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Impact of Packaging Material and Storage Duration on Shelled Groundnut (*Arachis hypogaea* L) Seed Quality

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Abstract

Groundnut is an important annual legume crop grown for its protein and edible oil, adapted to warm temperate and tropical areas. An experiment was done during the 2020 cropping season to determine the best storage materials for a long period to prevent test a damage, which would reduce the seed quality in the Benishangul-Gumuz region. The trial was set using four replicates of a randomized complete block design. Dirib released variety, seven packaging materials, and 10 periods of storage times (0-9 months) were used as treatment combinations. 20kg shelled homogenized pre-basic seed stored for nine months in each of packing materials such as Polypropylene bag, Metal silo, Polypropylene bag with polyethylene sheet lining (Fertilizer bag), PICS bag, Super grain pro bag, Zero flay and Jut bag and the samples were drawn monthly for laboratory analysis. Analysis of the laboratory experiment data revealed that packaging materials and storage period interacted significantly ($P < 0.05$) influencing all parameters studied except root length and seedling dry weight. Increased moisture content (11-16%) caused an increased thousand seed weight which reduced germination speed and standard germination, shoot length, root length, seedling dry weight, vigor index-I, and vigor index-II. In all packing materials under consideration, the highest quality seed was often obtained from shelled groundnut seeds stored for three months and from seeds stored in PICS bags for more than three months. So, the study concluded that a PICS bag was the best treatment recommended for keeping shelled groundnuts for more than three months. The maximum storage time for shelled groundnuts in all packing materials for premium seeds or standard germination is 90 days.

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Keywords

Shelled, Quality, seed, Storage period, Packaging materials, bag.

Introduction

Groundnut, a member of the family *Fabaceae* is an annual legume crop originating from South America. Groundnut *(Arachis hypogaea* L.) is an important crop grown in warm temperate and tropical regions of the world. The seeds are a rich source of edible oil and protein. In Ethiopia, the area coverage of groundnut is about 77283.21ha, and total production is up to 139278.43 tons (CSA2021/2022). Groundnuts are usually harvested from late November until the end of December in *the Benishangul Gumuz region*. Groundnut seed production needs to be stored for a long period before they are sown under high-temperature conditions where daytime temperatures often approach 35˚C which easily deteriorates the seeds (Nigam *et al.,* 2018).

Groundnuts are harvested with shells that protect the seed against physical damage, and storage insect attacks. Storage of the seeds with shells requires a larger store size than shelled seeds. Although unshelled groundnuts are bulky, keeping them in the shell as long as possible is an effective approach to reduce insect infestation during storage (Ranga *et al.,* 2010).

Groundnut is a seed that deteriorates quickly. As an oil seed crop, the seed has a limited shelf life and loses viability quickly. The ability to maintain seeds after harvest without degrading their quality is crucial for efficient seed production.

Aging in groundnut seed leads to increased lipid peroxidation, and decreased activities of several free radical and peroxide scavenging enzymes (Rao *et al.,* 2006). Seeds that are supposed to be planted in the subsequent season need to be dried and stored in moisture barrier materials to control loss of viability and vigor (Justice and Bass, 1979).

The rate of aging is determined mostly by genetics, moisture, and temperature. Thus, the material used to store seed plays an essential role in ensuring that the quality of the seed is preserved during storage. Furthermore, because the influence of these storage materials on the quality of seeds across different crops may vary, it is critical to investigate and identify the most appropriate packing material for the long-term conservation of shelled groundnut seeds.

This would give seed producers information on how to preserve the seed's quality throughout storage. So far, there is limited information on which packaging materials are best for shelled groundnut preservation. Realizing the importance of the crop and the existing information gap, this study was carried out to investigate the efficiency of different packing materials for shelled groundnut seed quality across various storage durations and to find the maximum storage time of shelled groundnut seed.

Materials and Methods

Sample Collection

The trial was conducted in Benishangul Gumuze Regional State, at Asossa Agricultural Research Centre, in the 2020 cropping season. The groundnut seed harvested during the 2019 main cropping season was obtained from EGS multiplication plots. A portion of the pods was shelled by hand. The groundnut variety, Dirib, which was recently released for the area was used for the trails.

Description of experimental treatments

The treatments of the laboratory experiment consisted of seven packaging materials and nine storage periods. The experiment was laid out as a randomized complete block design in replicated four times. Treatments were assigned to each plot randomly.

Polypropylene (PP) is a thermoplastic "addition polymer" made from a combination of propylene monomers.

Purdue Improved Crop Storage PICS bag is a three-layer storage technology that keeps grain free from insect infestation for more than two years.

The super grain pro bags are produced of a mix of polymers that retain the quality with a light green color and are airtight and penetration-resistant.

The jute bag material is a natural vegetable fiber that is made from the outer stem and skin of a jute plant.

Metal silo is a cylinder shape and is manufactured with galvanized sheets. The upper part and bottom part of the silo have an opening with a lid that serves to add and take the grain out respectively.

The polypropylene bag lined with polyethylene is mainly characterized by its water proofness ensured by the polyethylene lining as well as its resistance provided by the woven polypropylene.

ZeroFly® Storage Bag is a storage bag with insecticide incorporated in it to prevent damage from pest infestations.

Sampling Methods

20 kg homogenized pre-basic seed shelled before storage the seeds were shelled and tested in the laboratory. After every month representative samples from each packing material were drawn and tested in the laboratory for nine consecutive months and the data were analyzed.

Data Collection

Moisture content

The working sample was drawn and reduced to the submitted sample which was thoroughly mixed. The moisture of the shelled seed was measured by using an electronic moisture tester immediately after the representative samples drowned in the laboratory, moisture meter technology for in-shell peanuts licensed (2014).

Physical quality

Thousand Seed weight

Thousand seed weight was determined by counting from pure seed fraction and 1000 seeds were counted by seed counter and weighing on a two-digit sensitive balance (ISTA, 2023).

Determination of physiological quality

Germination index (GI)

Germination index of the seed was estimated from the seed set in the germination test by calculating the germination index following the formula below given by the Association of Official Seed Analysts (AOSA, 1983).

The number of seedlings was counted each day at the same time from the day after the seed set until the last count was made. The seedling that emerged each day having a plumule length of 2 cm or more was considered as germinated.

$$\text{Germination index} = \frac{\text{No. of seedling at } 1^{st} \text{ count} + \dots + \text{No. of seedling at final count}}{\text{Days to } 1^{st} \text{ count} + \dots + \text{Days to final count Seedling}} \quad \dots(1)$$

Standard Germination

The standard germination test was conducted by random counting four hundred seeds from the well-mixed pure seed. Then, 100 seeds were planted for each replication in a sterilized sand media. The planted seeds were germinated at room temperature of 25^0C for Ten days as specified by ISTA rules (2014).

After Ten days the seedlings were evaluated following the principles of ISTA. Germinated seedlings were divided into normal and abnormal seedlings whereas un-germinated seeds in into dead and fresh un-germinated seeds. Their Percentage mean values are calculated using the following formula.

$$\text{Standard Germination} = \left(\frac{\text{Number of normal seedling}}{Total\ number\ of\ seed\ sawn}\right) \text{x}100 \dots (2)$$

Vigor test

The following treats were measured as bases of vigor. Ten normal seedlings were randomly selected from each replication to determine the vigor index after the final count.

Shoot and root length of seedlings

The shoot length was measured from the point of attachment to the cotyledon to the tip of the seedling. Similarly, the root length was measured from the point of attachment to the cotyledon to the tip of the root.

Dry weight of seedlings

Ten seedlings randomly selected from each replication were placed in enclosed paper bags and dried in an oven at 80^0C for 24 hours and the dried seedlings were weighed.

Vigor index I and vigor index II

Seedling vigor index I was calculated by multiplying the standard germination with the average sum of shoot length and root length and vigor index II was again calculated by multiplying the standard germination with the mean seedling dry weight.

Experimental Design

20kg homogenized pre-basic seed shelled Dirib variety of groundnut, 7 packaging materials: Polypropylene bags, Polypropylene bags with polyethylene sheet lining (Fertilizer bags), PICS bags, metal silo, Grain pro bag, Zerofly, and Jut bags) and 10 periods of storage times (0-9 months) were used as treatment combinations for laboratory analysis. The treatments were stored at a seed store using a completely randomized design (CRD) in factorial combination.

Data Analysis

All data were subjected to analysis of variance (ANOVA) using the Generalized Linear Model (GLM) method of SAS (SAS, 2002). Differences between treatment means were separated using Turkey's Student Zed Range (HSD) test at 5% level of significance.

Results and Discussion

Moisture content and thousand seed weight

The interaction effect of storage duration and packing material on seed moisture content and thousand seed weight was strongly (P<0.05) significant (Table 1 and Table 2). Significant differences in moisture level and seed weights were noticed in various months in comparable packing materials. At the end of eight months of storage, the seed stored initially with a moisture level of 11.2% had the highest mean moisture content (16.5%) in zero fly bags, followed by (16%) moisture content in jute bags (Table 1). Elevated RH raises the equilibrium moisture contents of seed (Balesevic-Tubic *et al.,* 2005; Shelar *et al.,* 2008; Bradford *et al.,* 2018) and generates metabolic heat and ROS (Kibinza *et al.,* 2006; Shelar, 2008), which result in quality deterioration. Under harsh conditions when seeds are aged, seed moisture increases under high temperatures and relative humidity which promotes protein degradation, sugar hydrolysis, rise in metabolic and oxidation reactions (Tandoh *et al.,* 2017).

After three months of storage in the PICS, the seeds showed the lowest moisture content (7%) (Table 1). The variation in moisture content in zero fly bags, jute bags, and polypropylene bags was ascertained by an ambient temperature during the seed storage period, as the materials used for packing are not sealed airtight bags. The results confirm the assumption that seed storage in conventional bags cannot maintain lower moisture levels during storage due to direct contact with ambient RH (Walters *et al.,* 2010; Afzal *et al.,* 2017). The moisture contents of seeds stored after six months increased in ZeroFly, jute, and Polypropylene whereas storage bags of super grain pro, PICS metal silo, and Polypropylene bags with Polyethylene sheet liningtrend showed stability and decreased moisture percentage as compared with the moisture content before stored. Seed is highly hygroscopic living material therefore it absorbs moisture from air as stored in an environment where relative humidity is higher or lower than seed moisture content.

Since seeds are highly hygroscopic living materials gunny bags absorb more moisture from the surrounding atmosphere. In jute bags, the moisture content was increased from 8.7% to 16.70% and the increase of moisture content was lower in tin and poly bags as compared to jute bags as they were more or less moisture-proof (Nahar *et al.,* 2009).

At the end of eight months of seed storage, the highest mean values of (64.7g) thousand seed weight were recorded for seed samples from zero fly bags. Whereas the lowest (50.88g) thousand seed weight was reported after storage of one month in PICS bags (Table 2). The experimental analysis showed that at each storage period, the higher thousand seed weight was recorded by the seed stored in the zero fly bags except for the first, fourth, seventh, and eighth periods. Whereas the lower thousand seed weight was observed when the seed was stored in PICS bags at all storage times except 8th and 9th months. PICS bags retain the moisture content of the seeds, increasing thousand seed weight, and protecting storage pests, which cause seed deterioration, resulting in a decrease in thousand seed weight.

The moisture content of the shelled seeds ranges from 7.4 to 16.2 for jute, Polypropylene, and ZeroFly while 7 to 8.8% for Super grain pro, Metal silo, PICS, and Polypropylene bags with Polyethylene sheet lining bags. An increment of thousand seed weight was related to the moisture contents of the seed observed at all storage periods for non-airtight bags such as jute, Polypropylene, and zero fly bags. According to Nahar *et al.,* (2009), the moisture content of jute bags grew from 8.7% to 16.70%, whereas tin and poly bags saw a lesser rise in moisture content than jute bags because they were more or less moisture resistant.

Germination Speed

The interaction effect of packaging materials and storage duration had a highly significant (P<0.05) impact on the speed of germination (Table 3). The higher mean value of the speed of germination was recorded after storage of 3 months for all packing materials except Jute bags over the other storage months. The highest germination speed (7.8275) was observed for seeds stored for 3 months in Polypropylene followed by Super grain pro (7.77).The lowest germination speed (1.4) was recorded from the seeds which were stored for nine months in the Jute bags. This was due to the behavior of the jute bags, which are moisture-impermeable and have the lowest seed degeneration, seeds packed in airtight packing emerged uniformly early and created a high germination speed.

Analysis of variance revealed that the highest germination index ranges from 6-7.8 was observed at a storage period of three months and the lower was at storage periods of nine months for all packaging bags. The germination index of airtight bags (super grain pro, Meta silo, PICS bag, and Polypropylene bags with Polyethylene sheet lining) and non-airtight (Jute, ZeroFly, and Polypropylene) showed statistical Parity.

The results were comparable with findings of the percentage of germination, the speed of germination, length, dry weight, and vigor index of seedlings all showed a declining tendency as storage times rose. The seeds that showed the least amount of seed degeneration were those packaged in vacuum-packed bags because they are impermeable to moisture. The seeds stored in aluminum foil pouches scored in second (M.J., 2018).

Standard germination

According to the analysis of variance, the interaction effects of packing materials and storage duration affected standard germination significantly ($P<0.05$) (Table 4).

The highest (92%) of standard germination was recorded for seed sampled from polypropylene bags lined with polyethylene after storage periods of three months. The lowest standard germination (22.5%) was recorded as the seed stored in Jut bags for nine months followed by eight and seven months of seed storage period. The standard germination of shelled seeds of groundnut stored for three months ranged from 87.7 to 92% which is greater than the standard germination of Ethiopian seed standard (75%) for breeder and pre-basic seeds for all packaging materials. Furthermore, the investigation revealed that storing shelled seeds of groundnuts for three months and seeds stored in a PICS bag after storage of three months produced higher quality seeds than the other storage duration in all packing materials under investigation. It suggests that the maximum storage period for shelled groundnuts in all air-tight bags for high-quality seeds or standard germination is three months and the PICS bag preferred to store shelled seed for more than three months.

Lastly, research has shown that storage bags made of PICS, Metal Silo, Super Gain Pro, and PE are safer than Jute, Polypropylene, and Zero Fly bags for storing seeds for up to nine months. This is because the former bags are made of airtight packaging materials that are resistant to moisture, which exacerbates seed degeneration.

The percentage of seeds that germinated decreased as storage durations were extended in non-airtight packing materials. These findings corresponded well with those reported that unfavorable storage conditions (high air temperature and high humidity of air) accelerate seed deterioration, causing seed quality losses and therein lower germinability percentage of stored seed (Burris, 1980; Tewari and Gupta, 1981; Al-Yahya, 1995; Depaula *et al.,* 1996; Beratlief and Iliescu, 1997).

Seedling dry weight

Analysis of variance showed that the main factors of seed storage period, packaging materials, and their interaction significantly ($P<0.05$) influenced seedling dry weight (Table 5). The highest mean values of seedling dry weight were recorded after storage of seeds for a month in a PICS bag and followed by Polypropylene bags with Polyethylene sheet lining bags. The lowest seedling dry weight was recorded as the seeds were stored for nine months in the Jute and Polypropylene. The outcome of the seed sample collected for PICS bags recorded superior seedling dry weight over the other bags except for a storage period of five months.

Shoot length and Root length

Ten normal seedlings were randomly selected and measured for shoot and root length. Analysis of variance showed that the main factors of storage time, packaging materials, and their interaction significantly (<0.05) affected the shoot length while seedling root length influenced significantly ($P<0.05$) with the main factors of packaging material and duration of seed storage (Table 5 and Table 6). The highest mean value of the shoot length was recorded as the seed was stored for two months of storage in Polypropylene bags with Polyethylene sheet lining bags. The lowest shoot length was observed after storage of nine months in Jute bags.

The longest (18.65 cm) root was recorded at the end of four months of storage followed by five months in packaging bags of PICS and Super Grain Pro. The shortest (9.55cm) root length was observed before the seed was stored and followed by after storage of one month in Jute bag.

The higher shoot and root length were recorded after storage of three months and immediately dropped up to nine months of storage. Nahida *et al.,* (2017) also reported that both the shoot and root length of the rice variety decreased as the storage period progressed. The reduction in the rate of seedling development after a prolonged period of storage could be attributed to the depletion of seed food reserves due to seed deterioration.

Table.1 The influence of packing materials and seed storage durations on the moisture content of shelled groundnuts

	Percentage mean values of MC %									
	Storage month									
PM	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
G	11.2g	8.0^{u-w}	8.5^{p-r}	7.7^{xy}	8.4^{q-s}	8.4^{q-s}	8.4^{q-s}	8.4^{q-s}	8.5^{p-r}	7.3^{zab}
Ju	11.2g	8.0^{u-w}	7.4^{za}	7.8^{w-y}	9.6^{l}	9.3^{m}	10.3^{j}	10.3^{j}	16.2^{b}	10.8^{ih}
MS	11.2g	8.8^{on}	8.4^{q-s}	7.6^{zy}	8.4^{q-s}	8.2^{s-u}	8.3^{r-t}	8.3^{r-t}	8.4^{q-s}	7^{zc}
PC	11.2g	8.4^{q-s}	8.6^{o-q}	7^{zc}	8.9^{n}	8.3^{r-t}	8.5^{p-r}	8.5^{p-r}	8.8^{on}	7.2^{za-c}
PE	11.2g	7.1^{zbc}	8.7^{n-p}	7.9^{v-x}	8.4^{q-s}	10^{k}	8.6^{o-q}	8.6^{o-q}	8.1^{t-v}	7.3^{zab}
PP	11.2g	8.8^{on}	8.1^{t-v}	7.6^{yz}	9.7^{l}	10^{k}	10.6^{i}	10.6^{i}	14.8^{c}	11.7^{e}
ZF	11.2g	8.4^{q-s}	8.5^{p-r}	7.1^{zbc}	9.3^{m}	7.3^{zab}	11.2^{g}	11.2^{g}	16.5^{a}	$11.^{4fg}$
CV	0.87									
HSD(0.05)	0.2									
P.Value	***									

Means followed by the same letter within a column are not significantly different at 5% significance level. HSD = Tukey's studentized range test; CV = Coefficient of variation; G = Super grain pro; Jute= Jute; MS = Metal silo; PP =Polypropylene; PE = Polypropylene bags with Polyethylene sheet lining; ZF = Zero fly; PC=PICS bag

Table.2 Interaction effects of packaging materials and seed storage times on the thousand seed weight, of shelled groundnut

	Mean values of TSW(gm)									
	Storage month									
PM	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
G	53.08^{x-z}	54.83^{n-p}	53.63^{t-v}	52.43^{cd}	52.63^{bc}	53.23^{x-w}	53.83^{r-t}	53.93^{q-s}	64^{b}	54^{rq}
Ju	53.08^{x-z}	53.23^{w-y}	53.08^{x-z}	52.93^{az}	52.93^{az}	53.83^{r-t}	54.73^{op}	54.73^{op}	64.7^{a}	56.9^{h}
MS	53.08^{x-z}	50.53^{h}	52.08^{e}	53.63^{t-v}	56.63^{ij}	53.93^{q-s}	51.23^{g}	52.73^{ab}	53.6^{t-v}	56.4^{j}
PC	53.08^{x-z}	48.73^{l}	49.93^{i}	51.13^{g}	51.23^{g}	49.28^{k}	47.33^{m}	47.38^{m}	59.2^{e}	55^{n}
PE	53.08^{x-z}	51.73^{f}	51.18^{g}	50.63^{h}	53.43^{vw}	54.78^{n-p}	56.13^{k}	57.53^{g}	53.7^{ust}	51.5^{f}
PP	53.08^{x-z}	52.13^{e}	53.73^{st}	55.33^{m}	54.93^{no}	54.13^{q}	53.33^{wx}	53.13^{x-z}	62.9^{c}	53^{yz}
ZF	53.08^{x-z}	52.33^{ed}	54.58^{p}	56.83^{hi}	53.43^{vw}	55.48^{m}	57.53^{g}	55.83^{l}	60.3^{d}	57.9^{f}
CV	**0.16**									
HSD (0.05)	0.26									
P.value	***									

Means followed by the same letter within a column are not significantly different at 5% significance level. HSD = Tukey's studentized range test; CV = Coefficient of variation; G = Super grain pro; Jute= Jute; MS = Metal silo; PP =Polypropylene; PE = Polypropylene bags with Polyethylene sheet lining; ZF = Zero fly; PICS bag

Table.3 Interaction effects of packaging materials and seed storage times on the speed of germination of shelled groundnut

	Percentage mean values of Speed of germination									
	Storage month									
PM	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
G	4.42^{h-o}	7.718^{ab}	6.4^{a-h}	7.02^{a-e}	5.59^{c-m}	5.52^{c-m}	5.19^{e-n}	5.63^{c-l}	5.37^{c-m}	5.46^{c-m}
Ju	4.42^{h-o}	6.91^{a-f}	$5.96^{a-}1$	6.35^{a-i}	4.34^{i-o}	4.63^{h-o}	3.951^{-p}	5.15^{e-n}	3.06^{o-r}	1.42^{r}
MS	4.42^{h-o}	7.31^{a-d}	5.87^{a-l}	7.38^{a-c}	5.72^{b-l}	6.13^{a-k}	5.39^{c-m}	5.30^{d-n}	5.59^{c-m}	5.48^{c-m}
PC	4.42^{h-o}	7.10^{a-e}	6.36^{a-i}	7.02^{a-e}	5.82^{a-l}	5.41^{c-m}	5.22^{e-n}	5.50^{c-m}	$5.26^{e-}n$	5.48^{c-m}
PE	4.42^{h-o}	7.33^{a-c}	5.6^{c-m}	6.75^{a-g}	5.94^{a-l}	5.12^{e-n}	4.96^{f-o}	5.62^{c-l}	4.42^{h-o}	4.42^{h-o}
PP	4.42^{h-o}	6.21^{a-j}	6.33^{a-i}	7.83^{a}	6.12^{a-k}	5.72^{b-l}	5.12^{e-n}	5.17^{e-n}	$3.33r^{n-q}$	1.65^{rq}
ZF	4.42^{h-o}	5.78^{b-l}	4.84^{g-o}	7.14^{a-e}	5.60^{c-m}	5.41^{c-m}	4.99^{f-o}	5.62^{c-l}	3.59^{m-q}	2.13^{p-r}
CV	12.45									
HSD(0.05)	2.0218									
P.value	***									

Means followed by the same letter within a column are not significantly different at 5% level of significance. HSD = Tukey's studentized range test; CV = Coefficient of variation; G = Super grain pro; Jute= Jute; MS = Metal silo; PP =Polypropylene; PE = Polypropylene bags with Polyethylene sheet lining; ZF = Zero fly; PICS bag

Table.4 Interaction effects of packaging materials and seed storage times on the standard germination of shelled groundnut

	Percentage mean values of standard germination (%)									
	Storage month									
PM	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
G	75^{a-e}	75.5^{a-e}	87.5a-c	89.5^{ab}	87.5^{a-c}	85.5^{a-c}	71.5^{a-g}	71^{a-g}	71.5^{a-g}	75.5^{a-g}
Ju	75^{a-e}	74^{a-e}	77.5^{a-e}	85.5^{a-c}	82.5^{a-d}	63.5^{c-h}	71^{a-g}	47.5^{g-k}	41^{h-k}	22.5^{k}
MS	75^{a-e}	84^{a-d}	86.5^{a-c}	91^{a}	88^{a-c}	85^{a-c}	76.5^{a-e}	78^{a-e}	78^{a-e}	75^{a-e}
PC	75^{a-e}	79.5^{a-e}	83^{a-d}	90^{ab}	89.5^{ab}	85.5^{a-c}	84^{a-d}	84^{a-d}	84^{a-d}	84^{a-d}
PE	75^{a-e}	80.5^{a-e}	88^{a-c}	92^{a}	80^{a-e}	80^{a-e}	80^{a-e}	82^{a-d}	82.5^{a-d}	83^{a-d}
PP	75^{a-e}	77.5^{a-e}	80^{a-e}	91.5^{a}	87^{a-c}	77^{a-e}	56^{e-i}	70^{a-g}	46.5^{h-k}	25^{jk}
ZF	75^{a-e}	59.5^{d-g}	65^{b-h}	87.5^{a-c}	77^{a-e}	77.5^{a-e}	76.5^{a-e}	65^{b-h}	48^{f-j}	31.5^{i-k}
CV	11.25									
HSD(0.05)	25.31									
P.value	***									

Means followed by the same letter within a column are not significantly different at 5% level of significance. HSD = Tukey's studentized range test; CV = Coefficient of variation; G = Super grain pro; Jute= Jute; MS = Metal silo; PP =Polypropylene; PE = Polypropylene bags with Polyethylene sheet lining; ZF = Zero fly; PICS bag

Table.5 Effects of Packaging material and duration of storage times after shelling on root length and seedling dry weight of groundnut

Treatments	Parameters	
Duration of storage (month)	**Root length**	**Seedling dry weight**
0	9.55^{f}	4.018^{cb}
1	10.22^{f}	4.71^{a}
2	16.83^{cb}	4.41^{ab}
3	14.26^{ed}	4.22^{ab}
4	18.65^{a}	3.88^{cb}
5	18.3^{a}	3.58^{cd}
6	15.56^{cd}	4.06^{cb}
7	16.25^{cb}	3.35^{ed}
8	17.56^{ab}	3.14^{ed}
9	12.93^{e}	2.93^{e}
HSD (0.05)	**1.33**	**0.53**
PM (Packaging Materials)		
G	15.53^{a}	3.97
Ju	13.84^{c}	3.81
MS	15.06^{ab}	3.72
PC	15.57^{a}	4.1
PE	15.48^{ab}	3.75
PP	14.46^{cb}	3.72
ZF	15.13^{ab}	3.74
HSD (0.05)	**1.04**	**0.41**
CV (%)	**10.39**	**16.09**

Means followed by the same letter within a column are not significantly different at 5% level of significance. HSD = Tukey's studentized range test; CV = Coefficient of variation; G = Super grain pro; Jute= Jute; MS = Metal silo; PP =Polypropylene; PE = Polypropylene bags with Polyethylene sheet lining; ZF = Zero fly; PICS bag

Table.6 Interaction effects of packaging materials and seed storage times on shoot length of shelled groundnut

	Percentage mean values of shoot length(cm)									
	Storage month									
PM	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
G	11.19^{i-n}	11.21^{i-n}	18.2^{a-c}	15.49^{d-e}	12.4^{i-m}	11.68^{i-n}	9.23^{t-w}	8.08^{t-x}	11.68^{i-n}	9.48^{t-vn}
Ju	11.28^{i-n}	11.16^{i-n}	17.58^{a-e}	15.99^{c-e}	12.75^{h-k}	11.38^{i-n}	8.6^{t-x}	6.85^{wx}	10.18^{k-t}	6.25^{x}
MS	11.23^{i-n}	11.44^{i-n}	17.95^{a-d}	16.15^{b-e}	12.8^{g-j}	11.85^{i-n}	10.13^{l-t}	8.53^{t-x}	11.83^{i-n}	9.03^{t-w}
PC	11.11^{in}	11.38^{i-n}	18.23^{a-c}	16.69^{a-e}	13.28^{f-i}	11.2^{i-n}	10.05^{l-t}	8.05^{t-x}	12.03^{i-n}	8.95^{t-w}
PE	10.59^{j-nt}	10.87^{i-n}	18.84^{a}	15.25^{e-h}	12.5^{i-m}	11.78^{i-n}	10.45^{j-n}	8.38^{t-x}	12.25^{i-m}	8.9^{t-w}
PP	11.36^{i-n}	11.7^{i-n}	18.36^{a-c}	16.34^{a-e}	12.58^{i-m}	12.6^{i-l}	10.13^{l-t}	7.43^{u-x}	9.98^{um-tn}	6.68^{wx}
ZF	11.76^{i-n}	10.9^{i-n}	18.6^{ab}	15.38^{d-g}	13.05^{f-j}	12.93^{f-j}	9.55^{n-v}	8.53^{t-x}	11.08^{i-n}	7.33^{v-x}
CV	**7.34**									
HSD (0.05)	**2.6**									
P.value	***									

Means followed by the same letter within a column are not significantly different at 5% level of significance. HSD = Tukey's studentized range test; CV = Coefficient of variation; G = Super grain pro; Jute= Jute; MS = Metal silo; PP =Polypropylene; PE = Polypropylene bags with Polyethylene sheet lining; ZF = ZeroFly; PICS bag

Table.7 Interaction effects of packaging materials and seed storage times on vigor index-I of shelled groundnut

	Percentage mean values of vigor index-I									
	Storage month									
PM	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
G	781.9^{p-y}	798.6^{p-y}	1557.7^{e-g}	1343.8^{f-m}	1340.3^{f-m}	1323.3^{f-n}	813.9^{o-x}	1036.8^{h-v}	282.48^{a-h}	2162.2^{cb}
Ju	754.8^{q-y}	780.4^{p-y}	1301.1^{f-o}	1242.8^{f-q}	969.3^{j-w}	917.8^{j-x}	795.6^{p-y}	506^{w-y}	120.4^{h-k}	368.9^{y}
MS	678.5^{t-y}	898.7^{l-x}	1507.2^{e-h}	1371.3^{f-l}	1402.5^{f-k}	1328.8^{f-n}	1016.7^{h-v}	958.1^{j-v}	279.03^{a-h}	2020.6^{cd}
PC	733.3^{r-y}	908.4^{k-x}	1470.4^{f-i}	1408.1^{f-j}	1199.5^{f-s}	1105.3^{f-v}	1122.6^{f-u}	1002^{i-v}	313.13^{a-g}	1983^{c-e}
PE	733.8^{r-y}	847.8^{m-y}	1583.3^{d-f}	1375.9^{f-l}	1360.1^{f-l}	1321.6^{f-n}	1075.7^{g-v}	1078.2^{g-v}	249.2^{a-i}	2042.6^{cd}
PP	774.1^{p-y}	841.5^{o-y}	1401^{f-k}	1402.4^{f-k}	1219.7^{f-s}	1177.1^{f-s}	725.3^{s-y}	793.5^{p-y}	138.65^{g--k}	440.9^{xy}
ZF	831.6^{o-y}	630.1^{uv-y}	1143^{f-t}	1270.3^{f--p}	1238.3^{f-q}	1238.4^{f-q}	1063.5^{g-v}	854.4^{m-y}	148.03^{f-k}	621.4^{v-y}
CV	**13.9**									
HSD (0.05)	498.58									
P.value	***									

Means followed by the same letter within a column are not significantly different at 5% level of significance. HSD = Tukey's studentized range test; CV = Coefficient of variation; G = Super grain pro; Jute= Jute; MS = Metal silo; PP =Polypropylene; PE = Polypropylene bags with Polyethylene sheet lining; ZF = Zero fly; PICS bag

Table.8 Interaction effects of packaging materials and seed storage times on vigor index-II of shelled groundnut

	Percentage mean values of vigor index-II									
	Storage month									
PM	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
G	340.85^{a-d}	348.15^{a-d}	403^{ab}	419.6^{a}	311.8^{a-g}	320.28^{a-f}	290.48^{a-h}	271.5^{a-i}	282.48^{a-h}	269.1^{a-i}
Ju	294.6^{a-h}	326.25^{a-e}	339.25^{a-d}	357.55^{a-d}	260.05^{a-i}	242.73^{a-j}	308.2^{a-g}	151.75^{e-k}	120.4^{h-k}	61.35^{k}
MS	222.45^{c-j}	385.35^{a-d}	373.5^{a-d}	391.6^{a-c}	332.8^{a-d}	297.9^{a-h}	306.38^{a-g}	266.05^{a-i}	279.03^{a-h}	252.1^{a-i}
PC	308.65^{a-g}	413.2^{a}	385.05^{a-d}	377.65^{a-d}	299.1^{a-g}	281.58^{a-h}	331.75^{a-d}	344.15^{a-d}	313.13^{a-g}	262.15^{a-i}
PE	302.1^{a-g}	396.35^{a-c}	371.35^{a-d}	359.75^{a-d}	362^{a-d}	321.4^{a-f}	316.4^{a-f}	233.55^{b-k}	249.2^{a-i}	260.9^{5a-i}
PP	264.4^{a-i}	359.9^{a-d}	359.55^{a-d}	370.75^{a-d}	322.25^{a-f}	254.7^{a-i}	232.8^{b-k}	229^{b-k}	138.65^{g--k}	69.85^{jk}
ZF	317.75^{a-f}	281.85^{a-h}	273.3^{a-i}	355.25^{a-d}	279^{a-h}	267.88^{a-i}	314.68^{a-g}	212.7^{d-k}	148.03^{f-k}	97.05^{i-k}
CV	**20.38**									
HSD (0.05)	**177.57**									
P.value	***									

Means followed by the same letter within a column are not significantly different at 5% level of significance. HSD = Tukey's studentized range test; CV = Coefficient of variation; G = Super grain pro; Jute= Jute; MS = Metal silo; PP =Polypropylene; PE = Polypropylene bags with Polyethylene sheet lining; ZF = Zero fly; PICS bag

Vigor index

As observed from the analysis of variance packing material and storage period interacted to affect the vigor index-I and vigor-II significantly ($P<0.05$) (Table 7 and Table 8). Shelled groundnut seed stored for six and eight months in Super Grain Pro and Polypropylene bags with Polyethylene sheet lining recorded the highest vigor index-I followed by seed stored in packaging materials of Metal silo and PICS bags for 8 months. Thus, the highest mean value of vigor index-II was observed for seed tested after storage of one and two months in PICS and Super Grain Pro bags respectively. However, the seeds stored for nine months in the Jute bag recorded the lowest mean values of vigor index-I and vigor index-II of the seed stored (Table 4). The result agrees with airtight bottles and ziplock bags which are non-porous materials that maintain seed moisture, vigour, vigour index, protein, carbohydrate, and oil contents (Tandoh *et al.,* 2017). Noviana *et al.,* (2007); Beedi *et al.*, (2018); Grisi and Santos (2007) observed sunflower seed quality deterioration with an increase in the length of the storage period. The decline in the vigour index of sunflower seedlings with an increase in storage duration was also reported by Sajjan *et al.,* (2013). The Author also reported that a gradual decrease in the seed quality parameters was observed, germination percentage, speed of germination, seedling length, seedling dry weight, and seedling vigor index decreased with the increase in the Storage period.

Conclusion

An experiment was conducted on shelled groundnut seeds to identify proper storage materials concerning their maximum storage periods to minimize test a damage which resulted in a reduction of the seed quality. The investigation revealed that storing shelled seeds of groundnuts for three months and seeds stored in a PICS bag after storage of three months produced higher quality seeds than the other storage duration in all packing materials under investigation. It suggests that the maximum storage period for shelled groundnuts in all air-tight bags for high-quality seeds or standard germination is three months and the PICS bag preferred to store shelled seed for more than three months.

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