 m diam., and then one heap was inverted over the other in a way that the haulms of the upper heap cover the exposed peripheral pods of the lower heap from direct sunlight. In the evening upper heaps were removed and all the bundles were exposed. Again, the next morning bundles were arranged in the same way as before and the procedure was repeated for 7 d.

After drying, subsamples of pods were shelled in a laboratory sheller and by hand. Samples of shelled kernels were assessed for sound seed quality following the method of McLean and Sullivan (1981) and subdivided into three groups: (1) ELK (extra large kernels) - 15.0 × 8.0 mm, (2) SMK (sound mature kernels) - between 10-15 × 5-8 mm, and (3) SS (sound split kernels). Samples of shelled, dried kernels were grouped into three categories: (a) bald kernels, (b) split kernels, and (c) kernels with a percentage of skin slip following McPhee (1991).

These kernels were placed for accelerated aging at 100% RH and 40 C or stored under ambient conditions in the laboratory to determine their storage potential. Sound mature kernels were dried under temperatures ranging from 20-50 C (at an air velocity of 0.6-1.0 m/sec) and ambient to 50% RH conditions in a mechanical drier.

After drying, damaged kernels were again assessed using previously mentioned methods. Moisture content, germination tests, and vigor tests were performed according to ISTA (1986) procedures. All moisture content values reported are on a wet weight basis.

Leakage of electrolytes due to membrane damage has been found to be directly related to vigor status of the seed. Activity of a dehydrogenase enzyme, a respiratory enzyme, also is an indicator of viability, especially embryo soundness. Malondialdihyde formation due to lipid peroxidation is correlated to aging of seed, oil seeds in particular. Therefore, leakage of electrolytes was determined before and after storage following the method of Dadlani and Agrawal (1986). Dehydrogenase activity and total malondialdehyde formation were estimated following the method of Sung and Jeng (1994) for peanut.

Maturity studies in the field condition were conducted for three consecutive planting seasons. Laboratory experiments were replicated three times for each cropping season. Randomized block design and Duncan's Multiple range tests were followed for statistical analysis. Germination data obtained were transformed to arcsin values before statistical analysis.

Results and Discussion

Data presented in Table 1 show the effect of crop maturity on a light transmittance test of methanolic extract of peanut kernels harvested at different DAE in the field. Pods harvested at early dates (85-95 d after field emergence) showed a higher percentage of light transmittance of methanolic extract of seeds, low seed germination percentage, and very poor seedling growth. Pods harvested after 110 d of seedling emergence in the field showed a low light transmittance of the methanolic extract of seed coat, higher germination percentage of seeds, and vigorous seedling growth.

Table 1. Effect of crop maturity on light transmittance (T) of methanolic extract of seeds, seed germination, and seedling growth of peanut tested before and after storage.[a]

Days after emergence	T[b]	Before storage			After storage[c]		
		Germ.[a]	MSL[b]	MRL[c]	Germ.	MSL	MEL
	%	%	mm	mm	%	mm	mm
85	92 a	10 f	—	—	—	—	—
90	90 a	29 e	32 d	86 d	—	—	—
95	91 a	49 d	46 c	126 d	—	—	—
100	83 b	82 bc	49 c	182 c	15 d	21 d	42 d
105	84 b	95 a	76 bc	225 bc	46 c	42 c	115 c
110	67 cd	97 a	84 bc	289 a	75 b	59 b	192 c
115	62 d	96 a	102 a	298 a	89 a	72 ab	258 ab
120	56 e	98 a	112 a	305 a	91 a	78 a	279 a

[a]Germ. = germination, MSL = mean shoot length, and MRL = mean root length. Mean values within columns not followed by the same letter were different ($P < 0.05$) as determined by Duncan's Multiple Range Test.

[b]50 seeds/50 mL methanol for 3 hr.

[c]Storage under ambient conditions (RH *ca.* 75%, temp. 26 C) for 3 mo.

After drying and storage for 3 mo under ambient conditions (75 ± 6% RH, 26 ± 3 C), seeds harvested between 85 and 105 d after emergence did not germinate or showed very poor germination and seedling growth. On the other hand, seeds collected after 110 DAE maintained 89-91% germination and significantly better seedling growth.

Data presented in Table 2 show the effect of harvest date on seed maturation (visual assessment, such as white pericarp, white hull, and seed coat for immature seeds), moisture content and germination percentage of peanut seeds. Pods harvested at 85 DAE showed only immature nongerminable seeds with a higher moisture content. At 105 DAE or after, percentage of mature seeds increased steadily, seed moisture content declined rapidly, and seed germination percentage increased significantly, indicating that harvesting should be done between 110 and 120 DAE to obtain high quality seeds under the experimental field conditions of IIT, Kharagpur, India.

Table 2. Effect of harvest date on seed maturation, moisture content and germinability of peanut seeds.[a]

Days after emergence	Pods: Immature	Pods: Mature	Moisture content	Germination[b]
	-------- %	--------	%, wt/wt	%
85	98 a	2 d	46 a	5 d
90	82 a	18 c	51 a	28 c
95	65 b	35 c	49 a	58 b
100	48 b	52 bc	49 a	86 ab
105	38 bc	60 b	44 b	92 a
110	30 c	70 b	40 b	94 a
115	12 d	88 a	38 b	95 a
120	8 d	92 a	37 b	98 a

[a]50 pods taken for each experiment and replicated three times. Mean values within columns not followed by the same letter were different (P < 0.05) as determined by Duncan's Multiple Range Test.
[b]Only germination percentage after 96 hr recorded.

Kernels subdivided into three groups (SMK, ELK, SS) after pod drying and shelling showed that ELK and SS did not maintain high viability under both accelerated aging (6 d) and ambient aging conditions (4 mo) (Table 3). Only sound mature kernels showed a high germination percentage and better seedling growth under accelerated and ambient aging conditions.

Damage incurred during mechanical shelling was assessed for levels of split and bald kernels (by weight) and percentage skin slip, were kept under accelerated aging conditions for 7 d along with hand-shelled kernels (Table 4). Profuse leakage loss was observed from all categories of damaged kernels and compared to undamaged hand-shelled or mechanically shelled kernels tested before or after accelerated aging. Germination percentage and seedling growth did not show appreciable differences between damaged and undamaged seed when tested before aging. However, after accelerated aging at 100% RH and 40 C, only undamaged hand-shelled or mechanically shelled kernels had higher germination and better seedling growth than damaged seeds. Both split kernels and bald kernels failed to maintain storability because of fungal growth.

Table 3. Effect of harvesting and processing on viability of peanut seeds after accelerated aging (100% RH, 0 C) and natural aging under ambient conditions.[a]

Type of kernel	Aging at 100% RH, 40 C (6 d): Germ.	MSL	MRL	Natural aging (6 mo): Germ.	MSL	MRL
	%	mm	mm	%	mm	mm
SMK	82 a	66 a	218 a	92 a	58 a	235 a
ELK	49 b	48 c	147 b	64 b	60 a	174 b
SS	22 b	29 c	92 c	37 c	35 b	128 c

[a]SKM = sound mature kernels, ELK = extra large kernels, and SS = sound split kernels. Germ. = germination, MSL = mean shoot length, and MRL = mean root length. Mean values within columns not followed by the same letter were different (P < 0.05) as determined by Duncan's Multiple Range Test.

The effects of drying regimes and final seed moisture content on the susceptibility of peanut seeds to physical damage are presented in Table 5. Pods dried in the field (windrow drying) followed by drying of sound mature kernels (SMK) in the shed recorded a final moisture content of about 8.5%. In the DOR method of drying of pods followed by SMK drying in the shed, the final seed moisture content was about 8.2%. Forced air drying of SMK at room temperature or at elevated temperature reduced the moisture content to 5-6%, but caused more bald kernels in direct proportion to drying temperature.

At low temperature drying (20 C) using dehumidified air (40-50% RH), percentage skin slip increased substantially, although occurrence of bald kernels and split kernels was much less. These results indicate that skin slip is one of the physical quality factors most influenced by shelling and drying. Increased skin slippage is perhaps due to the high velocity of air or to differential shrinkage of cotyledons and skin during drying or both.

Data presented in Table 6 show the effects of drying conditions on germinability, membrane integrity, dehydrogenase activity, and malondialdehyde formation of peanut seeds under ambient storage conditions. Seeds dried under 20 C and 50% RH conditions showed lower leakage of electrolytes, higher dehydrogenase activity, lower malondialdehyde formation, and higher germination percentage after 3 mo of storage under ambient aging conditions compared to seeds dried by other methods. After 6 mo of storage only the DOR method of drying and 20 C and 50% RH drying proved to be effective in maintaining higher germination percentage, lower leakage loss of

Table 4. Effect of mechanical shelling on physical damage, membrane integrity, and storability of peanut seeds.[a]

Shelling method	Physical damage	Before storage				After storage[b]			
		EC	Germ.	MSL	MRL	EC	Germ.	MSL	MRL
	%	mmho/cm	%	mm	mm	mm	mmho/cm	%	mm
Hand shelled									
Split kernel	3.0±0.2	0.085 b	93 b	164 a	321 a	0.158 a	68 a	128 a	250 a
Mechanically shelled									
Split kernel	16.5±1.1	0.256 a	86 a	142 a	288 a	0.332 b	12 c	-	-
Bald kernel	2.8±0.4	0.248 a	89 a	152 a	294 a	0.496 b	21 c	-	-
Skin slip	14.2±1.4	0.205 a	88 a	151 a	292 a	0.395 b	54 b	92 b	198 b
Undamaged	66.7±2.8	0.092 b	5 a	160 a	299 a	0.172 a	72 a	119 a	243 a

[a]EC = electrical conductivity of seed leachate, Germ. = germination, MSL = mean shoot length, and MRL = mean root length. Mean values within columns not followed by the same letter were different ($P < 0.05$) as determined by Duncan's Multiple Range Test.

[b]100% RH, 40 C for 7 d.

Table 5. Effect of drying condition on final moisture content and physical damage of peanut kernels.[a]

Drying conditions	Final moisture content	Physical damage		
		Bald	Split	Skin slip
	%, wt/wt	----------	% by wt	----------
Windrow drying	8.52 b	2.0 a	0.5 a	4.3 a
DOR method + shed drying	8.20 b	2.6 a	0.3 a	5.3 a
DOR + hot air drying temperature[b]				
+ 50 C	5.35 a	14.7 c	4.7 c	19.8 c
+ 45 C	5.65 a	10.2 b	1.9 b	14.5 b
+ 40 C	5.82 a	6.8 ab	0.8 ab	9.7 ab
+ 32 C	6.00 a	3.7 a	0.3 a	4.8 a
20 C/50% RH[c]	6.93 ab	2.0 a	0.5 a	12.5 b

[a]Only sound mature kernels taken for drying. Mean values within columns not followed by the same letter were different ($P < 0.05$) as determined by Duncan's Multiple Range Test.

[b]Air flow rate 1 m/sec.

[c]Air flow 0.6 m/d.

electrolytes, higher dehydrogenase activity, and lower malondialdehyde formation. This suggests that slow drying or low temperature/low humidity drying could protect against autoxidation.

The results indicate that harvesting time is very important for controlling the physiological maturity of peanut seed. Pods harvested at 110 DAE or after maintained a higher percentage of matured kernels per pod, better germinability, and seedling vigor. These results are similar to those reported by Sombatsiri and Nuan-on (1987).

Seed processing (i.e., shelling) normally damages the seed surface and embryo. Adjusting pod moisture content at shelling may prevent damage to a large extent. The DOR method of drying in the field proved to be beneficial in lowering the occurrence of mechanical damage. Results presented here showed that slow drying helps to avoid physical damage, and thus reduces loss of vigor and viability which occur during elevated temperature drying. Previous workers (Steele, 1983; Nautiyal and Zala, 1991) also reported the beneficial effects of slow drying. According to McPhee (1991) an increased rate of skin slip is the major problem in high temperature drying. Our experiments showed that lowering the humidity and temperature of drying air reduces skin slip substantially. Kernels dried in low temperature and low humidity conditions or in the slow drying method fared better in terms of physiological deterioration and maintained better vigor and viability in storage.

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Table 6. Germinability, membrane permeability (EC), dehydrogenase (DHA), and malondialdehyde (MDA) formation of peanut kernels dried under different temperatures and RH and stored under ambient condition (%, RH 86±7, temp. C., 30±5).[a]

Drying conditon	Storage period							
	3 mo				6 mo			
	Germination	EC	DHA	MDA	Germination	EC	DHA	MDA
	%	mmho/cm	OD_{470}	OD_{520}	%	mmho/cm	OD_{470}	OD_{520}
Windrow	7 ab	0.142 b	0.285 b	0.158 a	56 c	0.248 b	0.230 b	0.265 b
DOR method	84 a	0.121 a	0.392 a	0.146 a	68 b	0.182 ab	0.332 a	0.225a
Mechanical drying[b]								
50 C	73 b	0.156 b	0.219 c	0.204 b	43 d	0.301 c	0.191 b	0.296 c
45 C	75 b	0.150 b	0.248 bc	0.186 b	52 c	0.264 b	0.205 b	0.404 c
40 C	76 b	0.148 b	0.256 b	0.178 b	57 b	0.228 b	0.208 b	0.309 c
RT	80 ab	0.116 a	0.279 b	0.164 a	60 b	0.193 b	0.228 b	0.287 b
20 C[c]	89 a	0.094 a	0.406 a	0.135 a	78 a	0.147 a	0.375 a	0.189 a

[a]EC = electrical conductivity of seed leachate, MSL = mean shoot length, and MRL = mean root length. Mean values within columns not followed by the same letter were different ($P < 0.05$) as determined by Duncan's Multiple Range Test.

[b]Air flow rate 1 m/sec.

[c]Air flow 0.6 m/d.

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