

**GERMINATION RESPONSES AS INFLUENCED BY VARYING OIL AND
PROTEIN CONTENTS OF NINE SOYBEAN (*Glycine max* (L) Merr.)
GENOTYPES STORED UNDER TWO STORAGE ENVIRONMENTS**

KNUST



BY

LOVETTA MEAYIAH GLEEKIA-KERKULA

AUGUST, 2012

**A THESIS SUBMITTED TO THE DEPARTMENT OF HORTICULTURE,
COLLEGE OF AGRICULTURE AND NATURAL SCIENCES, KWAME
NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL
FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE
DEGREE OF MASTER OF SCIENCE (MSC) IN SEED SCIENCE AND
TECHNOLOGY**

KNUST



LOVETTA MEAYIAH GLEEKIA-KERKULA

AUGUST, 2012

DECLARATION

I, Lovetta Meayiah Gleekia-Kerkula, that this thesis is my original work and has not been presented for the award of degree or certificate of any kind in this or any other University and all source materials used for the thesis have been duly acknowledged.

Signature: _____

Date: _____

Lovetta Meayiah Gleekia-Kerkula (Mrs.)

(Student)

Signature: _____

Date: _____

Prof. (Mrs.) Nana Sakiywa Olympio

(Supervisor)

Signature: _____

Date: _____

Dr. Robert A. Asuboah

(Co – Supervisor)

Signature: _____

Date: _____

Dr. Ben K. Banful

(Head of Department)

DEDICATION

This work is dedicated to my beloved husband Mr. Joe S. Kerkula, my siblings Lawrence Nemenlah Gleekia, Darius N. Dolo, Bobby Kardor Nuahn and my dear children Nokie N. Kerkula, Joetta M. Kerkula, Aldrich P. Kerkula and Steve J. Kerkula and my loving father Mr. Henry Dorwohn Gleekia (deceased) for being my sources of motivation to decide to join the course and the strength to successfully complete.



ACKNOWLEDGEMENTS

Glory be to the Almighty God for a successful completion of this thesis. He gave me good health, strength and courage from the beginning to the end of the project. This work would not have been possible if I did not have the following persons as my supervisor and guidance. My sincere and deepest gratitude go to my supervisors Prof. (Mrs.) Nana Sakyiwa Olympio and Dr. Robert A. Asuboah for their unreserved all rounded support and enriching comments, also to Prof. Richard A. Akromah for his valuable contribution and the key role he played in the choice of the topic and encouragements throughout to the end of the project and to Mrs. Agnes A. Ankomah who helped to analyze the data.

I am extremely grateful to the Alliance for Green Revolution of Africa (AGRA) for financing this project work. My sincere gratitude also goes to the Ministry of Agriculture and the Central Agricultural Research Institute (CARI) of Liberia, for selecting me as a beneficiary of the scholarship.

My sincere thanks also go to all laboratory technicians at the Grains and Legumes Development Board (GLDB) in Kumasi, administrations at all levels of the Board and the Development Department Staff for their cooperation, I feel greatly indebted to them for all their supports. My heartfelt gratitude also goes to my husband, father, mother, brothers, sisters and my lovely children for their moral and material supports and engagements, without whom it would have been difficult to successfully complete my study. Lastly, my sincere thanks go to my Christian brothers and sisters both of Liberia and Ghana, Kumasi for their endless prayers to secure God's guidance and protection for me during my study.

LIST OF ABBREVIATIONS

AGRA	Alliance for Green Revolution in Africa
ANOVA	Analysis Of Variance
CRI	Crops Research Institute
CARI	Central Agricultural Research Institute
CRD	Completely Randomized Design
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
FFA	Free Fatty Acid
FGP	Final Germination Percentage
GLDB	Grains and Legumes Development Board
ISTA	International Seed Testing Association
M	Mampong
MoFA	Ministry of Food and Agriculture
PI	Peroxide Index
RH	Relative Humidity
SDW	Seedling Dry Weight
ST	Storage Temperature
STP	Storage Period
TEMP.	Temperature
TVP	Textured Vegetable Product
USA	United States of America
USDA	United States Department of Agriculture
Var.	Variety
WISHH	World Initiative for Soy in Human Health

ABSTRACT

Experiments were set up to assess varietal differences on the effects of the oil and protein contents on the seed quality of nine soybean genotypes during storage. The samples used for the investigations were collected from three locations in Ghana. The seeds were of 12 % moisture content and further dried to a moisture content of 8%. The seeds were initially tested for germination, oil and protein contents and then packaged and stored at ambient temperature of $27^{\circ}\text{C}\pm 3/79.6\%\text{RH}$ and cold room of $15^{\circ}\text{C}\pm 3/65\%\text{RH}$ for 120 days. A $9\times 4\times 2$ factorial experiment was used for the storage trial. Samplings were carried out every 30 days until 120 days in storage to determine the viability of each genotype over time using standard germination tests. The results indicated that genotypes with higher protein contents were found to have lower oil contents. Genotype Nangbaare had the highest initial protein content (42.03%) and TGX-1834-5E had the lowest protein (39.29) while genotypes 1904-6F and Sallintuya 1 had the highest (13.06%) and lowest (8.40%) initial oil contents respectively. Storage period was observed to influence the germination potential of the genotypes; as storage period increased the germination percentages declined. Among the variables studied, oil content and storage period together were observed to have significant effects on the viability and this was indicated by reduced germination potential and shrinking of the seeds of genotypes with higher oil content. Only seeds stored with moderate oil contents and higher protein contents maintained higher germination potential throughout the 120 days of storage. The effects of storage temperatures were also observed on the genotypes. Differences among genotypes under the two storage environmental conditions in all of the parameters (Germination percentage, vigour index, and seedling

dry weight) were significant. Genotype (Anidaso (C) stored in cold room recorded the highest germination percentage of 93.81% while genotype TGX-1904-6F kept under ambient condition had the lowest germination percentage of 72.19%. However, the differences were not significant.

KNUST



TABLE OF CONTENTS

DECLARATION	i
DEDICATION	ii
ACKNOWLEDGEMENTS	iii
LIST OF ABBREVIATIONS	iv
ABSTRACT	v
TABLE OF CONTENTS	vii
LIST OF TABLES	xi
LIST OF PLATES	xii
LIST OF FIGURES	xiii
LIST OF APPENDICES	xiv
 CHAPTER ONE	 1
1.0 INTRODUCTION	1
 CHAPTER TWO	 4
2.0 LITERATURE REVIEW	4
2.1 TAXONOMY	4
2.2 ECONOMIC IMPORTANCE OF SOYBEAN	4
2.3 INDUSTRIAL VALUES OF SOYBEAN	5
2.4 SOYBEANS IN AGRICULTURE	5
2.5 CLASSIFICATION	5
2.5.1 Morphological Description and Physical Characteristics of Soybean	6
2.6 CHEMICAL COMPOSITION OF SOYBEAN SEEDS	7
2.7 MATURITY DATE	7
2.8 HARVESTING	8
2.9 FACTORS AFFECTING SOYBEAN SEED STORABILITY	8
2.10 CHANGES THAT OCCUR DURING STORAGE	9
2.11 MOISTURE EFFECTS ON SOYBEANS SEED STORABILITY	10
2.11.1 Storage Effects on Soybean Seed Quality.....	10
2.11.2 Influence of Genetic Characteristics on Soybean Seed Storability.....	10

2.11.3 Temperature Effect on Seed Quality.....	11
2.11.4 Storage Duration Effects on Soybean Seed Storability.....	11
2.12 PROTEIN AND OIL EFFECTS ON SEED QUALITY	12
2.12.1 Oil Effects on Soybean Seed Quality.....	12
2.12.2 Protein Effect on Soybean Seed Quality.....	14
CHAPTER THREE.....	16
3.0 MATERIALS AND METHODS.....	16
3.1 STUDY AREA	16
3.2 SOURCE OF SEEDS.....	16
3.3 SAMPLE SIZE	17
3.4 STORAGE ENVIRONMENTS UNDER REVIEW	17
3.5 EXPERIMENTAL DESIGN AND PROCEDURES.....	19
3.6 STUDY VARIABLES	19
3.7 LABORATORY ANALYSIS.....	19
3.7.1 Germination Testing.....	19
3.7.2 Seed Vigour Testing.....	21
3.7.3 Nutritional Analysis	22
3.7.3.1 Crude protein determination	22
3.7.3.2 Ether extract (oil) determination	23
3.8 STATISTICAL ANALYSIS.....	24
CHAPTER FOUR.....	25
4.0 RESULTS	25
4.1 EFFECT OF STORAGE PERIOD ON MOISTURE CONTENT OF SOYBEAN SEEDS	25
4.2 EFFECTS OF STORAGE PERIOD AND ENVIRONMENTS ON MOISTURE CONTENT OF SOYBEAN SEEDS	26
4.3 OIL CONTENT OF SOYBEAN SEEDS	27
4.4 EFFECT OF GENOTYPE AND STORAGE PERIOD ON PROTEIN CONTENT OF SOYBEAN SEEDS	28

4.5 EFFECT OF GENOTYPES AND STORAGE ENVIRONMENT ON GERMINATION PERCENTAGE OF SOYBEAN SEEDS	31
4.6 EFFECT OF STORAGE PERIOD AND STORAGE ENVIRONMENT ON GERMINATION PERCENTAGE OF SOYBEAN SEED AFTER STORAGE	33
4.7 EFFECT OF GENOTYPES AND STORAGE PERIOD ON SEEDLINGS VIGOUR OF SOYBEAN SEEDS AFTER STORAGE	34
4.8 EFFECT OF GENOTYPES AND STORAGE PERIOD ON SEEDLING DRY WEIGHTS OF SOYBEAN SEED.....	35
4.9 EFFECT OF GENOTYPES AND STORAGE ENVIRONMENT ON SEEDLING DRY WEIGHT OF SOYBEAN.....	37
CHAPTER FIVE.....	39
5.0 DISCUSSION	39
5.1 VARIETAL DIFFERENCES OF SOYBEAN SEED PROTEIN AND OIL CONTENTS	39
5.2 EFFECTS OF SOYBEAN SEED PROTEIN CONTENT ON SOYBEAN SEEDS QUALITY	39
5.3 EFFECT OF SEED OIL CONTENT ON SOYBEAN SEEDS STORABILITY	40
5.4 STORAGE PERIOD EFFECTS ON THE GERMINATION OF SOYBEAN SEEDS	41
5.5 EFFECTS OF STORAGE ENVIRONMENTS ON SOYBEAN SEEDS QUALITY	41
5.5.1 Effects of Storage Duration on Protein and Oil Contents of Soybean Seeds.....	42
5.5.2 Storage Environments Effect on Soybean Oil and Protein Content	43
5.5.3 Effects of Storage Period and Storage Environments on Soybean Vigour Index and Seedlings Dry Weight	43
5.5.4 Effects of Storage Period and Environment on Moisture Content of Soybean Seeds	44
5.6 EFFECT OF GENOTYPES/VARIETIES ON SEED QUALITY	45
5.7 THE EFFECTS OF PROTEIN AND OIL CONTENT ON GERMINATION RESPONSES OF SOYBEAN	45

CHAPTER SIX	47
6.0 CONCLUSION AND RECOMMENDATIONS.....	47
6.1 OIL EFFECTS	47
6.2 PROTEIN EFFECTS	48
6.3 RECOMMENDATIONS	48
REFERENCES.....	49
APPENDICES	59

KNUST



LIST OF TABLES

Table 4.1 Effect of Storage Period on the Moisture Content of Soybean Seeds	25
Table 4.2 Effect of Storage Period and Environments on the Moisture Content of Soybean Seeds	26
Table 4.3 Varietal Differences in Oil Content of Soybean Genotypes after 120 days in storage.....	27
Table 4.4 Effect of Genotypes and Storage Period on Protein Content of Soybean Seed	28
Table 4.5 Effects of Genotypes and Storage Environment on Germination Percentage of Soybean Seeds after Storage.....	32
Table 4.6 Effects of Storage Period and Storage Environment on Germination Percentage of Soybean Seed after Storage.....	33
Table 4.7 Effect of Genotypes and Storage Period on Seedlings Vigour of Soybean Seeds.....	34
Table 4.8 Effect of Genotypes and Storage Period on Soybean Seedling Dry Weights	36
4.9 Effect of Genotypes and Storage Environment on Seedling Dry Weight of Soybean.....	37

LIST OF PLATES

Plate 1. Sampling of Soybean Seeds for an Experiment.....	17
Plate 2. Soybean Seeds Packaged and Stored in Cold room at 15°C.....	18
Plate 3. Soybean Seeds Packaged and Stored under Ambient Condition of 27°C	18
Plate 4. Sorted Soybean Seeds Ready for Storage	20
Plate 5. Setting Up a Germination Test.....	20
Plate 6. Evaluation of Germinated Soybean Seeds after 8 Days of Sowing.....	21

KNUST



LIST OF FIGURES

Figure 1. Relationship between seed protein content and germination of soybean seeds stored under ambient environment ($27^{\circ}\text{C}\pm 3/79.6\%\text{RH}$) for 120 days	29
Figure 2. The effects of genotypes and storage period on germination percentage of soybean seeds.....	30

KNUST



LIST OF APPENDICES

APPENDIX A: Analysis of Variance (ANOVA) Tables.....	59
APPENDIX B: Environmental Conditions Charts.....	62
APPENDIX C: Initial Characteristics of the Soybean Genotypes before Storage.....	63

KNUST



CHAPTER ONE

1.0 INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a leguminous species native to East Asia (USDA, 2011). Soybean is an important global legume crop that grows in the tropical, subtropical and temperate climates. Like peas, beans, lentils and peanuts, it belongs to the large botanical family, Leguminosae, in the subfamily Papilionideae. It is a self-fertile species with less than 1% out-crossing (Shurtleff and Aoyagi 2007; IITA, 2009). It is widely grown for its edible bean which has numerous uses. Soybean is a crop of global importance and is one of the most frequently cultivated crops worldwide. The plant was classified as an oilseed rather than a pulse by the Food and Agricultural Organization (FAO, 2003). Soybean seeds contain about 42 to 45% proteins as well as up to 22% edible oil (Mondal *et al.*, 2002).

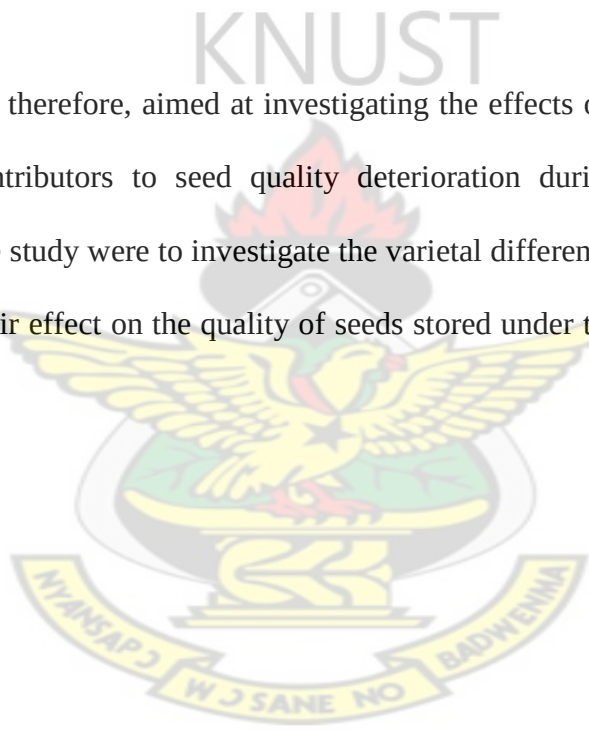
It has a high nutritional value and remains an excellent source of vegetable oil. In West Africa, soybean has become a major source of high quality and cheap protein for the poor and rural households. It is used in processing soy meat, cakes, and baby foods and 'dawadawa', a local seasoning product for stews and soups, (Abbey *et al.*, 2001). It is also used to fortify various traditional foods such as gari, sauces, stew, soups, to improve their nutritional levels (MoFA and CSIR, 2005). Soybean improves soil fertility through biological nitrogen fixation and also controls the parasitic weed, *Striga* (Adu-Dapaah *et al.*, 2004).

World demand for soybean has been able to absorb the ever-increasing production at prices that are profitable to producers. Worldwide, land cultivated to soybean is about 94.1 million hectares annually (FAO, 2010). World soybean production in 2009/2010 was about 260 million metric tons (USDA, 2011), and for the same period, world average yield per ha was 2371 kg (FAO, 2010). The main producers were the United States (35%), Brazil (27%), Argentina (19%), China (6%) and India (4%) with Africa's production being the lowest 1.4 tons per hectare which accounts (67%). In Africa, the leading producers are Nigeria (592,000 MT) from an area of 625,667 ha followed by South Africa (332 MT) from an area of 199,323 ha, Uganda 176,333 MT from 146,667 ha, with Zimbabwe and Malawi following respectively in the fourth and fifth places with productions of 96,008 and 50,000 MT from 60,679 and 71,333 ha, respectively (FAO, 2010).

Quality seed is a major factor in crop development and productivity. Seed quality, as measured by its viability and vigor worldwide, plays a major role in field establishment as well as the final crop yield. Seed deterioration leads to reductions in seed quality, performance and stand establishment (McDonald, 1999). Despite the numerous contributions soybeans continue to make in improving the world economy, its poor storability remains a great challenge in soybean production worldwide. The germination and vigor potential of soybean is short lived as compared to other grain crops and it is often reduced prior to planting time (Nkang and Umoh 1997). Soybean seeds rapidly deteriorate in quality during storage and therefore soybean farmers and storage managers around the world face lots of seed quality challenges during the seeds storage.

Given the significant world production of soybeans, quality seed is essential for the sectors involved in production and or processing of this crop (Brooker *et al.*, 1992). Non-availability of good quality seed due to poor storability remains one of the major constraints of soybean cultivation worldwide and therefore, it is essential that investigations are made to ascertain those factors that contribute to the rapid deterioration of soybean seeds in storage in order to maintain the quality of the seeds and ensure their viability when in storage.

The project was therefore, aimed at investigating the effects of soybean oil and protein contents as contributors to seed quality deterioration during storage. The specific objectives of the study were to investigate the varietal differences in seed protein and oil contents and their effect on the quality of seeds stored under two storage environmental conditions.



CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 TAXONOMY

Soybean (*Glycine max* (L.) Merrill) is an annual legume that belongs to the family Fabaceae (Flaskerud, 2003). It is predominantly a tropical crop and is a strictly self-pollinating legume. The earliest known cultivation of the crop in Africa was in 1896, in Algeria (Shurtleff *et al.*, 2010). Starting in 1908 there was a dramatic increase of interest in growing soybeans in Africa. Soybeans were first grown in Ghana in 1909 (Mercer-Quarshie and Nsowah, 1975). However, serious attempts to establish the production of the crop in Ghana as well as Liberia started in the early 1970s and 1977 respectively (Mercer-Quarshie and Nsowah, 1975; Shurtleff and Aoyagi, 2010).

2.2 ECONOMIC IMPORTANCE OF SOYBEAN

Legumes are the principle sources of protein for human beings. Soybeans contain significant amounts of essential amino acid which are of great importance to both humans and animals health (USDA, 2006). Traditional non fermented food uses of soybeans include soy milk, flour or powder. Fermented foods include soy sauce, fermented bean paste, natto and tempeh, among others. The oil is used in many industrial applications such as in the production of margarine, cheese, and others. Soybean is also a nutritional powerhouse used in solving the protein energy malnutrition problems in West Africa and the World at large. It has great potential in the

development of three key sectors of the economy such as Health, Agriculture and Industry (WISHH, 2006).

2.3 INDUSTRIAL VALUES OF SOYBEAN

Industrial uses of soybeans are many. When crushed, soybean is separated into two major components: oil (including lecithin) and protein (meal or flour) and these products are widely used in the industry. They are used as raw materials for manufacturing printers' ink, cosmetics, plastics, paint, glue, soap shampoo and many more. Detergents and gasoline (USA) are also made from soybeans (Adu-Dapaah *et al.*, 2004). Other industrial uses of soybeans include paints, in dressings or water – proofings for textiles, and a sizing for paper (Shurtleff and Aoyagi, 2009).

2.4 SOYBEANS IN AGRICULTURE

Soybean fixes atmospheric nitrogen, therefore enhances sustainable crop production and improves soil fertility especially when in rotation with cereals. Soybean plants are good soil cover that reduces soil erosion and suppresses weed growth. It also breaks pest and diseases cycles when grown in rotation with cereals. Soybean reduces Striga population when it precedes cereals, causing suicidal germination of Striga seeds (Adu-Dapaah *et al.*, 2004).

2.5 CLASSIFICATION

The genus *Glycine* was originally introduced by Carl Linnaeus in his first edition of *Genera Plantarum* (Wikipedia, 2009). Glycine is a Greek word meaning sweet. The

cultivated soybean first appeared in *Species Plantarum*. The combination *Glycine max* (L.) Merr. as proposed by Merrill in 1917, has become the valid name for this useful plant (Wikipedia, 2009).

2.5.1 Morphological Description and Physical Characteristics of Soybean

Soybean is an annual, erect hairy herbaceous plant, ranging in height from 30 to 183 cm, depending on the genotype (Ngeze, 1993). The pods, stems, and leaves are covered with fine brown or gray hairs. Some genotypes have prostrate growth, not higher than 20cm or grow up to two meters high. Soybean varies in growth and habit in two forms: determinate and indeterminate types (Ngeze, 1993; MoFA and CSIR, 2005). The determinate genotypes grow shorter and produce fewer leaves, but produce comparatively more pods, while the indeterminate genotypes grow taller, produce more leaves and pods right from the stem to shoot. The flowers are small, inconspicuous and self-fertile; borne in the axils of the leaves and are white, pink or purple (Ngeze, 1993). The leaves are trifoliolate, having three to four leaflets per leaf, and the leaflets are 6–15 cm (2.4–5.9 inches) long and 2–7 cm (0.79–2.8 inches) broad. The leaves fall before the seeds are mature. The fruit is a hairy pod that grows in clusters of three to five. Each pod is 3–8 cm long (1–3 inches) and usually contains two to four (rarely more) seeds 5–11 mm in diameter (Chung *et al.*, 2006). Soybean occurs in various sizes, and in many hull or seed coat colors, including black, brown, yellow and green. The hull of the mature bean is hard, water resistant, and protects the cotyledon (germ) from damage (Chung *et al.*, 2006; Borget, 1992). Gary and Dale, (1997) also described soybean growth and development in two main stages: the vegetative stage and the reproductive stage. The

vegetative stage starts with the emergence of seedlings, unfolding of unifoliate leaves, through to fully developed trifoliate leaves, nodes formation on the main stem, nodulation and the formation of branches. The reproductive stage begins with flower bud formation, through full bloom flowering, pod formation, pod filling to full maturity.

2.6 CHEMICAL COMPOSITION OF SOYBEAN SEEDS

Soybeans are composed of roughly 22% lipids and are susceptible to qualitative deterioration processes via degradation of these compounds when stored improperly and can result in serious damage to the food and seeds industries. Soybean also contains about 30.16g of carbohydrates, 7.33g sugar, 2.88g saturated fat and many other nutrients (Song *et al.*, 1999).

2.7 MATURITY DATE

The importance of planting date and or maturity date in relation to seed quality has long been realized. According to Wilcox *et al.* (1992), early maturing cultivars are more adversely affected by delayed harvest than late maturing. Early and mid season cultivars are more susceptible to seed deterioration than full season cultivars because they matured at warmer temperature than the full season cultivars (Khalil *et al.* 2001). Soybean plants that mature early during hot, dry periods yield lower-quality seeds than those that mature after temperatures drop (Sidibe *et al.*, 1999). Combinations of warm days and warm nights produced the highest dry weights. Maturity dates of soybean vary within varieties ranging between 90-115 days. Soybean maturity begins with one normal pod on the main stem which obtains the mature color (brown). This is visually seen

when all green color is lost from both the seeds and pods appearing yellow. The seeds contain about 60% moisture at physiological maturity and about 15% moisture when the soybean plant is fully mature (Sidibe *et al.*, 1999).

2.8 HARVESTING

Harvesting of soybean is said to commence approximately 7 to 14 days after the plants are physiological mature. Adverse weather conditions during the post-maturation, pre-harvest period cause moderate to severe seed quality problems in soybean (Delouche, 1980). Timely harvest of mature soybean seeds is extremely important in maintaining high seed quality. Harvest delays beyond optimum maturity increase field exposure and intensify seed deterioration. Seeds vigor declines when seeds are harvested 30 days after harvest maturity, especially if hot, humid conditions prevailed (Tekrony *et al.*, 1984). Seed vigor and viability reached a peak at physiological maturity (Ching *et al.*, 1972; Trammell, 1983). The rate of seed quality loss after physiological maturity depends on the degree of unfavorable environmental conditions surrounding the seeds.

2.9 FACTORS AFFECTING SOYBEAN SEED STORABILITY

Among the many variables that affect the storability of seeds, temperature and the storage duration are the most critical factors (Acasio, 2010). The major constraints in soybean production in tropical and sub-tropical countries of the world are poor storability of seeds (Brooker *et al.*, 1992). For soybeans, however, temperature does not only affect the storability but can promote chemical changes in the seeds such as hydrolytic and oxidative rancidity (changes in oil quality) leading to poor seed quality

and subsequent loss of viability, therefore, leading to seed quality changes over time (Baskin and Delouche, 1973).

2.10 CHANGES THAT OCCUR DURING STORAGE

Changes occurring in seed during aging are significant as far as seed quality and longevity are concerned and are a consequence of the effects of different storage conditions. The chemical composition of seed with high oil content is related to specific processes occurring in seed during storage. Changes that occur in seed during aging are significant in terms of seed quality, the feature that, among other things, also implies seed longevity (Milošević and Malešević, 2004). The rate at which the seed aging process takes place also depends on the ability of seed to resist degradation changes by protection mechanisms which are specific for each plant species. Seeds of different plant species lose viability to a various degree when kept under the same storage conditions (Balešević-Tubić, 2001). Shrinking and breaking of seeds during storage are some of the physical changes that occurred in soybean seed in storage (Narayan *et al.* 1988a). According to Narayan *et al* (1988b), physical, chemical and biochemical alterations may occur in soybeans, depending on conditions and storage duration. The chemical composition of oilseeds causes specific processes to occur during storage. The seeds rich in lipids have limited longevity due to their specific chemical composition. For example, soybean seed storage demands special attention due to its high oil content, otherwise processes may occur that lead to the loss of germination ability and seed viability (Balešević-Tubić *et al.*, 2007b).The qualitative changes during storage

contribute to the loss of oil and meal quality (Orthoefer, 1978), as well as other derivatives such as tofu and soymilk (Hou & Chang, 2004; Kong *et al.*, 2008).

2.11 MOISTURE EFFECTS ON SOYBEANS SEED STORABILITY

The moisture content of seed during storage is one of the most influential factors affecting the longevity. As seed deterioration is affected by moisture content, it is important to create a conducive storage environment to minimize deterioration (Bass *et al.*, 2011). Seeds stored at 11% moisture content or below are recommended for storing seeds under temperature between 5 and 8°C and can be stored for two years without development of fungi, while seeds stored at 30°C with the same moisture content can be infected by fungi within a few weeks and severely damaged after six months of storage (Acasio, 2010).

2.11.1 Storage Effects on Soybean Seed Quality

Irrespective of genotypes, the germination potential of soybean seeds decreased during storage (Shelar, 2002). The longevity of seeds in storage is influenced by some major factors such as i) genetics, ii) Quality of the seed at the time of storage, iii) Moisture content of seed and iv) the storage temperatures (Gupta, 1976).

2.11.2 Influence of Genetic Characteristics on Soybean Seed Storability

According to Shelar *et al.* (2008), variation in speed of seed deterioration of genotypes is associated with genetic character. Soybean genotypes differ in their ability to maintain seed longevity. They also observed superior storability of soybean seeds of smaller size

as compared to larger seeds. Larger seeds deteriorated faster than small seeds. Baskin *et al.* (1998) observed that the small seeded varieties deteriorated more slowly than the large seeds. Cultivars which are highly permeable are observed to have normal seed coat (NSC) that allows them to imbibe water rapidly (Heatherly *et al.*, 1995).

2.11.3 Temperature Effect on Seed Quality

Temperature is another very important factor influencing soybean storage. The parameters of temperature and relative humidity during storage are decisive in the process of loss of seed viability and alterations in the seed color and composition (Whigham and Minor, 2003). Growth of fungi and chemical changes such as oxidation increased with temperature in both meal and whole beans (Wine and Kueneman, 1981). Loss of viability and vigour under high temperature and RH conditions is a common phenomenon in many crop seeds but it is well marked in soybean. The rate of seed deterioration is positively related to ambient temperature, relative humidity and seed moisture content (Ellis and Roberts, 1982 & 1989, Shelar *et al.* 2008).

2.11.4 Storage Duration Effects on Soybean Seed Storability

Deterioration in seeds is also associated with storage duration. Changes associated with seed deterioration are depletion in food reserve, increased enzyme activity, increased fat acidity and membrane permeability. As the catabolic changes continue with increasing age, the ability of the seed to germinate is reduced. Decline in viability or germination capacity does not begin immediately after maturation. Under favorable storage conditions, the initiation of decline in germination may be from few months to many

years depending on storage conditions, kind of seed and conditions during seed development (Shelar *et al.* 2007).

According to Burris (1980), the fast deterioration of soybean seeds during the period of storage is also influenced by the moisture content and temperature. The qualitative deterioration of soybean stored with initial moisture contents between 9.8 and 13.8% in tropical conditions (30°C) was verified to have a more pronounced reduction in the percentage of germination between 5 and 9 months of storage, and this was more accentuated in seeds with higher initial moisture content (Bhattacharya and Raha, 2002). In tropical areas, such as Brazil, ambient temperatures of storage are observed above 20°C, and the decrease in germination was more alarming (Dhingra *et al.*, 2001).

2.12 PROTEIN AND OIL EFFECTS ON SEED QUALITY

2.12.1 Oil Effects on Soybean Seed Quality

Lipid oxidation is a spontaneous and inevitable phenomenon with direct implications on the market value of either the fatty bodies, or of all the products formulated from them. The hydro peroxides formed from the reaction between oxygen and unsaturated fatty acids are the primary products (Silva *et al.*, 1999). Although these compounds do not exhibit taste or odor, they are rapidly decomposed even at room temperature into aldehydes, ketones, alcohols, hydrocarbons, esters, lactones and furans, causing unpleasant taste and odor in oils and fats through peroxide index (O'Brien, 2004; Eys *et al.*, 2006) with adverse effects on the seed quality. One of the methods used to determine the degree of oxidation in fats and oils is the peroxide index. The peroxide

index (PI) is a measure of oxidation or rancidity in its initial phase (O'Brien, 2004). These changes over time may cause seed quality reductions for soybeans and other oil seed crops in storage.

Oil seeds are very sensitive to harsh environmental conditions. It is hypothesized that their oil content readily oxidizes, which causes deterioration of the seeds health in storage (Kausar *et al.*, 2009). Hydrolytic rancidity can affect taste, odor and other characteristics of oil thereby affecting the storage quality (O'brien, 2004). Vegetable oils may present relatively high contents of free fatty acids (FFA) if the grains or seeds present damages due to procedures in the field or incorrect storage practices. During storage, lipids are hydrolyzed by the lipases in free fatty acids (FFAs) and glycerol, mainly in high temperatures and moisture contents (Molteberg, 1995). Wilson *et al.* (2004) also reported that losses in refinement of soybean between 1 and 1.5 % are considered normal; however, such losses can reach up to 4% or more with higher values of FFA. Yanagi *et al.* (1985) confirmed the influence of storage duration, when soybean was stored at 30°C and 80% relative humidity, on the free fatty acid percentage of crude oil. The variation in percentage of FFA effects on crude oil extracted from soybean grains stored at different moisture contents was studied by Frankel *et al.* (1987). The free fatty acid percentage from crude oil extracted from stored soybean increased significantly due to the interaction of grain moisture content and storage period also influence the seed quality (Dhingra *et al.*, 1998).

Stored soybeans may undergo physical, physiological and chemical changes even under ideal storage conditions. Some of the changes may or may not have a negative effect on the final use of seeds and meal depending on the degree of change. One common indicator of chemical change in stored soybean is the levels of free fatty acid (FFA) present (Padin *et al.*, 2002). An increase of FFA above 1% may translate into lower quality of its oil content. Other important changes include decline in soybean seed viability, change in the grain color, increase or decrease in its moisture, decomposition of phospholipids, and the denaturation of its protein (Sinclair, 1998).

2.12.2 Protein Effect on Soybean Seed Quality

All seeds contain one or more groups of proteins that are present in high amounts that serve to provide a store of amino acids for use during germination and seedling growth. These storage proteins are of particular importance because they determine not only the total protein content of the seed but also its quality for various end uses (Shewry *et al.*, 1993).

Despite wide variation in their detailed structures, all seed storage proteins have a number of common properties. First, they are synthesized at high levels in specific tissues and at certain stages of development. Their synthesis is regulated by nutrition, and they act as a sink for surplus nitrogen. However, most protein also contain cysteine and methionine, and adequate sulfur is therefore also required for their synthesis. Differences in speed of water absorption verified in different species would be mainly related to seed chemical composition; higher protein content usually corresponds to a

faster water uptake by soybean seeds (Shewry *et al* 1993). Despite the numerous health importance of soybean seed protein content, the negative correlation with yield remains a setback for cultivation of high protein soybean (Wehrmann *et al.*, 1987).

KNUST



CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY AREA

The laboratory investigations were carried out at the Grains and Legume Development Board (GLDB) of the Ministry of Food and Agriculture while the nutrients analyses were conducted at the Soil Science Laboratory at the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology also in Kumasi, Ghana.

3.2 SOURCE OF SEEDS

Seeds of nine (9) soybean genotypes harvested between October and November, 2011 were obtained from three different locations in Ghana. Four (4) of the varieties: Anidaso (CRI), Nangbaare, TGX-1904-6F and TGX-1903-7F were obtained from the Crops Research Institute (CRI) in Fumesua, Kumasi, while one variety: Anidaso (Mampong) was obtained from the Grains and Legumes Development Board (GLDB) farm at Mampong Ashanti. The remaining four (4) varieties: Sallintuya 1 and 2, Quarshie and TGX1834-5E were obtained from the Savannah Agricultural Research Institute (SARI), in Tamale, Ghana. The various samples were sun-dried to the same basal moisture levels of 8% before using them in the investigations.

3.3 SAMPLE SIZE

The samples received were sorted for pure seeds component. One kilogram each of the pure seeds was used for the investigations. All parameters were assessed initially (Appendix D) to ascertain their pre-storage viability. The samples were divided into two lots (500g) each, packaged in polythene bags, well sealed and then placed under the two separate storage conditions.



Plate 1. Sampling of soybean seeds for experiment

3.4 STORAGE ENVIRONMENTS UNDER REVIEW

Two storage environments, ambient ($27^{\circ}\text{C}\pm 3$; 79.6%) (Appendix B1) and 79.6% RH the cold room ($15^{\circ}\text{C}\pm 3$; 65% RH) (Appendix B2) at the Grains and Legume Development Board (GLDB) Head Office and GLDB Asuoyeboah respectively, were used during the study. The initial germination percentages of the samples were observed to range from

72-99%. The highest germination percentage (99%) was recorded for Anidaso (M) while Quarshie recorded the lowest (72%). The seeds were stored for 120 days (November-March).

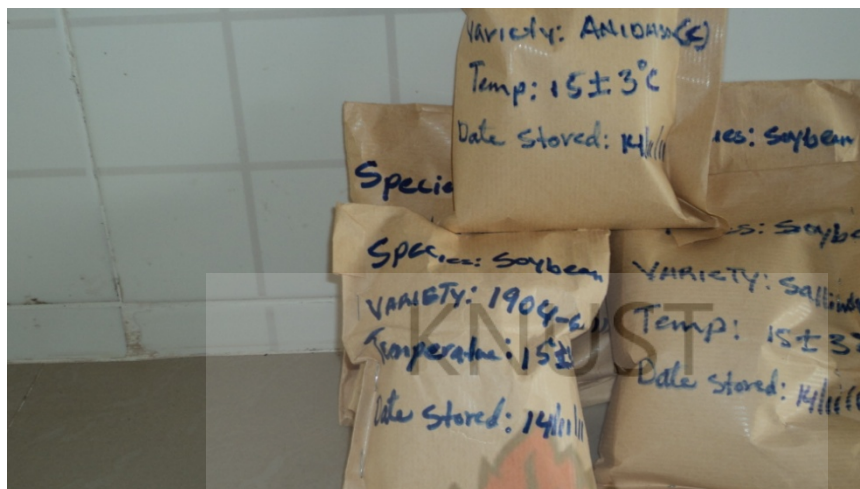


Plate 2. Soybean seeds packaged in paper bags and stored in cold room at temperature of $15^{\circ}\text{C}\pm 3$ /65% RH

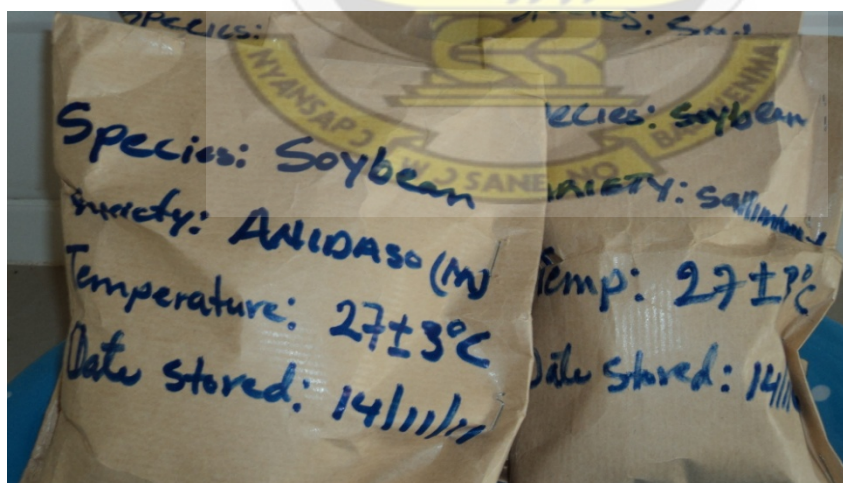


Plate 3. Soybean seeds packaged in paper bags and stored under ambient temperature of $27^{\circ}\text{C}\pm 3$ /79.6% RH

3.5 EXPERIMENTAL DESIGN AND PROCEDURES

The experimental design was a 9x4x2 CRD factorial comprising 9 varieties, two storage environments and 4 storage periods. Least significant difference (LSD) at 5% was used to compare the treatment means. The seeds in storage were sampled periodically (30, 60, 90 and 120 days) to determine quality by conducting standard germination test with four hundred seeds (100 seeds/rep) (ISTA 2005). Analysis of variance of all parameters (protein, oil, viability, vigour and seedlings dry weight) was computed using Statistix version 8.

3.6 STUDY VARIABLES

Various variables investigated during the study were characteristics of the seeds, Protein effect on soybean seeds storage quality, oil effects on the viability of the seeds, moisture content over time, storage environments and storage period effect on soybean seed quality.

3.7 LABORATORY ANALYSIS

3.7.1 Germination Testing

In order to evaluate the effects of the various variables on the quality of soybean seeds after storage, germination and vigour analysis were conducted. Germination counts were made on day four to serve as vigour indicator as well as the taking of the seedling dry weights (SDW) (Perry, 1981) and fourth day seedling count as vigor indicators of the

various samples. Final germination counting was recorded 8 days after planting and total percent germination determined (ISTA, 2007).



3.7.2 Seed Vigour Testing

According to ISTA (2005) seed vigour is the sum of those properties that determine the activity and performance of seed lots of acceptable germination in a wide range of environments. Thus a vigorous seed lot should perform well even if the environmental conditions are not optimal for growth of that specific species. The vigour of nine soybean genotypes was determined using seedlings dry weight (SDW) (Perry, 1981). Twenty-five seedlings from each replication of the eighteen samples were selected at random. Each sample was enveloped and oven dried at 80°C using GALLENKAMP size 2 and 5 ovens for twenty-four hours to dry. After wards, the dried samples were cooled and weighed using analytical balance. The recorded weight was divided by the number of seedling (25) to obtain the seedling dry weight. The vigour was then calculated by multiplying the seedling dry weight by the germination percentage (%) of each replication as indicated below.

Vigour = Germination % $\times$ Seedling dry weight (Perry, 1981).



Plate 6. Evaluation of germinated soybean seeds after 8 days of sowing

3.7.3 Nutritional Analysis

Protein and oil content of seeds of soybean varieties were determined using Kjeldahl method and Soxhlet method, respectively.

3.7.3.1 Crude protein determination

The crude protein content of soybean seeds was determined by the modification of a technique originally devised by Kjeldahl. The micro-Kjeldahl technique is adopted to estimate the total N content in the samples. With this method, the N in protein or any organic material is converted to ammonium sulphate by concentrated H_2SO_4 . To determine the protein contents, a 25 g sample of dry soybean seeds from each lot was finely ground. Nitrogen (N) was determined by micro-Kjeldahl technique for each environment and genotype. Crude protein content ($\text{N} \times 5.71$) was calculated by using 5.71 as the conversion factor (William, 1980).

Procedure

To determine the protein contents, 100mg sample (milled) was weighed and transferred to a 30 ml digestion flask. 1.9g potassium sulphate, 80mg mercuric oxide and 2ml of concentrated H_2SO_4 were added to the digestion flask. Boiling chips were added and the sample was digested for an hour till the solution became colorless and was allowed to cool. The samples were diluted with distilled ammonium- free water and transferred to the distillation apparatus. Hundred (100) ml conical flasks containing 5ml boric acid

solution (stabilizes the ammonium so it does not evaporate) was used with a few drops of mixed indicator below the surface of the solution. Ten (10) ml of the mixture was added in a flask with 20ml (40%) sodium hydroxide. Sodium thiosulphate solution was added and put into the test solution in the apparatus. At least 15 to 20 ml of distillate is collected using a clean condenser tip to titrate the solution against the standard acid until the solution obtains violet color. The seed protein contents were expressed on a dry matter basis (William, 1980).

Calculation of protein content in soybean seeds

The Nitrogen (N) content each sample was calculated as follows:

$$N(g\ kg^{-1}) = \frac{(ml\ HCl - ml\ blank) \times Normality \times 14.01}{Weight\ of\ sample\ (g) \times 10}$$

3.7.3.2 Ether extract (oil) determination

Procedure

The oil content was extracted with n-hexane using Automatic Soxhlet apparatus. Two (2) grams of each sample (milled) was put in filter paper and folded properly. A second filter paper was wrapped around it and a piece of cotton wool placed at the top to evenly distribute the solvent as it drop on the sample during extraction. The sample packet was placed in the butt tubes of the Soxhlet extraction apparatus. The extraction flask was placed in an oven at 110°C for about 5 minutes, then cooled and weighed. The extraction continued with petroleum ether for 2-3 hours without interruption by gently heating, allow cooling and then dismantle the extraction flask. The ether was then evaporated using water bath until there was no odor of the ether remaining. It was then

cooled at room temperature and the extraction flask was re- weighed (William, 1980). Oil percentage was determined by weight differences). Seed oil contents were expressed on a dry matter basis (William, 1980).

Calculation of Soybean seeds Oil Content

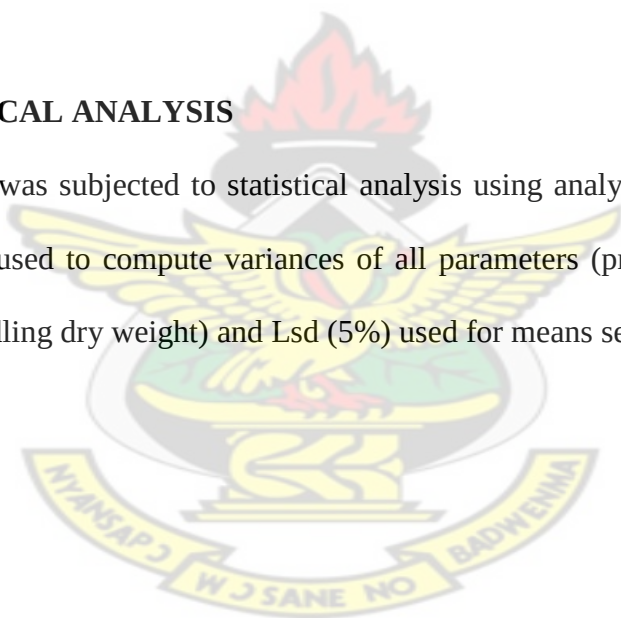
$$(A+B) - A = B,$$

$$\% \text{ Ether Extract} = \frac{B}{C} \times 100 \quad (4)$$

Where A = Flask weight, B= ether extract weight. C = sample weight

3.8 STATISTICAL ANALYSIS

Data collected was subjected to statistical analysis using analysis of variance. Statistix version 8 was used to compute variances of all parameters (protein, oil, viability, and vigour and seedling dry weight) and Lsd (5%) used for means separation.



CHAPTER FOUR

4.0 RESULTS

4.1 EFFECT OF STORAGE PERIOD ON MOISTURE CONTENT OF SOYBEAN SEEDS

Table 4.1 shows the effect of storage period on moisture content of soybean seeds. The highest moisture content was recorded in seeds stored for 120 days while the lowest was recorded in those stored for 30 days and they ranged from 8.19% to 8.48% during the study period.

Table 4.1 Effect of Storage Period on the Moisture Content of Soybean Seeds

Storage period (days)	Soybean seed moisture content (%)
30	8.19
60	8.24
90	8.27
120	8.48
Lsd (0.05)	0.13
CV (%)	3.2

The soybean seeds stored for 120 days had the highest moisture content of 8.48% and seeds stored for 30 days had the lowest moisture content of 8.19%. Significant differences ($P < 0.05$) were observed in the moisture content of the soybean seeds among the different storage periods used.

4.2 EFFECTS OF STORAGE PERIOD AND ENVIRONMENTS ON MOISTURE CONTENT OF SOYBEAN SEEDS

Table 4.2 shows the effect of storage period and temperature on the moisture content of soybean seeds. The moisture content of the soybean seeds stored under the two storage conditions and four storage periods were observed to have been influenced. The moisture contents ranged from 8.03% to 8.49.

Table 4.2 Effect of Storage Period and Environments on the Moisture Content of Soybean Seeds

Storage Period (Days)	Storage Environment		Means Moisture Content (%)
	Cold (15°C±3/65% RH)	Ambient (27°C±3/79.6% RH)	
30	8.03	8.15	8.09
60	8.20	8.18	8.19
90	8.21	8.24	8.26
120	8.47	8.49	8.48
Means (%) Storage Temperature (°C)	8.23	8.27	
Lsd_{moisture}	= 0.06		
CV(%)	= 3.20		

Table 4.2 shows the effect of storage period and environments on the moisture content of soybean seeds. Significant differences ($P < 0.05$) were observed in the moisture content of the soybean seeds under both storage temperatures for the different storage periods used (Appendices B 1 and 2).

4.3 OIL CONTENT OF SOYBEAN SEEDS

Table 4.3 shows the oil contents of the various soybean genotypes. The oil levels in the soybean varieties ranged between 8.03% and 13.06%.

Table 4.3 Varietal Differences in Oil Content of Soybean Genotypes after 120 days in storage

Genotypes	Oil Contents (%)
Anidaso(M)	10.01
Anidaso(C)	9.83
Quarshie	12.47
Sallintuya 1	8.03
Sallintuya 2	8.06
Nangbaare	8.04
TGX1834-5E	9.04
TGX-1903-7F	12.04
TGX-1904-6F	13.01
Lsd (0.05)	0.34
CV (%)	6.85

Table 4.3 above shows varietal differences among the genotypes in oil content. Genotype TGX-1904-6F recorded the highest oil content of 13.01%, followed by Quarshie with oil content of 12.47% while Sallintuya 1 recorded the lowest oil content of 8.03%. There were significant differences ($P < 0.05$) observed among the soybean genotypes in terms of oil content.

4.4 EFFECT OF GENOTYPE AND STORAGE PERIOD ON PROTEIN CONTENT OF SOYBEAN SEEDS

The effects of genotypes and storage period on the protein content of the various soybean varieties are presented in Table 4.4.

Table 4.4 Effect of Genotypes and Storage Period on Protein Content of Soybean Seed

Genotypes	Storage Period (Days)				Mean Protein content (%)
	30	60	90	120	
Anidaso(M)	40.10	40.19	40.09	40.11	40.12
Anidaso(C)	42.14	42.11	42.11	42.02	40.20
Quarshie	37.70	37.79	37.86	37.86	37.80
Sallintuya 1	37.79	38.43	39.16	39.89	38.82
Sallintuya 2	41.38	41.49	41.56	41.60	41.51
Nangbaare	42.14	42.14	42.26	42.65	43.65
TGX-1834-5E	40.03	40.04	40.04	40.50	42.02
TGX-1903-7F	39.18	39.03	39.01	39.01	39.06
TGX-1904-6F	38.78	39.33	39.86	40.13	38.55
Means	39.98	40.06	40.20	40.30	40.19
Lsd_{variety} = 0.04					
Lsd_{storage period} = 0.06					
Lsd_{variety x storage period} = 0.13					

The protein content varied among genotypes ranging between 37.7 and 42.7% among the varieties as indicated above. The maximum protein content of (42.7%) was recorded for Nangbaare and minimum (37.7%) in Quarshie. Generally, the protein content of the soybean seeds increased with storage period. Storage period 120 days showed the

highest protein content while the lowest was recorded after 30 days of storage. The result of the interaction between variety and storage period (Table 4.4) showed Nangbaare to record the highest protein content when stored after 120 days and the least was also recorded in Quarshie stored after 30 days. There were significant differences ($P < 0.05$) observed among soybean genotypes and storage period on protein content.

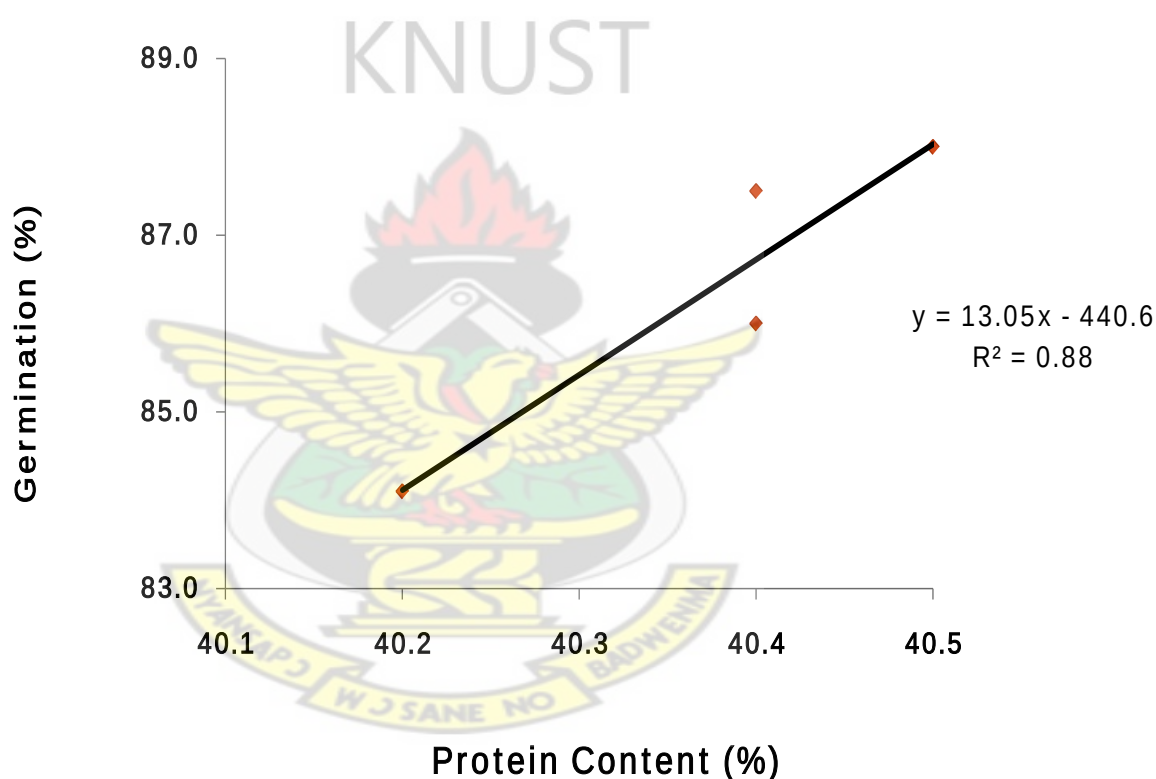


Figure 1. Relationship between seed protein content and germination of soybean seeds stored under ambient environment ($27^{\circ}\text{C} \pm 3/79.6\% \text{RH}$) for 120 days

The Protein contents and storage duration positively correlated with the germination percentages of the genotypes stored under ambient temperature. As the seeds aged, the

protein contents increased as germination also increased. The highest germination percentage and protein content were observed after 120 days of storage while the lowest protein content and germination percentage were recorded after 30 days. The protein contents range from 40.2 to 40.5% and the germination were between 84.3 and 88.4. Significant differences ($P < 0.05$) were observed in protein content and the germination percentages as the storage period increased.

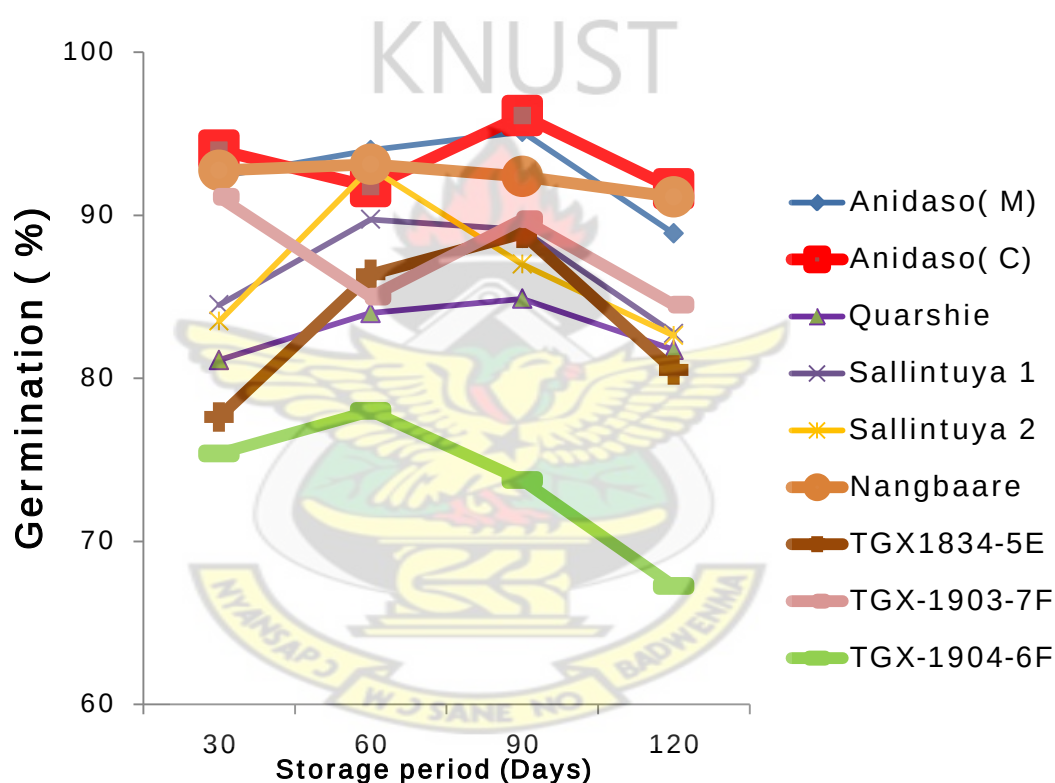


Figure 2. The effects of genotypes and storage period on germination percentage of soybean seeds

Differences among the genotypes in germination was also significant ($P < 0.05$) as indicated in (Appendices A4). Except 1904-6F, all the other genotypes studied

maintained more than 80% germination percentages up to 120 days of storage. Anidaso (C) stored for 90 days had the highest germination percentage of 96.12%, followed by Anidaso (M) stored for 90 days which recorded a germination percentage of 95.12%. The lowest germination percentage of 67.25% was recorded for TGX-1904-6F stored for 120 days.

4.5 EFFECT OF GENOTYPES AND STORAGE ENVIRONMENT ON GERMINATION PERCENTAGE OF SOYBEAN SEEDS

The effect of soybean variety and storage temperature on germination percentage of soybean seeds is presented in Table 4.5.

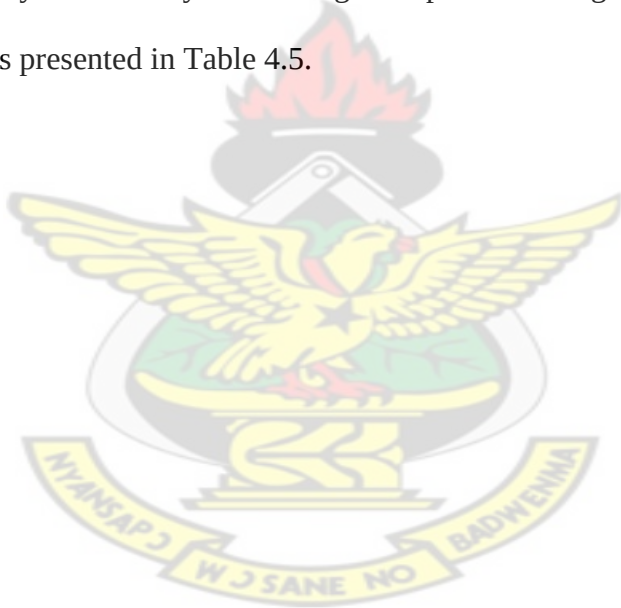


Table 4.5 Effects of Genotypes and Storage Environment on Germination Percentage of Soybean Seeds after Storage

Genotypes	Storage Environments		Means Germination Percentage (%)
	Cold room (15 °C / 65%RH)	Ambient condition (27 °C / 79.6%RH)	
Anidaso(M)	92.88	92.31	92.60
Anidaso(C)	93.81	93.06	93.44
Quarshie	82.88	83.00	82.94
Sallintuya 1	86.12	86.94	86.53
Sallintuya 2	87.69	85.12	86.41
Nangbaare	92.31	92.38	92.35
TGX1834-5E	82.12	84.56	83.34
TGX-1903-7F	88.81	86.38	87.60
TGX-1904-6F	75.00	72.19	73.60
Means	86.85	86.23	86.54
Lsd variety	= 1.68		
Lsd storage temperature	= 0.79		
Lsd variety x storage temperature	= 2.38		

Irrespective of the storage environment, genotype Anidaso (C) stored under both conditions recorded the highest germination percentage of 93.81% and 93.06% for 15°C and 27°C respectively. Most of the genotypes also recorded germination percentage above 80 percent. However, soybean genotype TGX-1904-6F kept under ambient condition had the lowest germination percentages of 75 and 72.19% under 15°C and 27°C respectively. Significant differences ($P < 0.05$) were observed in germination percentage among the soybean genotypes stored under the two storage environments.

4.6 EFFECT OF STORAGE PERIOD AND STORAGE ENVIRONMENT ON GERMINATION PERCENTAGE OF SOYBEAN SEED AFTER STORAGE

Table 4.6 shows the effect of storage period and storage temperature interaction on germination percentage of soybean seeds. Soybean seeds stored for 90 days and kept in cold room had the highest germination percentage of 88.97% followed by seeds stored for 60 days in the same environment with a germination percentage of 88.69%.

Table 4.6 Effects of Storage Period and Storage Environment on Germination Percentage of Soybean Seed after Storage

Storage Period	Storage Temperature			Means Germination Percentage (%)
	Cold (15 °C/65%RH)	Room Ambient (27 °C /79.6%)	condition	
30 days	85.22	86.47		85.85
60 days	88.69	87.83		88.26
90 days	88.97	88.14		88.56
120 days	84.50	82.42		83.46
Means (%)	86.85	86.22		86.53
Lsd storage period	= 1.12			
Lsd storage temperature	= 0.79			
Lsd storage period x storage temperature	= 1.58			

Soybean seeds stored for 120 days and kept under ambient temperature (27°C/79.6%RH) had the lowest germination percentage of 82.42%. Seeds stored for 90 days and at 15°C/65%RH had the highest percentage of 88.97. Significant differences

($P < 0.05$) in germination percentages were observed among the different storage periods and storage environments.

4.7 EFFECT OF GENOTYPES AND STORAGE PERIOD ON SEEDLINGS VIGOUR OF SOYBEAN SEEDS AFTER STORAGE

Table 4.7 shows the effect of variety and storage period on germination vigour of soybean seeds.

Table 4.7 Effect of Genotypes and Storage Period on Seedlings Vigour of Soybean Seeds

Genotypes	Storage Period (Days)				Means Seed Vigor (%)
	30	60	90	120	
Anidaso(M)	8.88	8.50	6.75	5.63	7.44
Anidaso(C)	8.38	9.00	8.50	8.00	8.47
Quarshie	7.50	7.38	6.25	5.88	6.75
Sallintuya 1	7.50	7.00	6.63	5.75	6.72
Sallintuya 2	8.13	6.63	6.13	5.13	6.50
Nangbaare	8.25	8.38	7.88	7.63	8.03
TGX-1834-5E	8.00	7.25	6.50	6.75	7.13
TGX--1903-7F	6.38	8.00	5.88	6.38	6.66
TGX-1904-6F	7.63	8.00	8.13	5.88	7.41
Means (%)	7.85	7.79	6.96	6.33	7.23
Lsd variety	= 0.482				
Lsd storage period	= 0.321				
Lsd variety x storage temperature	= 0.963				

Anidaso (C) stored for 60 days recorded the highest germination vigour of 9.00, followed by Anidaso (M) stored for 30 days which recorded germination vigour of 8.88. The lowest germination vigour of 5.13 was recorded for Sallintuya 2 stored for 120 days. Significant differences ($P < 0.05$) were observed in the germination vigour among the varieties and storage periods.

4.8 EFFECT OF GENOTYPES AND STORAGE PERIOD ON SEEDLING DRY WEIGHTS OF SOYBEAN SEED

The effect of variety and storage period on seedling dry weight is presented in Table 4.8. There were significant differences ($P < 0.05$) among the genotypes in terms of seedling dry weight. It was observed that there were negative correlations between the storage period and dry weight. As storage period increased, seedlings dry weight decreased. The seedling dry weight ranged from 0.07 to 0.11 g.

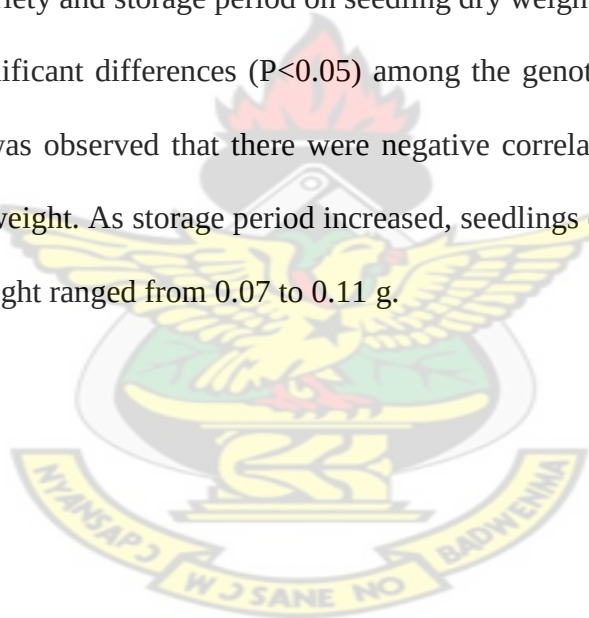


Table 4.8 Effect of Genotypes and Storage Period on Soybean Seedling Dry Weights

Genotypes	Storage Period (Days)				Means (g)
	30 days	60 days	90 days	120 days	
Anidaso(M)	0.09	0.10	0.07	0.07	0.08
Anidaso(C)	0.09	0.09	0.09	0.09	0.09
Quarshie	0.09	0.09	0.07	0.07	0.08
Sallintuya 1	0.08	0.08	0.08	0.08	0.08
Sallintuya 2	0.08	0.08	0.07	0.07	0.07
Nangbaare	0.09	0.09	0.09	0.09	0.09
TGX-1834-5E	0.10	0.09	0.07	0.08	0.09
TGX-1903-7F	0.09	0.08	0.07	0.07	0.08
TGX-1904-6F	0.11	0.10	0.11	0.09	0.10
Means (g)	0.09	0.09	0.08	0.08	0.08
Lsd_{variety}	= 0.006				
Lsd_{storage period}	= 0.004				
Lsd_{variety x storage period}	= 0.012				

Soybean genotype TGX-1904-6F stored for 30 days and 90 days recorded the highest seedling dry weight of 0.11g. Soybean genotypes Sallintuya-2, Anidaso (M), Quarshie and accessions 1903-7F and TGX-1834-5E stored for 90 and 120 days recorded the least seedlings dry weight of 0.07g. Anidaso (M) stored for 60 days recorded the second highest seedling dry weight of 0.10g. Significant differences ($P < 0.05$) were observed among the soybean genotypes and storage periods on seedling dry weight.

4.9 EFFECT OF GENOTYPES AND STORAGE ENVIRONMENT ON SEEDLING DRY WEIGHT OF SOYBEAN

The effect of variety and storage temperature on seedlings dry weight of soybean is presented in Table 4.9.

Table 4.9 Effect of Genotypes and Storage Environment on Seedlings Dry weight

Genotypes	Storage Environment		Means Seedling Dry weight (g)
	Cold Room (15 °C±3/65%RH)	Ambient condition (27 °C±3 /79.6%)	
Anidaso(M)	0.08	0.08	0.08
Anidaso(C)	0.09	0.09	0.09
Quarshie	0.08	0.08	0.08
Sallintuya 1	0.08	0.08	0.08
Sallintuya 2	0.07	0.07	0.07
Nangbaare	0.09	0.09	0.09
TGX1834-5E	0.09	0.08	0.09
TGX-1903-7F	0.08	0.07	0.08
TGX-1904-6F	0.10	0.10	0.10
Means (g)	0.09	0.08	0.08
Lsd_{variety}	= 0.003		
Lsd_{storage temperature}	= 0.006		
Lsd_{variety x storage temperature}	= 0.008		

Seedling dry weight ranged from 0.07 g to 0.10 g among the various genotypes assessed during the current study. Maximum seedling dry weight of 0.10 g was recorded in soybean genotype TGX-1904-6F kept under storage environments of 15°C±/65% RH

and $27^{\circ}\text{C} \pm 79.6 \text{ RH } \%$. However, genotypes Sallintuya 2 kept under both environments ($15^{\circ}\text{C} \pm 65\% \text{ RH}$ and $27^{\circ}\text{C} \pm 79.6 \text{ RH } \%$) and TGX-1903-7F stored under ambient condition recorded the lowest seedling dry weight of 0.07g. Significant differences ($P < 0.05$) were observed among soybean genotypes and storage environment on seedlings dry weight.

KNUST



CHAPTER FIVE

5.0 DISCUSSION

The effects of protein, oil, storage environment as well as the duration of storage were collectively and individually evaluated as discussed below: The nine soybean genotypes; Anidaso (M), Anidaso (C), Quarshie, Sallintuya 1, Sallintuya 2, Nangbaare, TGX-1903-7F and TGX-1904-6F responded differently to each treatment and the treatments also individually and collectively affected each variable.

5.1 VARIETAL DIFFERENCES OF SOYBEAN SEED PROTEIN AND OIL CONTENTS

The protein and oil contents varied among the nine genotypes studied during the investigations. Variations in oil content among genotypes were significant. Similarly, variation in the genotypes protein content was significant (Appendix A). Genotypes with higher protein contents were found to have lower oil contents and vice versa. This result collaborate the work of Schwender *et al.* (2003) who observed negative correlation in the protein and oil contents of soybean genotype and stated that every 1% reduction in total oil content will lead to a 2% increase in total protein content.

5.2 EFFECTS OF SOYBEAN SEED PROTEIN CONTENT ON SOYBEAN SEEDS QUALITY

The protein contents of the various soybean genotypes studied were observed to have significant effects on the germination potential and vigor of the seeds for the duration of

storage (four months) and the temperature at which they were stored. Genotypes containing higher protein were observed to have lower seedling dry weights. In the investigations, the varieties which were found to contain higher protein showed up to have the maximum germination percentages. As shown by the results of this study, Nangbaare which had the highest protein content and vigor, among the varieties stored under both ambient and cold room conditions, was among the first three varieties with the highest germination percentages but recorded lower seedling dry weight. This result is similar to that of (Shewry *et al.*, 1993) who associated the relationship between seed protein contents and germination with chemical composition; seeds with higher protein content usually correspond to a faster water uptake and maximum germination.

5.3 EFFECT OF SEED OIL CONTENT ON SOYBEAN SEEDS STORABILITY

Seed oil content was observed to have significant influence on the germination of soybean as revealed in this study. Varieties with higher oil contents recorded the lowest germination percentages. TGX-1904-6F which had the highest oil content had the lowest germination percentage. When the effects of protein and oil on the viability of soybean seeds were compared, it was evident that seed oil had negative significant effects on the storage quality of soybean seeds with adverse effect on germination rather than the protein content. Kausar *et al.*, (2009) reported similar result stating that oil content of soybean seeds readily oxidize and caused seeds to deteriorate leading to poor germination.

5.4 STORAGE PERIOD EFFECTS ON THE GERMINATION OF SOYBEAN SEEDS

Among the variables studied, storage periods were also observed to have a significant influence on soybean seed storability and germination as indicated by reduced germination potential and shrinking of seeds after 120 days of storage. Genotype 1904-6F stored for 120 days recorded the lowest germination percentages (67.25%) below certification level as compared to seeds stored for 30-90 days. The highest germination percentage was recorded for the rest of the varieties stored up to 90 days indicating that seeds may conveniently be stored for the period 90 days and still keep this quality considering the storage environments and moisture content. Germination potential declined with time. However, the trend of the reduction of germination potential took place independently among the varieties. It was clear that the reduction was more accentuated as the storage period increased. Baskin and Delouche (1973) also confirmed that chemical changes occurred in soybean seeds in storage due to temperature and this caused the seed quality to change over time thereby decreasing germination. Basavaraju (1996) also observed significant differences among varieties in germination where in some cultivars tested by him (TMV-2) maintained germination above the minimum seed certification standards (70%).

5.5 EFFECTS OF STORAGE ENVIRONMENTS ON SOYBEAN SEEDS QUALITY

Storage temperatures were also observed to influence the seed germination and storage quality as indicated by variations in germination potential of seeds stored at different

storage temperatures. The seeds stored at 27°C and 79.6% relative humidity recorded the minimum germination percentages as compared to seeds stored at 15°C and 65% relative humidity which recorded the highest germination percentage. This result agreed with that of Burris (1980) who reported that the fast deterioration of the soybean is influenced by storage temperature in association with moisture and the storage period. Whigham and Minor (2003) also reported that ambient temperature and relative humidity are decisive in the process of loss of seed viability and alterations in seed color and composition.

Similarly, Arulnandhy and Senanayake (1991) reported that soybean cultivars stored under controlled temperature (20°C) and ambient conditions (18-26°C) declined rapidly in viability and seeds stored under ambient conditions beyond three months germinated poorly. Shelar *et al.* (2008) also reported that temperature and relative humidity prevailed during storage and this affected the germination of soybean seeds stored at 30°C and maximum reduction in germination percentage was observed when seeds were stored for 50 days.

5.5.1 Effects of Storage Duration on Protein and Oil Contents of Soybean Seeds

Storage period was observed to influenced both protein and oil contents of the genotypes. Some of the genotypes increased in parameters while others decreased with storage period. The protein contents of soybean seeds were observed to increase while the oil content decreased as the storage duration increase. This result is similar to Orthoefer (1978), who reported that qualitative changes of soybeans during storage

contribute to the loss of oil. Narayan et al. (1988a), also reported that physical, chemical and biochemical alterations may occur in soybeans, depending on conditions and storage duration.

5.5.2 Storage Environments Effect on Soybean Oil and Protein Content

Storage temperatures used during the study were observed to influence protein and oil contents of soybean among the genotypes studied. Irrespective of the storage environment genotype Anidaso (C) recorded the highest germination whereas genotype TGX-1904-6F had the lowest. Differences in the protein and oil contents varied among genotypes under the two storage environments. The highest protein was recorded in seeds stored under $15^{\circ}\pm C/65\%RH$ while the lowest protein content was recorded for seeds kept at $27^{\circ}\pm 3C/79.6\%RH$. Similarly, the effects of environmental conditions on the oil and protein content of soybean seeds were reported by (Zhang *et al.*, 2005) who observed the effect of storage environment on the quality of soybean seeds under different environments. The researchers also reported that environmental conditions had the greatest effect on the oil and protein content of soybean seeds when they stored soybean seeds at different temperatures.

5.5.3 Effects of Storage Period and Storage Environments on Soybean Vigour

Index and Seedlings Dry Weight

Storage periods and storage environment similarly affected soybean vigour and seedlings dry weight significantly (Appendices A4 and 5. The vigour of seeds declined as seed age increased as observed in the nine genotypes assessed during this study. As

the seed age in storage increased from zero to several days, the vigour decreased and the seed declined in vigour. According Murthy *et al.* (2003), loss of seed vigour is associated with biochemical deterioration during seed ageing. Anidaso (C) recorded highest vigour (9.00%) and the lowest (5.13%) was in Sallintuya 2 after 120 days of storage.

Irrespective of the locations and crops, Anidaso (C) also recorded significant higher seedling dry weight (1.89g) while Anidaso (M) recorded lower seedling dry weight (1.86g) after the second month of storage. A similar trend was noticed up to the fourth month of storage. Makkawi & van Gastel (2006), also reported a reduction in seedling dry weights after different periods of accelerated ageing treatment on seeds of different varieties of lentil (*Lens culinaris* Medikus).

5.5.4 Effects of Storage Period and Environment on Moisture Content of Soybean Seeds

Statistically, the effect of storage duration and storage environment were significant on the moisture content of the seeds (Appendix A1 :). Even though there were slight increases observed in the moisture content among the genotypes but did not influence the viability of the genotype. The moisture content slightly increased under both storage environments. Seeds stored under 15°C±/65%RH for 30 days recorded the lowest moisture (8.03) while the highest moisture content was also recorded in seeds stored under (27°±C/79.6%RH) for 120 days. Delouche (1982) gave a similar finding stating that storability of seeds is largely determined by its pre-storage history and the condition and length of storage.

5.6 EFFECT OF GENOTYPES/VARIETIES ON SEED QUALITY

Variations among the genotypes were significant ($P < 0.05$) in this study. There were varietal differences in most of the parameters assessed (oil, protein, germination, vigour and seedlings dry weight). Similar results were reported by Venkatareddy *et al.* (1992) who observed varietal differences in the storability of soybean. The authors found that Monetta variety maintained highest germinability (66.40%) as compared to Hardee (59%) followed by KHSB-2, Bragg and PK-471 even after nine months of storage under ambient conditions. Kalavathi *et al.* (1994) also reported variations in performances of soybean genotypes. Kurdikeri *et al.* (1996) as well observed significant differences between soybean varieties germination and reported that variations occurred among soybean varieties tested and some maintained germination above the minimum seed certification standard (70%) after several months under ambient storage conditions. All these reports confirm the findings presented in this study.

5.7 THE EFFECTS OF PROTEIN AND OIL CONTENT ON GERMINATION RESPONSES OF SOYBEAN

In all, protein content had a positive effect on germination while oil content had negative effects on germination. The oil content had negative significant effect on soybean seeds quality while protein had positive effects on the germination performance. Rupollo *et al.*, (2004) working with soybean reported that soybeans are subjected to qualitative and quantitative losses due to several factors such as lipid

degradation in soybean seeds due to biochemical processes, such as respiration or oxidation. There were significant differences ($P<0.05$) in the germination percentage.

KNUST



CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

In this study, the following parameters: germination percentages, seedlings vigour, seedling dry weights, protein and oil contents were evaluated. The main effects of storage periods (30, 60, 90 and 120 days), storage environments (cold room and ambient conditions) and nine soybean varieties: Anidaso (M), Anidaso (C), Quarshie, Sallimtuya-1, Sallimtuya-2, Nangbaare, TGX-1834-5E, TGX-1903-7F and TGX-1904-6F collected from three localities in Ghana were assessed. Varietal differences among genotypes in all the parameters were significant. The genotypes varied in their protein and oil levels.

6.1 OIL EFFECTS

Seeds oil content had a positive relationship with seedling dry weight but had negative effects on germination. Significant variations ($P < 0.05$) in oil content were observed among the genotypes (Appendix A2). In general, oil content of the seeds changed over time but the trend of changes was irregular among the genotypes. Genotypes TGX-1904-6F, Anidaso (M), Anidaso (C), Quarshie, Sallimtuya-1 & 2 and TGX-1834-5E experienced increase, while Nangbaare and TGX-1903-7F decreased in oil content. Oil content positively correlated with vigour but had negative effects on seed germination. Genotypes with higher oil contents recorded lower percent germination and seedling dry weights but were equally vigorous.

6.2 PROTEIN EFFECTS

The protein contents also varied among the varieties showing similar irregular trends as reported for the oil contents. The protein content was observed to have influenced seed germination positively. The highest germination percentages were recorded in genotypes with higher protein contents.

The Results led to the Following Conclusions:

1. Varietal differences in seed oil and protein contents existed between the soybean genotypes.
2. Whereas high seed protein content resulted in higher germination, high oil content led to poor germination among the genotypes.
3. Except genotype TGX-1904-6F, all the other genotypes maintained higher germination up to 120 days
4. Oil content had inverse relationship with the protein content.

6.3 RECOMMENDATIONS

From the study, the following conclusions and recommendations can be made:

- i. Oil and protein contents of soybean seeds should be analyzed before storage.
- ii. Genotypes with high oil content and stored under ambient condition should not be stored beyond 90 days to avoid loss of quality.
- iii. Moisture content of soybean seeds for storage should be kept at 8%.
- iv. The duration for the experiment should be extended beyond 120 days in order to conclude whether protein content has negative effect on germination.

REFERENCES

- Abbey, T.K., Ameyibor, K., Alhassan, A., Essiah, J. W., Fometu, E. and Wiredu, M. B.** (2001). Integrated science for senior secondary schools. GAST. MOE. 75-78.
- Acasio, A.** (2010). Handling and storage of soybeans and soybean meal. *International Journal Plant Production*, Vol.53 (4): pp. 41-50.
- Adu-Dapaah, H.K., Asafo-Adjei, B., M., Asiedu, E.A., Owusu-Akyaw M. and Amoah, S** (2004). Sustainable soybean production in Ghana. Paper presented at the Garden City Radio. 8pp. (Unpublished)
- Arulnandhy, V. and Senanayake, D.A.,** (1991). Changes in viability, vigour and chemical Composition of soybean seeds stored under humid tropical conditions. *Legume Research*, 14 (3): 135-144.
- Balešević-Tubić, S.,** (2001). Influence of aging on the viability and biochemical changes sunflower seeds. Doctoral dissertation, Faculty of Agriculture, Novi Sad. Bales, 30(47): 61-67.
- Balešević-Tubić, S., Tatić, M., Hrutić, M., Miladinović, J., Maksimović, L.,** (2007b). The influence of aging process on germination and seedling growth of sunflower seed. In: *Proceedings of The First Joint PSU-UNS International Conference on BioScience: Food, Agriculture, and the Environment*, Thailand: 198-202.
- Basavaraju, G.V.,** (1996). Contribution of production factors on seed yield and quality of groundnut. In: *Proceedings of National Workshop on Groundnut Seed Technology*, University of Agricultural Sciences, Raichur. pp. 63-66.

- Baskin**, C. C. and Delouche, J.C. (1973). Accelerated ageing techniques for predicting the relative storability of seed lots. *Seed Science & Technology*. 14: 427-452.
- Bass**, L. N., Janick, J. (2011). Seed Viability During Long –Term Storage. Horticultural Reviews, Volume 2 Summary. Published online, 2011.
- Bhattacharya**, K. and Raha, S. (2002). Deteriorative changes of maize, groundnut and soybean seeds by fungi in storage. *Mycopathologia* 155, 135-141.
- Borget**, M. (1992). Food Legumes. The Tropical Agriculturalist. CTA. 103pp.
- Brooker**, D.B., Bakker-Arkema, F.W. and Hall, C.W. (1992). *Drying and storage of grains and oilseeds*, Springer, New York, United States.
- Burris**, J.S. (1980). Maintenance of soybean seed 9th International Working Conference on Stored Product Protection 36 quality in storage as influenced by moisture, temperature and genotype. *Iowa State Journal of Research* 54, 377-389.
- Ching**, C.C., Andrews, H., Baskin, C.C. and Delouche, J.C. (1972). Influence of quality of seed on growth development and productivity of some horticultural crops. Proc. Int. Seed Test. Assoc. 37: 923-936.
- Chung** G., Singh, R.J. and Nelson, R.L. (2006). Genetic resources, chromosome engineering, and crop improvement: *Oilseed Crops, Volume 4*. Crop Research. p.15.
- Delouche**, J.C. (1980). Environmental effects on seed development and quality. *Horticultural Science* 15:775 -780.
- Delouche**, J. C. (1982). Physiological changes during storage that affect soybean seed quality. P 57- 66 in: Sinclair, J. B. and J. A. Jackobs, eds. Proc. Soybean Seed

Quality and Stand Establishment Conf. International Soybean Program, Univ. of Illinois, Urbana-Champaign, Illinois.

Dhingra, O. D.; Jham, G.; Napoleão, I. T. (1998.) Ergosterol accumulation and oil quality changes in stored soybean. (A. glaucus group). *Mycopathologia*, v.143, p.85-91,

Dhingra, O.D., Mizubuti, E.S.G., Napoleão, I.T, Jham, G., (2001). Free fatty acid accumulation and quality loss of stored soybean seeds invaded by *Aspergillus ruber*. *Seed Science and Technology* 29, 193-203.

Ellis, R.H., Osci-Bonsu, K. and Roberts, E.H. (1982). The influence of genotype, temperature and moisture on seed longevity in chickpea, cowpea and soybean. *Annals of Botany*. 50: 69-82.

Ellis, R.H., Hong, T. D. and Roberts, E. H. (1989). A comparison of the low-moisture-content limit to the logarithmic relation between seed moisture and longevity in twelve species. *Annals of Botany* 63:601-611.

Eys, J.E., Offner, A. and Bach, A. (2006). *Manual of quality analyses for soybean products in the feed industry*, 12.06, Available from <http://www.asaimeurope.org/Backup/Library/library - e.htm>.

FAO (2003). Multilingual Multiscript Plant Name Database. Retrieved February 16, 2012.

FAO (2010). FAOSTAT. Food and Agriculture Organization of the United Nations, Rome, Italy.

Flaskerud, G. (2003). Brazil's soybean production and impact. North Dakota State

University, Extension Service, Fargo, North Dakota. Available at:

<http://www.ag.ndsu.nodak.edu>.

- Frankel**, E.N., Nash, A.M. and Snyder, J.M. (1987). A methodology study to evaluate quality of soybeans stored at different moisture levels. *Journal of the American Oil Chemists' Society*, Vol.64, No.7, pp. 987-992.
- Gary**, L.K. and Dale, L. F (1997). Growth and development of the soybean plant. Soybean production handbook. Kansas state university. 32 pp.
- Gupta**, P.C. (1976). Deterioration in soybean seed quality during storage due genetic variability. *Seed Research*. 4 (1): 32-39.
- Heatherly**, L.G., Kenty, M.M., Kilen, T.C. (1995). Effects of storage environment and duration on impermeable seed coat in soybean *Field Crop Research*. 40 (1): 57-62.
- Hou**, H.J. and Chang, K.C. (2004). Storage conditions affect soybean color, chemical composition and tofu qualities. *Journal of Food Processing and Preservation*, Vol.28, No.6, pp. 473-488.
- IITA**, (2009). Soybean overview. Summary. 5pp.IITA Abadan.
- ISTA**, (2005). International Seed Testing Association *International Rules for Seed Testing*. 2005 Edition, International Seed Testing Association, Bassersdorf, Switzerland.
- ISTA** (2007). International rules for seed testing. International Seed Testing Association 2007 Edition, Supplement. Bassersdorf, Switzerland.

- Kalavathi**, D., Ramamoorthy, K. and Sundareswaran, S., (1994). Relative viability and vigour of different genotypes of soybean (*Glycine max* (L.) Merrill) during storage. *Madras Agricultural Journal*, 81 (11): 612-615.
- Kausar** M., Mahmood, T. Basra, S.M.A. and Arshad, M. (2009). Invigoration of low vigor sunflower hybrids by seed priming. *Int. Journal. Agric. Biol.* 11: 521-528.
- Khalil**, S.K., J. G., Maxal and L.W. Murry (2001). Soybean seed maturity on different dates affect the seed quality. *Pakistan Journal, Biology Science*. 4: 365-370.
- Kong**, F., Chang, S.K.C., Liu, Z. and Wilson, L.A. (2008). Changes of soybean quality during storage as related to soymilk and tofu making. *Journal of Food Science*, Vol. 73, No.3 pp.134-144.
- Kurdikeri**, M.B. (1996). Deterioration in soybean seed quality during storage effect on Germination: *Journal Agricultural Science*. 9 (3): 552-554.
- Makkawi**, M. and van Gastel A.J.G. (2006). Effect of accelerated ageing on germination and vigour of lentil (*Lens culinaris* Medikus) seed. *J. New Seeds* 8:87-97.
- Mercer-Quarshie**, H. and Nsowah, G. F. (1975). Soybean in Ghana. In D. K. Whigham ed. Soybean production, protection and utilization. INSOY series 6: 200-2007.
- McDonald**, M.B. (1999) Seed deterioration: physiology, repair and assessment. *Seed Science. & Technology* 27: 17.
- Milosevic**, M., Malešević, M., (2004). Seed. Institute of Field and Vegetable Crops, Novi Now: 110-114.
- MoFA and CSIR**, (2005). Soybean Production Guide. Food crops development project.

Ghana's Ministry of Food and Agriculture. 38pp.

Molteberg, G.L., Vogt, G., Nilsson, A. and Frolich, W. (1995). Effects of storage and heat processing on the content and composition of free fatty acids in oats. *Cereal Chemistry* 72:88- 93.

Mondal, M.R.I., Wahab, M.A. Alam, M.S. Ahmed, M.M.U. and Begum, F. (2002). Leaflet of BARI soybean 5. ORC. BARI, Joydebpur, Gazipur.

Murthy U.M.N., Kumar P.P. and Sun, W.Q. (2003). Mechanisms of seed ageing under different storage conditions for *Vigna radiata* (L.) Wilczek: lipid peroxidation, sugar hydrolysis, maillard reactions and their relationship to glass transition. *J. Exp. Bot.* 54:1057-1067.

Narayan, R., Chauhan, G.S. and Verma, N.S. (1988a). Changes in the quality of soybean during storage. Part 1 – Effect of storage on some physico-chemical properties of soybean. *Food Chemistry*, Vol.27, No.1, pp. 12-23.

Narayan, R.; Chauhan, G.S. and Verma, N.S. (1988b). Changes in the quality of soybean during storage. Part 2 – Effect of soybean storage on the sensory qualities of the products made there from. *Food Chemistry*, Vol.30, No.3, pp. 181- 190.

Ngeze, P. B. (1993). Learn How to Grow Soybean. Nairobi, Kenya. CTA Publ. 21pp

Nkang, A. and Umoh, E.O. (1997). Six month storability of five soybean cultivars as influenced by stage of harvest, storage temperature and relative humidity. *Seed Science and Technology* 25:93-99.

O'Brien, R.D. (2004). *Fats and Oils Formulating and Processing for Applications*, CRC Press, Boca Raton, United States.

- Orthoefer, F.T.** (1978). Processing and utilization. In: *Soybean: physiology, agronomy and utilization*, A.G. Norman, (Ed.), 219-246, Academic Press, New York, United States.
- Padín, S., Bello, G.D. and Fabrizio, M.** (2002). Grain loss caused by *Tribolium castaneum*, *Sitophilus oryzae* and *Acanthoscelides obtectus* in stored durum wheat and beans treated with *Beauveria bassiana*. *Journal of Stored Products Research*, Vol.38, No.1, pp. 69-74
- Perry, D. A** (1981). (Ed.) *Handbook of vigour test methods*. Zurich: International Seed Testing Association, (1981). pp. 37-41.
- Rupollo, G., Gutkoski, L.C., Marini, L.J., Elias, M.C.** (2004). Hermetic and conventional storage systems in oat grains conservation. *Ciência Rural* 34, 1715-1722
- Schwender, J., Ohlrogge JB, Shachar-Hill Y** (2003) A flux model of glycolysis and the oxidative pentosephosphate pathway in developing *Brassica napus* embryos. *Journal, Biological Chemistry* 278: 29442–29453
- Shelar, V.R. and Shaikh N.** (2002). Soybean seed quality during storage. *Seed Technology research. Agricultural Review*, 29 (2):125-131.
- Shelar, V. R.,** (2007). Strategies to Improve the seed quality and storability of soybean – A REVIEW. Seed Technology Research Unit (NSP), Mathtme Phule Krigi Vidyprrth, Rahuri 413- 722, India. *Agricultural Review*, 28 (3): 188-196, 2007.
- Shelar, V.R., Shaikh, R.S. and Nikam, A.S.,** (2008). Soybean Seed Quality During Storage: A Review. Seed Technology Research Unit (NSP), MPKV, Rahuri

413 722, Dist. Ahmednagar (MS) INDIA *Agricultural Review*, 29 (2): 125 - 131, 2008

Shewry, P.R., Miles, M.J. and Tatham, AS. (1993). The prolamin storage proteins of wheat and related species. *Prog. Biophys. Molecular Biology*. 61, 37-59.

Shurtleff, W. and Aoyagi, A. (2007). History of soybeans and soyfoods in the Middle East. A special report on the history of soybeans and soyfoods around the world. A Chapter from the unpublished manuscript, History of soybeans and soyfoods: 1100 B.C. to the 1980s. Copyright 2007 Soyinfo Center, Lafayette, California.

Shurtleff, W. and Aoyagi, A., (2009). History of soybeans and soyfoods in Africa, (1857-2009). *SoyInfo Center*. ISBN: 978-19289114-25-9. Lafayette, CA.

Shurtleff, W. and Aoyagi, A., (2010). A Chapter from the Unpublished Manuscript, *History of Soybeans and Soyfoods: Australia, New Zealand: 1100 B.C. to the 1980s* Pp. 229.

Sidibe, A., Watson, C. E., Cabreba, E.R., and Keith, B. (1999). Group IV Soybean Seed Quality as affected by planting and harvesting date in the Mississippi Delta in 1996. Mississippi Agricultural and Forestry Experiment Station. *Bulletin 1084*.

Silva, F.A.M., Borges, M.F.M. and Ferreira, M.A. (1999). Métodos para avaliação do grau de oxidação lipídica e da capacidade antioxidante. *Química Nova*, Vol.22, No.1, pp. 94-103

Sinclair, J.B. (1995). Reevaluation of grading standards and discounts for fungus-damaged soybean seeds. *Journal of the American Oil Chemists' Society*, Vol.72, No.12, pp. 1415-1419

- Song** T.T, Hendrich S, Murthy P A (1999). Estrogenic activities of glycine. *Journal, Agricultural Food Chemistry*. 47 (4): 1607 – 1610.
- Tekrony**, D.M., D.B. Egli, J. Balles, L. Tomes, and R.E. Stuckey. (1984). Effect of date of harvest maturity on soybean seed quality and *Phomopsis* sp. seed infection. *Crop Sci.* 24:189-193.
- Trammell**, C A. (1983). Influence of maturity level on variety response of Southern pea to desiccation by glyphosate, M. S. Mississippi, State, University of Mississippi, USA.
- USDA** (2006). U.S. soybean inspection, *Journal of the American Oil Chemists' Society*, Vol.72, No.12, (1995), pp. 1415-1419. Available from [http:// www.Usda.gov/gipsa/reference-library/brochures/soyinspection.pdf](http://www.usda.gov/gipsa/reference-library/brochures/soyinspection.pdf)
- USDA** (2011). *U.S. soybean inspection*, Available from <http://www.usda.gov/commodity/wasde/latest.pdf>.
- Venkatareddy**, D.M., Bommegowda, A. and Paramesh, (1992), Storability of soybean seeds as influenced by genotypes and containers. *Seed Tech News*, 22(2): 41.
- Wehrmann**, V.K., Fehr, W.R., Cianzio, S.R. and Cavins, J.F. (1987). Transfer of high seed protein to high-yielding soybean cultivars. *Crop Science*, volume .27, p.927-931.
- Whigham**, D.K. Minor, H.C. (2003). Agronomic characteristics and environmental stress. In: Norman, A.G. (Ed.), *Soybean physiology, agronomy and utilization*. New York, pp. 77- 118.
- Wikipedia**, (2009). Wikipedia Foundation Inc. U.S.A. registered. 501(c) (3) Page 32.
- William**, S. and Akiko A.A. (1980). Chapter from the Unpublished Manuscript, *History*

of Soybeans and Soyfoods: 1100 B.C. to the 1980. Copyright, Soyinfo Center, Lafayette, California.

- Wilcox, J.R.,** and J.F. Cavins. (1992). Normal and low linolenic acid soybean strains: Response to planting date. *Crop Science*. 32:1248-1251.
- Wilson, R.F.** (2004). Seed composition. (In) H R Boerma, J E Specht, eds, *Soybeans: Improvement, Production, and Uses*, Vol 3. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, Madison, WI, pp 621– 677.
- Wine, H.C.** and. Kueneman, E.A. (1981). Soybean seed quality during storage. *Seed Technology Field Crop research, Agricultural Review*, 29 (2): 125-131.
- WISHH** (2006). *World Initiative for Soy in Human Health*. Industrial application of soybean. St. Louis, Missouri, USA. Malnutrition International Development and public partnership review conference.
- Yanagi, S.O.,** Galeazzi, M.A.M., Saio, K. (1985). Properties of soybean in model storage studies. *Agricultural and Biological Chemistry* 49, 525-528.
- Zhang, Z.,** Liu, C., Ma, H., Wang, X., Gao, W., and Xiao, L., (2005). Functional properties of protein isolates from soybeans stored under various conditions. Original Research Article. *Food Chemistry, Volume 111, Issue 1, 1 November 2008*, pp.29-32.

APPENDICES

APPENDIX A: ANALYSIS OF VARIANCE (ANOVA)

APPENDIX A1: ANOVA for Moisture

Source	DF	SS	MS	F	P
VARIETIES	8	0.5804	0.07255	1.03	0.4162
STORAGE PERIOD	3	3.5272	1.17573	16.65	0.0000
STORAGE TEMP.	1	0.2363	0.23633	3.35	0.0687
VAR.*STORAGE PERIOD	24	0.9465	0.03944	0.56	0.9540
VAR*STORAGE TEMPERATURE	8	0.5725	0.07157	1.01	0.4266
ST PERIOD*ST TEMP.	3	0.4090	0.13633	1.93	0.1255
VARIETIES*STPERIOD*STTEMP	24	0.9119	0.03800	0.54	0.9632
Error	216	15.2510	0.07061		
Total	287	22.4350			
Grand Mean 8.2954 CV 3.20					

APPENDIX A2: ANOVA for Soybean Seed Oil Content

Source	DF	SS	MS	F	p
VARIETIES	8	789.806	98.7258	212.18	0.0000
STORAGE PERIOD	3	2.927	0.9757	2.10	0.1016
STORAGE TEMP.	1	1.517	1.5167	3.26	0.0724
VAR.*STORAGE PERIOD	24	15.361	0.6401	1.38	0.1208
VAR*STORAGE TEMPERATURE	8	4.861	0.6076	1.31	0.2418
ST PERIOD*ST TEMP.	3	1.852	0.6173	1.33	0.2666
VARIETIES*STPERIOD*STTEMP	24	10.849	0.4520	0.97	0.5051
Error	216	100.502	0.4653		
Total	287	927.676			
Grand Mean 9.9649 CV 6.85					

APPENDIX A3: ANOVA for Soybean Seed Protein Content

Source	DF	SS	MS	F	p
VARIETIES	8	592.769	74.0962	4609.01	0.0000
STORAGE PERIOD	3	6.161	2.0536	127.74	0.0000
STORAGE TEMP.	1	0.413	0.4125	25.66	0.0000
VAR.*STORAGE PERIOD	24	24.095	1.0040	62.45	0.0000
VAR*STORAGE TEMPERATURE	8	1.909	0.2386	14.84	0.0000
ST PERIOD*ST TEMP.	3	0.069	0.0229	1.42	0.2365
VARIETIES*STPERIOD*STTEMP	24	0.596	0.0248	1.54	0.0559
Error	216	3.472	0.0161		
Total	287	629.484			

Grand Mean 40.127 CV 0.32**Appendix A4: ANOVA for Germination**

Source	DF	SS	MS	F	p
VARIETIES	8	9914.7	1239.34	106.71	0.0000
STORAGE PERIOD	3	1224.8	408.25	35.15	0.0000
STORAGE TEMP.	1	28.8	28.75	2.48	0.1171
VAR.*STORAGE PERIOD	24	1340.9	55.87	4.81	0.0000
VAR*STORAGE TEMPERATURE	8	194.6	24.32	2.09	0.0375
ST PERIOD*ST TEMP.	3	103.3	34.45	2.97	0.0330
VARIETIES*STPERIOD*STTEMP	24	1065.9	44.41	3.82	0.0000
Error	216	2508.8	11.61		
Total	287	16381.7			

Grand Mean 86.531 CV 3.94

Appendix A5: ANOVA for Vigor

Source	DF	SS	MS	F	p
VARIETIES	8	115.694	14.4618	15.15	0.0000
STORAGE PERIOD	3	113.344	37.7813	39.57	0.0000
STORAGE TEMP.	1	12.087	12.0868	12.66	0.0005
VAR.*STORAGE PERIOD	24	72.750	3.0313	3.17	0.0000
VAR*STORAGE TEMPERATURE	8	15.694	1.9618	2.05	0.0415
ST PERIOD*STTEMP.	3	4.288	1.4294	1.50	0.2163
VARIETIES*STPERIOD*STTEMP	24	59.306	2.4711	2.59	0.0002
Error	216	206.250	0.9549		
Total	287	599.413			

Grand Mean 7.2326 CV 13.51

APPENDIX A6: ANOVA for Seedling Dry Weight

Source	DF	SS	MS	F	p
VARIETIES	8	0.01910	0.00239	16.93	0.0000
STORAGE PERIOD	3	0.01137	0.00379	26.88	0.0000
STORAGE TEMP.	1	0.00142	0.00142	10.09	0.0017
VAR.*STORAGE PERIOD	24	0.00687	0.00029	2.03	0.0043
VAR*STORAGE TEMPERATURE	8	0.00289	0.00036	2.56	0.0109
ST PERIOD*ST TEMP.	3	0.00095	0.00032	2.25	0.0832
VARIETIES*STPERIOD*STTEMP	24	0.00826	0.00034	2.44	0.0004
Error	216	0.03045	0.00014		
Total	287	0.08131			

Grand Mean 0.0831 CV 14.30

APPENDIX B: Environmental Conditions

APPENDIX B1: Ambient Condition

Storage Environment		Day 1	30 Days	60 Days	90 Days	120 Days	Means
Relative Humidity (%)		84	82	78	75	79	79.6
Temperature (°C)		29	27	28	26	28	27.6

APPENDIX B2: Cold Room

Storage Environment		Day 1	30 Days	60 Days	90 Days	120 Days	Means
Relative Humidity (%)		68	69	64	62	61	64.8
Temperature (°C)		17	15	16	17	15	15.4

APPENDIX C: Initial Characteristics of the Soybean Genotypes before Storage

Variety	Moisture Content (%)	Oil Content (%)	Protein Content (%)	Germination (%)	Vigor (%)	Seedling Dry Weight (g)
Anidaso(M)	8	10.00	39.29	99	10.06	0.09
Anidaso(C)	8	9.80	41.34	89	9.52	0.09
Quarshie	8	8.60	37.98	72	8.42	0.09
Sallintuya 1	8	8.40	41.17	95	7.55	0.08
Sallintuya 2	8	8.90	40.82	86	8.45	0.10
Nangbaare	8	11.00	42.04	83	9.42	0.09
TGX-1834- 5E	8	8.90	37.89	82	8.36	0.11
TGX-1903- 7F	8	12.00	39.90	92	7.29	0.15
TGX-1904- 6F	8	13.06	39.29	89	8.36	0.12
Means	8	10.07	39.96	87.44	8.6	0.10