PEANUT SCIENCE

The Journal of the American Peanut Research and Education Society

ARTICLE

Evaluation of Quality of Peanut (*Arachis hypogaea* L.) Seed in Ghana from Three Seed Sources

Jennifer Abogoom[1]; Richard Akromah[2]; Robert Aidoo[3]; Emil Awuah[4]; David Jordan[5*]

[1]Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana;

[2]Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana;

[3]Department of Agricultural Economics, Agribusiness and Extension, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana;

[4]Department of Biochemistry and Biotechnology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana;

[5]Department of Crop and Soil Sciences, North Carolina State University, Raleigh, NC 27695.

ARTICLE INFORMATION

Keywords:
Groundnut, pathogens, seed quality, seed systems

Corresponding Author:
David Jordan
david_jordan@ncsu.edu

DOI: 10.3146/0095-3679-492-PS22-11

ABSTRACT

Peanut (*Arachis hypogaea* L.) contributes to food security and reduction of poverty in Ghana. However, low yields minimize the potential financial return of peanut in part because of limited access by farmers to high quality seed. The objective of this study was to assess the quality of peanut seed saved by farmers, seed purchased from local markets, and seed received from public research institutions. Forty-six, forty-five, and nine seed samples were collected from these respective sources in 2019 during the planting season across five regions in Ghana. Uniformity of phenotypes from seed samples was at least 96% for all sources with the greatest uniformity observed for plants derived from seed collected from research institutions. Field emergence was greatest for seed collected from research institutions followed by farmer-saved seed and then seed collected from local markets. However, field emergence did not exceed 53% of seed planted regardless of seed source. Nine fungal species were identified on peanut seeds, with *Aspergillus niger, A. flavus,* and *Curvularia lunata* being the most prevalent. However, differences among seed sources were noted only for *A. niger* and *A. tamarii*.

INTRODUCTION

Peanut *(Arachis hypogaea* L.) contributes to food security and serves as a cash crop in Ghana (Angelucci and Bazzucchi, 2013; Quiñones and Diao, 2011). Peanut is cultivated by approximately 74% of households in the Northern Savannah of Ghana and is an important source of protein in human diets (Quiñones and Diao, 2011). It is the most popular legume crop cultivated in Ghana. In 2016, farmers in Ghana produced approximately 425,825 MT of peanut on 336,450 ha of land. In 2017 and 2018, 433,772 MT and 521,032 MT were produced on about 338,000 ha and 394,231 ha, respectively (FAOSTAT, 2020). However, the current production of peanut has not been able to supply the increasing demand by consumers. Historically, peanut yield in Ghana was lower than the estimated attainable yield of 2.50 to 3.50 MT/ha (MOFA, 2021). For example, average yield in 2016 and 2020 was 1.3 Mt/ha and 1.67 Mt/ha in the country, respectively (MOFA, 2016, 2017, 2021).

Numerous factors can affect yield, quality, and contamination by aflatoxin for peanut (caused by *A. flavus* and *A. parasiticus*) (Jordan *et* al., 2018; Nigam *et* al., 2018). Limited access to improved cultivars and quality seed are major contributors to low yields and quality (Akpo *et* al., 2021; DFID, 2014). The seed sector in Ghana is characterized by two sources that include informal and formal seed systems. The informal seed system is the primary source of seed for planting

and consists of seed saved by farmers (Anonymous, 2016; Puozaa *et* al., 2021). The formal seed system includes certified seed. Certified peanut seed accounts for only 1% of plantings by farmers in Ghana (Anonymous, 2016). Farmers also rely on seed purchased in local markets as well as exchanges with other farmers. Owusu-Adjei *et* al. (2017) reported that 59% of peanut producers source seeds from their previous harvest, 28% purchase seeds from local markets, and 13% obtain seeds as gifts from non-governmental organizations, friends, and relatives. However, the quality of seeds obtained from these sources is a concern and documentation of quality is limited. According to FAO (2018), the level of seed quality can vary within the informal seed system depending on the source of seed. Less than ideal stand establishment is associated with seed quality (Matthews *et* al., 2012). Greater seed quality is associated with a 15-20% increase in yield (Abebe *et* al., 2017; Chauhan *et* al., 2015).

Information relative to quality across all sources of peanut seed in Ghana is limited. Therefore, the objective of this research was to compare seed quality attributes that exist in peanut seed obtained from farmers, local seed markets, and research institutions.

MATERIALS AND METHODS

Seeds were collected in Ghana from 46 farmers, 45 open markets, and 9 research institutes across the Northern, Upper West, Upper East, Ashanti, and Bono East Regions in November 2019. These regions constitute 98% of peanut production in Ghana (MOFA, 2017). The research institutes where samples were collected included the Council for Scientific and Industrial Research-Crops Research Institute (CSIR-CRI) and the Council for Scientific and Industrial Research-Savanna Agricultural Research Institute (CSIR-SARI). Seed was stored in poly sacks at ambient temperature for approximately three months prior to the seed quality evaluations. This approach to storage is similar to that of farmers in Ghana.

Seed moisture was determined using a portable seed moisture tester (Moisture Chek-Plus-SW08120, John Deere, AgraTronix, Streetsboro, OH) for each sample using three replicated seed lots. Physical purity of seed was determined using 400 g of seed removed from samples. Seed in each sample was separated into three components including 1) seed only, 2) other crop seed, and 3) foreign matter. Each component was weighed and percent of total sample calculated.

Germination was determined using the pure seed fraction collected from each sample. Two-hundred seeds were divided into four replicates of fifty seed and planted on sand substrate in 34 cm × 11.5 cm size plastic dishes. Two-thirds of the plastic dishes were filled with sterilized loamy-sand soil. Germination dishes were maintained in a greenhouse at 25 ± 2°C. The number of germinated seed was recorded 5 d after water imbibition daily through 10 d and calculated as a percentage of seed placed in each dish. At the end of day 10, normal seedlings were counted and expressed as percentage of total seed. Seed vigor was measured using Mean Germination Time (MGT) and Mean Germination Rate (MGR) procedure (Ranal *et* al., 2009).

A sub-set of collected samples was randomly selected to document the presence of pathogens associated with seed and included 11 samples from farmer-saved seed, 30 samples of seed from open markets, and 9 samples of seed from research institutions. Potato Dextrose Agar media (PDA) was prepared from a commercial product (Sigma-Aldrich, Steinhein, Germany). Samples were individually sterilized in 50 ml of a 10% sodium hypochlorite solution for 30 s followed by a rinse in 50 ml of distilled water. The sterilized seeds were then inoculated on 9.0 cm petri dishes containing PDA media. Five seed in ten replicates were arranged equidistantly on the media. Samples were incubated at 25 ± 2°C for 7 d under 12 h alternating light and dark conditions. On the eighth d, seed was examined for fungal infection. Fungal infection was examined through visual assessment of the fungal colonies. Fungi were identified based on morphological features of colonies including color and texture (Diba *et* al., 2007; Klich, 2002). The number of seeds with visible infection was determined and expressed as percentage of total number of seeds.

Phenotype uniformity of plants produced from seed from 95 samples was assessed after planting in the field. Fifty seed from each sample were planted in rows spaced 75-cm apart with seed spaced 30-cm apart with a plot length of 4 m. Seed samples were replicated three times. Individual plants were examined throughout the growing season to determine the number of plants with the same phenotype characteristics deviating from the majority of plants. The total number of plants and those deviating were recorded at maturity and expressed as percentage relative to the majority of morphological features of plants.

The experimental design in all experiments was a completely randomized design with three replications. Data for average moisture content, germination percentage, emergence percentage, germination time, germination rate, and plant phenotype uniformity for the 45 collections from farmers, 46 collections from open markets, 9 collections from research institutes were subjected to analysis of variance. Data for infection by pathogens for 11 collections from farmers, 30 collections from open markets, and 9 collections from research institutes were also subjected to analysis of variance. Means were separated using the Fisher's Protected LSD test at $p < 0.05$.

RESULTS AND DISCUSSION

Moisture content of seeds from the research institutes was lower than seed obtained from the market or saved by farmers (Table 1). Farmer-saved seed recorded the highest average moisture content (6.57%) while seed obtained from the research institutes recorded the lowest moisture content (5.42%). Dhedhi *et* al. (2017) reported mean moisture content of 5.07% for peanut in India. Moisture content of 7.5% is widely reported as the most appropriate storage for peanut (Beuchat and Koehler, 1979; McDonald and Copeland, 2012; Nautiyal, 2002; Smith *et* al., 1995). However, lower amounts of moisture content can be achieved with oil crops (Sastry *et* al., 2007). The low moisture content recorded in the present study may be attributed to the dry climatic conditions of seed collection, suggesting that seeds were dried adequately before storage. Gebeheyu *et* al. (2019) reported similar results in rice (*Oryza sativa* L.) seeds in Tanzania.

Table 1. Moisture content of seed and plant phenotype uniformity of plants from seed collected across informal and formal seed sectors in Ghana.[a]

Seed source	Moisture content of seed	Plant phenotype uniformity
	%	
Farmer	6.57 a	96.8c
Open market	6.09 b	98.4 b
Research institutes	5.43 c	100.0 a
P > F	<0.001	<0.001
Coefficient of variation (%)	0.7	0.3

[a]Means within a column followed by the same letter are not significantly different at p < 0.05 based on Fisher's Protected LSD test.

No difference in purity among seed sources was observed and exceeded 98% (data not shown). This is most likely because individuals in all three segments of the seed industry shell farmer stock by hand and separate fractions by hand for the market (e. g., splits, damaged kernels, and foreign material).

Germination in the greenhouse and emergence in the field evaluating phenotype uniformity were affected by source (Table 2). Germination in the greenhouse was 54.1%, 50.9%, and 66.5% when seed was collected from farmers, local markets, and research institutes, respectively. Emergence in the field from seed derived from these respective sources was 46.8%, 37.6%, and 53.1%. Germination was greater for seed collected at research institutes than seed from farmers and local markets: germination was similar for famer-saved and market-purchased seed. When comparing emergence in the field, a higher percentage was noted for seed from research institutes than local markets while emergence of famer-saved seed was intermediate. Although differences were noted in final germination and emergence, no difference in germination was observed with respect to MGT or MGR (Table 2).

Table 2. Germination and field emergence of peanut plants from seed collected from informal and formal sources across Ghana.

Seed Source	Greenhouse experiment			Emergence in field phenotype uniformity trial		
	Total germination	Time	Rate	Total emergence	Time	Rate
	%	d	d^{-1}	%	d	d^{-1}
Farmer	54.1 b	2.25 a	0.444 a	46.8 ab	9.98 a	0.100 a
Open market	50.9 b	2.23 a	0.450 a	37.6 b	10.15 a	0.099 a
Research institutes	66.5 a	2.06 a	0.485 a	53.1 a	9.84 a	0.102 a
P > F	<0.001	0.081	0.067	0.007	0.152	0.163
Coefficient of variation (%)	3.3	4.7	4.5	6.4	1.5	1.5

[a]Means within a column followed by the same letter are not significantly different at p < 0.05 based on Fisher's Protected LSD test.

Low germination and plant emergence in the field from three seed sources is likely an indication of environmental and edaphic conditions during the previous growing cycle, nutrition in seed, timing and handling of peanut pods at harvest, and storage conditions after harvest but before collection for these experiments. Germination of seed and peanut emergence from deteriorated seed can result in establishment of uneven populations and seedlings with low vigor (Biabani *et al.,* 2011; Cho and Scott, 2000; Hamman *et* al., 2002; Sharanappa *et* al., 2018).

Differences in plant phenotype uniformity were observed based on seed source (Table 1). Seeds from research institutes recorded the highest phenotypic uniformity levels (100%) while uniformity of plants derived from farmer-saved seeds was 97%. Uniformity of plants from local markets was 96%.

Nine fungal species were isolated from seed and included: *A. niger* Tiegh., *A. flavus* Link, *A. fumigatus* Fresenius, *A. ochraceus* Wilhelm, *A. versicolor* (Vuillemin) Tiraboschi, *A. tamarii* Kita, *Collectotricum gleosporiodes* Penz., *Curvularia lunata* (Wakker) Boedijn, and *Trichoderma viride* Persoon. Out of these nine fungal species, there was no difference in infection for seven fungal species when comparing seed sources (Table 3). Infection by *A. tamarii* was higher in samples collected from local markets and research institutes than seed saved by farmers. With respect to *A. niger,* infection was greater for seed collected from research institutes compared with farmer-saved seed: infection of seed from local markets was intermediate. Although infection by *A. flavus* and *Curvularia lunata* was relatively high, there were no significant differences in infection among seed sources.

Even though seed samples from all three sources were of low moisture content, high incidence of fungi were identified and associated with the seed. Genetic factors such as cultivar type can influence seed micro-flora as seed infection, micro-flora and pathogens are cultivar-dependent and usually a result

Table 3. Percentage of infection by pathogens in peanut seed collected from three sources in Ghana.[a]

Seed source	*A. niger*	*A. flavus*	*A. fumigatus*	*A. ochraceus*	*A. versicolor*	*A. tamaris*	*Collectotricum gleosoriodes*	*Curvularia lunata*	*Trichoderma virdi*
	%								
Farmer	17.6 b	33.3 a	4.2 a	0 a	0.6 a	11.2 b	0 a	18.8 a	0 a
Open market	34.7 ab	24.7 a	3.3 a	0 a	0 a	0 a	7.3 a	24.0 a	0 a
Research institutes	42.2 a	17.4 a	1.5 a	2.2 a	0 a	0 a	1.5 a	20.0 a	3.7 a
P > F	0.034	0.258	0.477	0.160	0.444	0.001	0.444	0.853	0.001
Coefficient of variation(%)	23.4	40.6	85.5	173.0	300.0	41.8	300.0	55.5	300.0

[a]Means within a column followed by the same letter are not significantly different at p < 0.05 based on Fisher's Protected LSD test.

of cultivar resistance (Cochran, 2015). Additionally, the limited availability of inputs for crop production and storage facilities may impede the ability of these three sources to produce and maintain quality seeds, especially in Ghana characterized by warm climate where disease incidence can be high. Similar results were reported by Adithya *et* al. (2017) where *A. niger* was predominant followed by *A. flavus* in peanut seed samples collected from farmers and markets in India. Additionally, Rathod *et* al., (2015) reported high incidence of *A. niger* (40%) followed by *A. flavus* (15%) in seed samples obtained from the research institute. Seed samples from the markets recorded the highest fungal incidence of pathogens.

In conclusion, in some instances quality of farmer-saved peanut seed was similar to quality of seed obtained from the research institutes. Seed from the research institutes was of higher quality than seeds from local markets and farmer-saved seed in relation to physical purity and plant phenotype uniformity. Seed from all three sources were poor in physiological quality and seed health. The poor performance of farmer-saved seeds and that of seed from the local markets with respect to physiological quality and seed health is most likely a result of inadequate quality control at production, selection, storage and marketing stages of the seed value chain by actors in these sectors. The formal seed system in Ghana has limited capacity to deliver high quality seed to smallholder farmers. Strengthening farmer-saved seed production and community-based seed systems should be recognized as possibilities until a national seed system for peanut can be developed and maintained.

ACKNOWLEDGEMENT

This research was supported by the United States Agency for International Development, as part of the Feed the Future initiative, under the CGIAR Fund, award number BFS-G-11-00002, the predecessor fund the Food Security and Crisis Mitigation II grant, award number EEM-G-00-04-00013, and the Office of Agriculture, Research and Policy, Bureau of Food Security, U.S. Agency for International Development, under the terms of Award No. AID-ECG-A-00-07-0001 to The University of Georgia as management entity for U.S. Feed the Future Innovation Lab for Peanut. The opinions expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Agency for International Development.

LITERATURE CITED

Abebe G. and A. Alemu. 2017. Role of improved seeds towards improving livelihood and food security at Ethiopia. International Journal of Research – Granthaalayah. 5:338-356.

Adithya G., Rajeshwari B., Keshavulu K., Sudini H., & Swathi Y. (2017). Mycoflora associated with groundnut seeds collected from selected groundnut growing districts of Telangana State, India. International Journal of Current Microbiology and Applied Sciences. 6(7):4335-4342.

Akpo E., Ojiewo C.O., Kapran I., Omoigui L.O., Diama A. and Varshney R.K., 2021. Enhancing smallholder farmers' access to seed of improved legume varieties through multi-stakeholder platforms: Learning from the TLIII project experiences in sub-Saharan Africa and South Asia. Page 205). Springer Nature.

Angelucci F., and A. Bazzucchi. 2013. Analysis of incentives and disincentives for groundnuts in Ghana. Technical Notes Series, MAFAP, FAO, Rome.

Anonymous. 2016. Ghana early generation seed study. AGRA-SSTP. Availabe at: https://www.agrilinks.org/sites/default/files/resource/files/ghana_early_generation_seed_report.pdf.

Beuchat L. R., and P. E. Koehler. 1979. Effect of moist heat treatment on sensory qualities of peanut kernels. Peanut Sci. 6(2):93-95.

Biabani A., L. C. Boggs, M. Katozi, and H. Sabouri. 2011. Effects of seed deterioration and inoculation with Mesorhizobium cicerion yield and plant performance of chickpea. Australian Journal of Crop Science. 5(1):66-70.

Chauhan J. S., S. R. Prasad, and P. Satinder. 2015. Quality seed: A mega factor in enhancing crop productivity. Pages

357-366 in A. L. Singh, ed. In: Recent Advances in Crop Physiology. Vol. 2. Daya Publishing House, New Delhi.

Cho Y., and R. A. Scott. 2000. Combining ability of seed vigor and seed yield in soybean. Euphytica. 112(2):145-150.

Cochran K. A. 2015. Soybean seed quality and vigor: influencing factors, measurement, and pathogen characterization. Graduate Dissertations. Available at: https://scholarworks.uark.edu/etd/1261.

Department of International Development (DFID). 2014. Groundnut market diagnostics. DFID Market Development (MADE) in Northern Ghana Programme. DAI and Nathan Associates.

Dhedhi K. K., C. B. Dhobi, N. N. Chaudhari, J. S. Sorathiya, and M. D. Khanpara. 2017. Assessment of farmers saved groundnut seed quality of Devbhoomi Dwarka district of Gujarat, India. Agricultural Science Digest-A Research Journal. 37(1):16-21.

Diba K., P. Kordbacheh, S. H. Mirhendi, S. Rezaie, and M. Mahmoudi. 2007. Identification of *Aspergillus* species using morphological characteristics. Pakistan Journal of Medical Sciences. 23(6):867.

FAO [Food and Agricultural Organization]. 2018. Farmer seed systems and sustaining peace. Rome. 52 pp. License: CC BY-NC-SA 3.0 IGO. Available at: https://www.fao.org/resilience/resources/resources-detail/ar/c/1160196/.

FAOSTAT [Food and Agriculture Organization Corporate Statistical Database]. 2020. Statistical data on crops, groundnut, area, production quantity of Ghana, Africa and World. Available at: https://faostat.fao.org.

Gebeyehu S., J. Kangile, and E. Mwakatobe. 2019. Assessment of seed quality along the rice seed value chain in Tanzania. Development in Practice. 29(7):854-866.

Hamman B., D. B. Egli, and G. Koning. 2002. Seed vigor, soilborne pathogens, preemergent growth, and soybean seedling emergence. Crop Science. 42(2):451-457.

Jordan D., R. Brandenburg, G. Payne, D. Hoisington, N. Magnan, J. Rhoads, M. Abudulai, K. Adhikari, J. Chen, R. Akromah, W. Appaw, W. Ellis, M. Balota, K. Mallikarjunan, K. Boote, G. MacDonald, K. Bowen, B. Bravo-Ureta, J. Jelliffe, A. Budu, H. Chalwe, A. Mweetwa, M. Ngulube, A. Dankyi, B. Mochia, V. Hoffman, A. Muitia, A. Mwangwela, S. Njoroge, D. Okello, and N. Opoka. 2018. Preventing mycotoxin contamination in groundnut cultivation. Pages 181-214 in S. Sivasankar, D. Berguinson, P. Gaur, S. Kumar, S. Beebe, and M. Tamó, eds., Achieving Sustainable Cultivation of Grain Legumes; Improving Cultivation of Particular Grain Legumes. Volume 2. Burleigh Dodds Series in Agricultural Science. Burleigh Dodds Science Publishing, Cambridge, UK.

Klich M. A. 2002. Identification of common *Aspergillus* species. Utrecht, Netherlands: Centraalbureau voor Schimmelcultures.

Matthews S., E. Noli, I. Demir, M. Khajeh-Hosseini, and H. M. Wagner. 2012. Evaluation of seed quality: from physiology to international standardization. Seed Science Research. 22:S69-S73.

McDonald M. F. and L. O. Copeland. 2012. Seed production: principles and practices. Springer Science and Business Media, Dordrecht, Germany.

MOFA [Ministry of Food and Agriculture]. 2016. Agricultural sector progress report 2016. Ministry of Food and Agriculture, Monitoring and Evaluation Directorate. Available at: file:///C:/Users/dljorda2/Downloads/Agricultural200B%20Sector%20Progress%20Report%202016.pdf.

MOFA [Ministry of Food and Agriculture]. 2017. Agriculture in Ghana: facts and figures (2016). Ministry of Food and Agriculture Statistics, Research and Information Directorate (SRID). Available at: https://mofa.gov.gh/site/images/pdf/AGRICULTURE%20IN%20GHANA%20F&F%202017.pdf.

MOFA [Ministry of Food and Agriculture]. 2021. Agriculture in Ghana: Facts and Figures (2020). Ministry of Food and Agriculture Statistics, Research and Information Directorate (SRID). Available at: https://srid.mofa.gov.gh/sites/default/files/Agriculture%20In%20Ghana%200B20Facts%20%26%20Figures_%202020%20FINAL.pdf.

Nautiyal P. 2002. Groundnut: Post-harvest operations, New Delhi, India: ICAR-National Research Centre for Groundnut. Available at: http://www.icar.org.in/.

Nigam S. N., D. L. Jordan, and P. Janila. 2018. Improving cultivation of groundnuts. Pages 155-180 in S. Sivasankar, D. Berguinson, P. Gaur, S. Kumar, S. Beebe, and M. Tamó, eds., Achieving Sustainable Cultivation of Grain Legumes; Improving Cultivation of Particular Grain Legumes. Volume 2. Burleigh Dodds Series in Agricultural Science, Burleigh Dodds Science Publishing, Cambridge, UK.

Owusu-Adjei E., R. Baah-Mintah, and B. Salifu. 2017. Analysis of the groundnut value chain in Ghana. World J. Agriculture. 5(3):177-188.

Puozaa D. K., A. N. Jinbaani, D. S. Adogoba, D. Busagri, M. A. Rasheed, A. R. Issah, and R. Oteng-Frimpong. 2021. Enhancing access to quality seed of improved groundnut varieties through multi-stakeholder platforms in Northern Ghana. Pages 65-79 In E. Akpo, C. O. Ojiewo, I. Kapran, L. O. Omoigui, A. Diama, and R. K. Varshney, eds., Enhancing Smallholder Farmers' Access to Seed of Improved Legume Varieties Through Multi-stakeholder Platforms. Springer, Singapore. Available at: http://oar.icrisat.org

/11690/1/Akpoetal2021_Book_EnhancingSmallholderFarmersAcc.pdf.

Quiñones E. J., and X. Diao. 2011. Assessing crop production and input use patterns in Ghana –What can we learn from the Ghana Living Standards Survey (GLSS5)? Ghana Strategy Support Program (GSSP) GSSP Working Paper No. 0024. Available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.227.442&rep=rep1&type=pdf.

Ranal M.A., D. G. D. Santana, W. R. Ferreira, and C. Mendes-Rodrigues. 2009. Calculating germination measurements and organizing spreadsheets. Brazilian Journal of Botany. 32:849-855.

Rathod L. R., S. M. Naikade, and M. R. Mote. 2015. Biodiversity of *Aspergillus* spp. on groundnut seeds. International Journal of Life Sciences. Special Issue A 4: 47-50.

Sastry D. V. S. S. R., H. D. Upadhyaya, and C. L. L. Gowda. 2007. Survival of groundnut seeds under different storage conditions. Journal of SAT Agricultural Research. 5: 3.

Sharanappa S. B., N. M. Shakuntala, S. N. Vasudevan, and P. H. Kuchanur. 2018. Influence of packaging materials on storability of groundnut (*Arachis hypogaea* L.). Journal of Pharmacognosy and Phytochemistry. 7(3):3013-3016.

Smith J. S., P. D. Blakenship, and F. P. Mcintosh. 1995. Advances in peanut handling, shelling and storage from stock to processing. Pages 500-527 in H. E. Pattee and H. T. Stalker, eds. Advances in Peanut Science. American Peanut Research and Education Society, Inc. Stillwater, OK.