ASSESSMENT OF THE QUALITY OF MARKETED CERTIFIED VEGETABLE SEEDS IN ORIGINAL PACKAGE AND THOSE REPACKAGED AT RETAILERS' END IN THE ASHANTI REGION OF GHANA

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL IN SEED SCIENCE DEGREE

WEST AFRICA CENTRE FOR CROP IMPROVEMENT

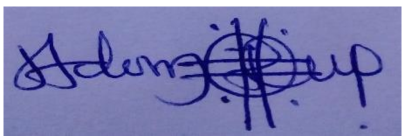
COLLEGE OF BASIC AND APPLIED SCIENCES

UNIVERSITY OF GHANA, LEGON

JULY, 2019

DECLARATION

I hereby declare that except for references to works of other researchers, which have been duly cited, this thesis is the results of my own findings and has neither in part or whole, been submitted for a degree in Ghana or elsewhere.



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ABSTRACT

The use of quality seed is a prerequisite for high vegetable productivity. The Ghana Seed Inspection Division conducts seed quality assessment to ensure that seeds meet minimum quality standards before they are certified to be sold to farmers. Poor seed storage practices and repackaging of certified seeds at retailers' end could adversely affect seed quality before farmers purchase these for planting. Post-certification surveillance was undertaken to assess the quality of certified vegetable seeds in their original package and those that were repackaged at commercial retailers' end in the Ashanti Region to ascertain the quality of vegetable seeds that would eventually end up with farmers for planting. Structured questionnaires were administered to 25 commercial vegetable seed retailers who constituted the main vegetable seed delivery channels to farmers across the Ashanti Region of Ghana. Survey data was analysed to ascertain vegetable seed retailers' knowledge and practices on the handling of certified vegetable seeds and to determine marketing challenges retailers faced in their operations. Survey results indicated that retailers were educated, and had adequate knowledge and experience in the handling of certified seeds. Retailers' major marketing challenges were seed pricing in relation to farmers' dissatisfaction with the cost of seeds, lack of cold storage facilities, farmers' dissatisfaction with seed package sizes being too small or too large, and poor access to credit facilities. Thirty vegetable seed samples, out of which 15 were in their original containers and 15 had been repackaged into transparent plastic bags were initially sampled from 22 retail shops for seed quality tests at the National Seed Testing Laboratory of the Ghana Seed Inspection Division. Following the first sampling, 3 specific vegetable seeds, each in original container and repackaged form, common to 3 retail shops were sampled for another evaluation. Both laboratory evaluations were arranged in a Completely Randomized Design with 4 replications and evaluated for percentage purity, moisture content, percentage germination, seedling vigour, and seed health. Data collected from both laboratory tests were analysed using Genstat statistical package 12th Edition. Fishers' Protected LSD was used to separate treatment means at 5% significance level. Results from the laboratory analysis indicated that with the exception of 6 out of the 30 seed samples, both seeds in original package and those repackaged had germination percentages and vigour indices that were within minimum quality standards. All but 5 seed samples also had purity percentages that were within minimum quality standards. Twenty (20) of the 30 seed samples had moisture contents above the acceptable maximum moisture content of 8%. High seed moisture content and decline in seed viability of some samples were attributed to the poor storage conditions witnessed at retail shops such as high temperature (29.0 ^{0}C – 36.9 ^{0}C) and high relative humidity (40% - 64%). Two storage fungi, *Aspergillus niger* and *Aspergillus flavus*, were found to be associated with 13 out the 30 seed samples. Seeds in original package had mean percentage purity, mean moisture content, mean germination percentage, mean vigour index, and fungal prevalence to be 98.43%, 8.82%, 83.20%, 10.23 and 33.3% respectively whilst those repackaged had mean percentage purity, mean moisture content, mean germination percentage, mean vigour index, and fungal prevalence to be 95.78%, 8.91%, 77.70%, 9.28 and 53.33% respectively. These findings indicated that seed repackaging had adverse effect on vegetable seed quality.

DEDICATION

This work is dedicated to my siblings, Solomon Owusu, Philip Owusu, Vida Owusu, Elizabeth Owusu, Abigail Owusu, Susanna Amankwah Antwi, Nathaniel Yeboah Antwi, Esther Nyamekye Antwi, Drusilla Darkoaa Antwi, Jared Osei Antwi, and Lady Julia Asantewaa Antwi.

ACKNOWLEDGEMENT

I am most grateful to the Almighty God who granted me life, strength, wisdom, and knowledge to successfully complete my master's programme. May His holy name be praised forever and ever.

I thank the West Africa Centre for Crop Improvement (WACCI) Team for the opportunity granted me to be part of the third Cohort of the Master of Philosophy in Seed Science and Technology Programme. I am highly indebted to the World Bank for financially supporting my studies. Indeed, I could not have achieved this feat without your support.

My heartfelt appreciation goes to my research supervisors, Dr. Daniel Dzidzienyo and Prof. John Ofosu-Anim, and all the lecturers at WACCI whose critiques and guidance in diverse ways made this work a success.

My sincere gratitude goes to the Ghana Seed Inspection Division (GSID), Pokuase for granting me access to the National Seed Testing Laboratory during the second part of my research. I thank the entire staff of GSID for the assistance they rendered me during my laboratory seed analysis.

Finally, I thank Mrs. Mabel Owusu (Headmistress of Kotwi D/A JHS), family, colleagues and friends who have in diverse ways supported me throughout my study period. God richly bless you all.

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LIST OF ABBREVIATIONS

ACB	African Centre for Biosafety
AGRA	Alliance for Green Revolution in Africa
ANOVA	Analysis of Variance
AOSA	Association of Official Seed Analysts
AOSCA	Association of Official Seed Certifying Agencies
ASFG	African Smallholder Farmers Group
ASTS	Alberta Seed Testing Standards
BECE	Basic Education Certificate Examination
CCIA	California Crop Improvement Association
CGRFA	Commission on Genetic Resources for Food and Agriculture
CRD	Completely Randomized Design
CRI	Crop Research Institute
CSIR	Council for Scientific and Industrial Research
DAS	Days after Sowing
DNA	Deoxyribonucleic acid
FAO	Food and Agriculture Organisation
GAIDA	Ghana Agricultural Input Dealers Association
GDP	Gross Domestic Product
GSID	Ghana Seed Inspection Division
HND	Higher National Diploma
IBM	International Business Machines
IFDC	International Fertilizer Development Centre

IFPRI	International Food and Policy Research Institute
ISHI	International Seed Health Initiative
ISTA	International Seed Testing Association
JHS	Junior High School
LSD	Least Significant Difference
MoFA	Ministry of Food and Agriculture
NGO	Non-Governmental Organisation
NSHI	National Seed Health System
NSS	National Seed Service
NSTL	National Seed Testing Laboratory
PASS	Programme for Africa's Seed Systems
PHS	Population and Housing Census
PPRSD	Plant Protection and Regulatory Services Directorate
QDS	Quality Declared Seeds
SARI	Savannah Agricultural Research Institute
SHS	Senior High School
SPSS	Statistical Package for Social Sciences
SRID	Statistics, Research and Information Directorate
SSA	Sub Saharan Africa
US	United States
WACCI	West Africa Centre for Crop Improvement
WASSCE	West Africa Secondary School Certificate Examination
GSS	Ghana Statistical Service

CHAPTER ONE

1.0 INTRODUCTION

Vegetables are indispensable parts of our daily diets (Slavin and Lloyd, 2012). In terms of nutritional value, they have high levels of minerals, proteins and vitamins which provide disease-resistance, and thus help maintain a healthy life (Welbaum, 2015). Adding to the importance of vegetables, Craig and Beck (1999) reported that one gets satisfactory minerals and vitamins from vegetables and thus when they are in shortage, the less privileged in the society will not be in the position to obtain equivalent mineral and vitamin supplements due the expensive nature of such supplements. MoFA's Statistics, Research and Information Directorate (SRID) has stated that onion, tomato, eggplant, green pepper, okra and beans are the main vegetables grown and consumed in Ghana, with onion and tomato being the two most-consumed vegetables (MOFA, 2014). Aside the nutritional benefits gained through their consumption, vegetable production is a good contributor to the Ghanaian economy; offering employment and earning foreign exchange for the country. The cultivation and sale of vegetables to foreign countries earned Ghana 75.64 million United States Dollars between the periods of 1995 and 2006 (Owusu and Owusu, 2010).

Seeds make up one of the basic and vital inputs in any crop production venture. Particularly in Ghana where agriculture is a major contributor to Gross Domestic Product (GDP), the use of quality seeds should be our topmost priority to achieve food security, and also improve our economy. Tripp (2001) indicated that vegetable seeds constitute the most valued resource for vegetable growers. He further stressed that the stability and diversity in vegetable seed supply is the sine qua non for sustaining high vegetable productivity. Adding to this, Satriyas (2006) indicated that the use of vegetable seeds of poor quality usually results in poor field emergence and production of seedlings that have less tolerance to biotic and abiotic stresses, eventually reducing crop yield and quality of produce. High vegetable productivity is thus seen to be directly proportional to the employment of quality seeds. Other agro-inputs such as good irrigation systems, agrochemicals and good fertilizers, complemented with modern farm machinery will have no direct bearing on productivity if they are not jointly used with vegetable seeds of high quality (Mugonozza, 2001).

Seeds of good quality can be generally measured in diverse ways, comprising germination and vigour, physical and genetic purity, uniformity in shapes and sizes, and the absence of seed-borne pathogens and insect infestations (Sabry, 2018).

In Ghana, seeds are obtained for cultivation from two main sources which are the formal and informal seed supply systems (Niangado, 2010). Seeds obtained from the formal seed supply system are produced under certification and quality control in conformity with required standards to ensure availability of quality certified seeds. However, those from the informal seed supply system are usually farmer saved seeds which are not produced under strict seed certification standards. Open-pollinated and hybrid varieties are currently the two types of vegetable seeds available within the Ghanaian seed market. Small-scale farmers mostly save the seeds of open-pollinated vegetable crops because of their genetic quality, whereas breeders are also responsible for the production of hybrid seeds with improved traits, and are usually imported in most African countries, including Ghana (Saavedra *et al*., 2016).

One significant and common practice acting as a constraint to seed marketing in Ghana is farmers' continuous use of their saved seeds. Other constraints include lack of seed storage facilities, instability in seed prices, inadequate resources in terms of personnel and logistics to enhance effective monitoring of seed inspection and certification, as well as post-certification surveillance to ensure seed quality maintenance among others (National Seed Policy, 2013).

The National Seed Certification Agency ensures that farmers are supplied with seeds of high quality. This is achieved through strict supervision of seed production activities by Ghana Seed Inspection Division (GSID). Locally produced, and or imported seeds are further subjected to quality analysis, specifically, germination tests, seed purity tests, seed health tests, and seed moisture tests to ensure that seeds meet minimum quality standards before certification is granted.

These initial activities by GSID may however not provide adequate guarantee that the seeds would reach the farmer in the same state as the seeds move through the various seed supply chains. Interruptions and deferments in seed conveyance, and how seeds are stored at the retailers' end could adversely affect seed quality (FAO, 2010). The prevailing high storage temperatures and relative humidity at retailers' end have been identified as the two most important factors that affect vegetable seed quality (Alhamadan *et al*., 2011; Demir *et al*., 2016). Furthermore, repackaging of certified seeds into smaller transparent plastic bags at retailers' end, which has caught little or no attention by appropriate regulatory bodies, also has the potential of exposing seeds to high relative humidity and temperatures, which may increase seed moisture content and eventually affect seed longevity. In addition, repackaged seeds may mix up with other seeds, and inert matter, thus reducing seed purity. Lastly, seeds may also be infected by air-borne pathogens during the repackaging process, hence, negatively affecting seed quality.

It is therefore imperative that investigations are done on the handling and storage of seeds, particularly, at retailers' end as post-certification checks to ensure seed quality maintenance. These post-certification checks are usually not conducted by the seed certifying agency mainly due to inadequate resources. Ensuring seed quality maintenance will help increase vegetable productivity and consequently boost farmers' income as well as food and nutrition security in Ghana. Vegetable production is a poverty alleviating venture for most urban and peri-urban dwellers in Ghana, as Kumasi and Accra alone supply about 90% of most perishable vegetables (Drechsel *et al*., 2006; Abdullai *et al*., 2017). The Ashanti Region was therefore selected for this research to provide a broader overview of the state of marketed certified vegetable seeds in Ghana.

The objective of this research was to evaluate the quality of certified vegetable seeds in their original package and those that were repackaged at the commercial retailers' end in the Ashanti Region to ascertain the quality of vegetable seeds that would eventually end up with farmers for planting.

The study specifically sought to:

1. Assess the quality of certified vegetable seeds in their original package and those that had been repackaged at retailers' end.
2. Assess the impact of seed repackaging on vegetable seed quality.
3. Ascertain vegetable seed retailers' knowledge and practices on the handling of certified vegetable seeds.
4. Determine the marketing challenges faced by commercial vegetable seed retailers.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Seed as Basic Input in Crop Production

A seed is that reproductive structure in flowering plants comprising of an embryonic plant and food supply (cotyledon(s) and endosperm) enclosed in a protective cover referred to as testa, or that part of a plant from which a new plant can be reproduced (Bajrang, 2008).

Seeds are fundamental inputs in crop production. More essentially, seeds of high quality of a preferred cultivar or variety are a foundation of high agricultural productivity because such seeds provide solutions to farmers' needs as they increase productivity and widen crop utilization (Pelmer, 2005). Seed remains the utmost investment made by small-scale farmers, but in Africa, there exists a complex seed supply chain within which it is necessary to understand the various actors (breeders, seed producers and companies, seed dealers), and farmers' behaviour that reinforces several sustainable plans in the production and distribution of seeds and related impact on farming (Monela, 2014).

An integral factor required to stimulate technology adoption and increase productivity in small-scale agriculture is the access to improved seeds. However, weaknesses within the seed supply systems in most Sub-Saharan African (SSA) countries have constrained the access to improved seeds (Tripp, 2000).

2.2 Improved Seeds

The key to increasing agricultural productivity is to prioritize the improvement of the quality of any crop variety (Louwaars and De Boef, 2012). Improved seeds of any variety are those that have been bred on the basis of formal techniques in plant breeding (Nkonya, 2001). FAO (2009) also defines improved seeds as seeds that target increase in crop production and produce quality by possessing unique genetic attributes such as high yielding, early maturing, and tolerance to biotic and abiotic stresses. Improved seeds can also be defined by grouping them into two sections which are open-pollinated seeds, and hybrid seeds. Seeds produced through natural and random pollination are termed as open-pollinated seeds whereas those produced by crossing parent plants to obtain desired traits are referred to as hybrids (Cho, 2013). In the traditional setting, farmers save the best of the open pollinated seeds and use them for cultivation year after year. However, plants resulting from hybrid seeds attain their full potential in the first cropping season but their seeds decline in genetic potential in subsequent generations, thus, farmers ought to buy new seeds each cropping season (Cho, 2013).

2.2.1 Availability of and Access to Improved Seeds

Improved seeds are central to food security and improved livelihood of farm households (McGuire and Sperling, 2011). The adoption of improved seeds or varieties increases with the availability and accessibility of different sources of seeds (Alene *et al*., 2000). A vibrant seed system is therefore pivotal to enhancing the supply of improved seeds (Maredia *et al*., 1999).

Small-scale farmers mostly save the seeds of open-pollinated vegetable crops because of high genetic quality, whereas breeders are also responsible for the production of hybrid seeds, which usually have improved traits, but are extensively not available (Saavedra *et al*., 2016). Most countries in Africa, including Ghana, currently import most hybrid seeds. The hope for Africa however is that, breeders breeding in Africa for Africa are on the rise, and since hybrids' adaptation to local conditions is crucial, these breeders bear in mind some critical issues such as soil requirements, climate requirements, as well as resistance to pests and diseases, when adapting these improved varieties (Saavedra *et al*., 2016).

Limited availability and poor accessibility of improved seeds have been consistently cited as a major constraint to rural farming in most countries, but the introduction of several initiatives in local and sustainable seed production have enhanced access to suitable, timely and inexpensive seeds (ASFG, 2011).

2.3 Seed Supply Systems in Ghana

In Ghana, two seed supply systems co-exist: the formal seed system that is established and controlled by various institutions of the state and their technical partners, and an informal or traditional system that is based on traditional principles of seed exchanges and offer of mutual assistance for one another among farmers within a particular zone (Niangado, 2010). Almekinders (2000) also defines the informal seed sector as the total production and distribution of seeds by farmers, usually, smallholder farmers whereas the production and distribution of seeds by publicly known seed producers and commercial seed companies and dealers is also termed as the formal seed sector.

CGRFA (2011) further explains that the formal system of seed supply involves a series of activities which are highly regulated and results in the production of certified seeds of known varieties. These regulated activities involve the breeding and release of improved varieties and the production of certified seeds based on acceptable standards. On the other hand, the informal system of seed supply, sometimes referred to as traditional, farmers' or local seed system, involves the supply of seeds for cultivation through farmers' own traditional arrangements (CGRFA, 2011).

The informal system of seed supply faces several challenges. This is because the system is mainly nature-dependent, and thus, has higher probability of experiencing seed shortages in case of adverse weather conditions, especially, drought or floods. Also, seeds obtained from any preferred variety are normally selected after harvest, therefore, seed availability is directly related to field performance and yield of that particular crop in the preceding planting season (Etwire *et al*., 2013). Furthermore, this seed system is usually inadequately prepared for incidence of diseases and pests and mostly suffers losses from agrobiodiversity (Louwaars and De Boef, 2012).

Ghana's formal seed supply system also faces several constraints. Etwire *et al*., (2013) described some of these constraints as follows:

i. Delays in service provision to seed companies and producers, resulting in decline in productivity, since the state through MoFA controls about 80% of all activities in this sector (registering seed growers, seed inspection, processing, testing and certification, and packaging).
ii. Poor distribution of certified seeds from production through various actors to the end users (farmers).
iii. Poor publicity of available seeds of improved qualities in remote or rural areas since agro-input shops mostly do not have outlets in these areas.
iv. Inadequate storage facilities resulting in loss of seed viability with time.
v. Poor infrastructural development in rural areas, especially, with respect to roads and electricity, thereby, affecting seed distribution and storage in these areas.

2.3.1 Linkages Between Formal and Informal Seed Sectors

Though conscious efforts have been made by the state and development associates to promote and reinforce the formal seed sector, the informal or traditional seed sector still plays a critical role in crop production in Ghana (Etwire *et al*., 2013). Etwire *et al*. (2013) further argue that the evaluation of these two systems appears to predict that both systems have over the years overlapped and thus, there is a probable emergence of a hybrid system grounded on best practices of the two systems which would solve the problems and meet expectations of smallholder farmers.

The enhancement in efficiency in operational activities of both seed sectors and the promotion of a general evolution of the seed sector is dependent on the functional linkages that exist between both sectors. This is because whilst the formal system is primarily the source of improved varieties, the informal system also provides basic information to farmers, more importantly, their expectations from new varieties, as well as new inputs and technical services. Vibrant small-scale enterprises can thus play a vital role in hybridizing both seed sectors, if they continuously gain access to improved varieties through state breeding programmes (FAO, 2009).

In contrast to conservatory views, both seed supply systems co-exist in most parts of developing countries and in certain parts of the developed world. Farmers will normally resort to either one or both systems for different crop varieties at different seasons for varied reasons (CGRFA, 2011).

2.4 Seed Quality

As defined by Hampton (2002), seed quality is the sum total of all characteristics that make the seed worthy for its preconceived purpose and the performance of the seed measuring up to the expectations of the end user, the farmer. Thus, if a seed lot meets the minimum quality standards for certification of a country, it is of good quality, and if it does not meet minimum quality standards for certification, it is of poor quality (Copeland and McDonald, 1995).

Seed possesses an exclusive feature among all agricultural inputs as it is a tool through which new technology is delivered to farmers. Seed quality, irrespective of the scale of crop production, governs crop productivity level amidst all other crop production inputs. About half of the global yield increase within the last fifty years has been attributed to seed quality and progress in genetics, with the complement of agronomic improvements and use of phyto-sanitary products (CGRFA, 2011).

Seed, unlike other inputs in crop production like fertilizers and other agrochemicals, has unique features which create difficulty when it is being delivered to farmers. According to CGRFA (2011), seed has life and thus requires apposite handling and storage conditions to ensure the maintenance of its viability until its cultivation in the field. Seed quality remains a crucial component of the seed system; when delivered to farmers must possess high germination and vigour, high analytical and genetic purity and must be disease and pest-free. Seeds of high quality thus remains a prerequisite for high agricultural productivity which leads to food security and poverty alleviation among agricultural households. Seeds with the highest quality have been reported to give rise to crops of the highest quality in field assessments which will eventually result in produce of the highest value (Mbora *et al*., 2009). According to Rickman *et al*. (2006), the quality of seeds is of great importance to farmers because it measures seeds' potential performance on the field under optimum conditions.

The description of seed quality is relative and can be characterized by the level of exactness when compared with an adequate standard seed. Seeds that satisfy the mandatory standards with respect to genetic purity, physiological quality (high germination and vigour), physical purity and good health are described as quality seeds.

The International Seed Testing Association periodically publishes standard procedures for seed quality assessment which are acceptable worldwide. Seed Quality can be grouped into four (4) main classes as follows:

i. Analytical/Physical quality which refers to the physical purity of the seeds in a particular seed lot.

ii. Physiological quality which has to do with aspects of viability, germination, and vigour of the seeds.

iii. Genetic quality which indicates the unique hereditary characteristics of the particular seed variety.

iv. Pathological quality which has to do with the health status of seeds, specifically, the incidence of pests and diseases within a particular seed lot (ISTA, 1985).

2.4.1 Analytical Quality

Analytical purity, which is also referred to as physical seed quality, is an indication of the true seeds of the species being tested in the sample, and also, the quantity of foreign materials that is present in the sample. Attributes of seed physical or analytical quality are often expressed as percentages of the total weight of the seed samples being analysed (Scott, 1980). Analytical seed quality thus refers to the percentage unadulterated seed of the desirable crop in a seed lot. Certain components such as moisture content, appearance, size, colour, presence of other undesirable materials and insect infestation are taken into account when measuring seed physical purity (Hasanuzzaman, 2015).

Species that are principally discovered, or specified by the source, in an analytical test is referred to as the pure seed component. This is applicable to all cultivars and varieties of the species in question. On the contrary, seeds and seed-like structures belonging to any plant species aside from the pure seed is referred to as other seed components (Hasanuzzaman, 2015).

Noxious weed seeds and inert matter are other components identified in seed physical purity tests. Noxious weeds are difficult to control and their seeds usually find their way into seed lots during harvesting. Inert matter portions also refer to materials such as straw, chaff, stones and soil particles, metal and plastic pieces, and physically injured or broken pieces of the pure seeds that are less than half of the original size present in the seed lot being analysed (Thomson, 1971; ISTA, 1985).

A seed sample or seed lot that possesses high physical quality must therefore have uniformity in terms of size, shape, weight, and colour, and must be devoid of seeds of other varieties or species, stones, dust, debris, plant parts, and other inert materials, and must also be free from shrivelled, moulded, discoloured, diseased mottled, injured and empty seeds (Vikaspedia, 2019).

Seed moisture content refers to the loss in weight of a seed sample after drying and is usually expressed as a percentage of the original weight of the seed sample. Seeds are biological materials that contain water and other complex substances like cellulose, starch and proteins (Thomson, 1979) and need to be dried to low moisture contents to avoid deterioration during storage.

2.4.2 Physiological Quality

Physiological quality comprises seed germination and seed vigour. The vivacity of a seed is known as viability. The capacity of a seed to produce decent seedlings (seedlings with standard roots and shoot) under suitable conditions is referred to as germinability (Vikaspedia, 2019). Seeds ability to germinate as reported by Hasanuzzaman (2015), includes factors such as germination capacity, viability, vigour and other characteristics related to seed dormancy.

The importance of the physiological quality of seeds cannot be underestimated because seeds can only perform their natural biological roles when they are viable. Accordingly, seeds of an adapted variety, with high physical quality will be of no use if they have poor vigour and germination.

According to Marcos Filho (2005), seeds have the utmost germination and vigour potential when they attain physiological maturity. At this stage, seeds possess high moisture content which affects automated harvesting. Harvesting should be done when physiological seed maturity is attained because seed quality starts to decline via the normal decay process after physiological maturity

(Krzyzanowski *et al*., 2008). Seed quality declines heavily when harvesting is postponed, especially, under adverse climatic conditions.

Seed germination is reliant on both internal and external factors. The most crucial external factors are air or oxygen, water, optimum temperature and in certain instances, darkness or light (Raven *et al*., 2005). Internal factors also include seed maturity, mechanical seed damage during harvesting and processing, genetic disorders through mutations, and influence of genotype which sometimes results in seed dormancy (Copeland and McDonald, 2001).

With reference to ISTA (1985), germination is defined in laboratory tests as the emergence and growth of essential structures out of the embryo of the seed being tested, providing an indication of the capability of the structures to mature into a normal plant under favourable field conditions. A seed lot's germination capacity is the percentage of pure seeds which produce normal seedlings after a specified period of time in laboratory tests (Thomson, 1979). Thus, if a particular seed sample or seed lot has 80% germination, it is an indication that 80 out of 100 seeds will most likely produce normal seedlings under favourable conditions over a specified period of time.

As defined by Schneidt (2000), seedlings which develop with all essential structures intact are normal seedlings, whereas seedlings that lack one or more essential structure(s) such as shoot, root, cotyledons, or were discoloured or infected by seed-borne pathogens are abnormal seedlings. Though Rickman *et al*. (2006) claim that normal and abnormal seedlings are counted on the tenth day after planting to determine germination percentage, count day vary for different species.

The primary aim of germination tests is to bring forth knowledge about a seed lot's planting value. This is important in crop production because it gives an indication of the quantity of seeds required for cultivation on a specific area of land from a particular seed lot. Furthermore, it provides an estimate of the number of plants expected to grow on the field from a particular seed lot. According to Thompson (1979), the occurrence of germination at the exact time and in the right place is an essential determinant of the probability of a seedling surviving to maturity.

Seed viability, sometimes referred to as germination capacity, is used to describe seeds possessing the ability to sprout and bring forth normal seedlings. Thus, a particular seed is described as being viable or not viable on the basis of its ability or inability to germinate and bring forth seedlings with normal attributes (Hasanuzzaman, 2015).

Many seed scientists, seed analysts, and seed testing associations have over the years suggested several definitions for seed vigour (Copeland and McDonald, 2001). Seed vigour has been defined as the summation of all characteristics (healthy and naturally robust) of a seed which decide the prospective level of liveliness and seed performance in the period of germination and emergence of seedling under a broad scope of field conditions (Perry, 1978; Woodstock, 1965). McDonald (1980) reported that AOSA gave a definition to seed vigour as the attributes of a seed which dictate the potential for quick, unvarying sprouting and growth of seedlings with normal attributes under a broad range of environmental conditions. This definition from AOSA is considered as operational definition since it concentrates on what seed vigour actually does (Copeland and McDonald, 2001).

With reference to the above definitions, seed vigour can thus be summarised as seed's capacity to survive, sprout and give rise to normal seedlings rapidly and uniformly, even under potentially stressful environmental conditions.

Seed vigour is very essential in successful crop production. According to Sharma (2018), seed vigour is one important aspect of seed quality and at acceptable levels, in addition to other quality attributes like high physical purity, good health and high germination, essential to gain optimum plant establishment and increase in crop yield. Furthermore, farmers' knowledge of the vigour of a seed lot helps them to make decisions on whether a seed lot is suitable for immediate planting or continued storage (Rickman *et al*., 2006; Tokpah, 2010).

2.4.3 Genetic Quality

Genetic quality or purity refers to the true-to-type nature of a particular seed lot, which means that, the plant established from the seed should be identical to the parent plant in all aspects (Vikaspedia, 2019). This quality attribute is essential for achieving the anticipated objective of cultivating that particular crop or variety, either for improved yield or resistance to pests and diseases, or for other desired quality features (Vikaspedia, 2019).

Since the genetic purity of all agricultural products produced from seed propagation begins with the genetic purity of the seeds used for cultivation, the fraction of contamination by seeds of other varieties or species describes how pure a seed lot is (Seedquest, 2015).

The Food and Agricultural Organization also defines varietal or genetic purity as the percentage pure seeds that give rise to offspring exhibiting the exact features of the variety in question, and is ascertained through field inspection of seed crop fields and/or DNA fingerprinting (FAO, 2010).

The primary sources of genetic contamination during seed production are the previously grown crop on the field, pollen transfer from nearby fields, and mixtures that occur in the process of harvesting and handling (Bradford, 2006).

Several guidelines are followed in order to produce seeds that are genetically pure. According to Bradford (2006), seed production should not be done on fields previously cultivated with crops of the same species within the past 3 to 5 years in order to prevent contamination from volunteer plants. To avoid contamination from outcrossing, isolation distances are employed, and the required isolation distance depends on several factors such as floral morphology, sexual compatibility with nearby crops, viability and quantity of pollen, and the mode by which pollen is disseminated (Sundstrom *et al*., 2002). Generally, cross-pollinated crops require wider isolation distances than self-pollinated crops which require relatively smaller isolation distances. However, seed certification standards applicable in a particular country provide guidelines for minimum distances required for isolation for specific crops (CCIA, 2005). Furthermore, contamination that may result from the process of harvesting, processing, and handling of seeds is also controlled by employing proper sanitary measures, specifically, thorough inspection and cleaning of all equipment used for seed harvesting, processing and handling before and after use (Bradford, 2006). Agencies responsible for seed certification also have laid-down standard operating principles for facilities that handle seeds (AOSCA, 2003).

According to Scott and Hampton (1985), the maintenance of varietal or cultivar purity is the primary purpose for the establishment of the seed accreditation schemes. Success in the maintenance of genetically pure seeds can only be achieved through the enforcement of national and international seed laws, and the cooperation of all actors (breeders, producers, dealers, wholesalers and retailers, and farmers) in the seed industry.

2.4.4 Pathological Quality

Pathological quality, also known as seed health quality is basically the absence or presence of pathogens such as bacteria, viruses, and fungi, nematodes, and insect pests in or on the seed (Misra *et al*., 1994).

Seed has been described as a microcosm of microbes, which means that the seed, though smaller in size, has the capacity to harbour and transfer wide range of fungi, viruses, bacteria, and (at times) nematodes, majority of which are pathogenic, causing various plant diseases (Sinclair, 1979). Some of these microbes only become harmful when they have favourable environmental conditions for growth and reproduction, and since these conditions are usually present in germination or growth chambers, they may cause seed rots and seedling blights, causing variation in germination results (Copeland and McDonald, 2001).

Seed health is vital for successful crop production as the seed is known to be the most essential input in crop production, such that it is an important exchange material for farming, seed production, breeding and other forms of research, both at national and international levels (Misra *et al*., 1994). Seed exchanges, transport, and distribution are major contributors to the spread of pathogens and pests (Misra *et al*., 1994). To mitigate the spread of these pathogens and pests within and across countries, critical measures such as regulations, phytosanitary certificates, export and import permits, seed inspections and treatments, isolation, seed quarantine and health testing have been adopted at both national and international levels to allow safe and smooth seed transfer (Kahn, 1988).

Although some plant diseases may be caused by insufficient or lack of plant nutrients in the soil, living organisms that usually cause diseases to seeds, seedlings, and adult plants have been categorized into five groups, namely, fungi, bacteria, viruses, nematodes, and insects (ISTA (1985).

The greatest number of diseases among plants are caused by fungi, with over 8,000 fungi species discovered as plant pathogens (Copeland and McDonald, 2001). According to Dharam Vir (1974), about 150 fungi species have been identified to be associated with stored seeds and grains, and their prevalence increases with high atmospheric humidity in the stages of seed development, and/or harvesting seeds amid wet season. Furthermore, poor store management and crop husbandry also have the tendency to accelerate occurrence of fungi infection (Santos *et al*., 2016).

Plant diseases that are caused by bacteria occur mostly in areas of high dampness or high relative humidity at the time heads are developed (Santos *et al*., 2016). According to Copeland and McDonald (2001), around 200 species of bacteria have been identified as causative agents of plant diseases, out of which very few of them cause diseases in seeds. Bacteria usually attack seeds with high moisture content amid average to warm temperatures because these are the conditions that promote their growth and development of diseases (Copeland and McDonald, 2001).

Around 200 viruses have been identified to cause plant diseases, out of which 100 of them are well known (Carrol, 1979). However, an estimate of only 80 viruses and virus-like organisms are known to be transmitted by seed (Copeland and McDonald, 2001). Generally, developing seeds are systemically infected by parent plants that have been infected either through pollination and fertilization, or through open wounds usually created by insects (Copeland and McDonald, 2001).

2.5 Seed Testing

Seed testing has been defined as the science of assessing the quality attributes of seeds to ascertain their worth for cultivation (Elias *et al*., 2012). Seed testing standards are grounded on scientific proofs and provide set procedures for facilities to perform tests in a uniform manner, so as to ensure comparable results for seed owners (ASTS, 2016).

Seed testing is essential for several reasons:

i. To ascertain a seed lot's quality based on seed quality characteristics.
ii. To justify seed price and buyer discrimination amongst seed lots as well as seed sources.
iii. To identify seed problem sources, hence, facilitating any required corrective measure(s).

iv. To satisfy legal and administrative requirements for various certified seed classes, thereby facilitating seed movement within countries and across international borders. (FAO, 2010).

The International Seed Testing Association (ISTA) establishes methodologies and benchmarks for carrying out seed tests for most crops, and intermittently review these methodologies and benchmarks when new scientific proofs and ideas are unravelled (FAO, 2010).

According to the FAO, four tests are routinely conducted in seed testing laboratories.

These include:

- Germination test
- Moisture content
- Purity test
- Incidence of noxious weed seed

Other seed tests carried out also include:

- Seed vigour test
- Varietal purity
- Seed Health Test

2.5.1 Seed Germination Test

According to ISTA (2013), germination is the emergence and development of the seedling to a point where the features of its essential structures indicate its possibility of developing further into a well-established plant under favourable conditions in the soil. Germination of a seed can also be defined as the emergence and development from the seed embryo, of those essential structures which, for the kind of seed in question, are indicative of the ability to produce a normal plant under favourable conditions (AOSA, 1999).

The prime motive of a standard germination test is to ascertain the germination potential of a seed lot or a seed sample. Germination potential is determined as the sum of strong and weak seedlings, expressed as a percentage of the total number of seeds planted (Byrum and Copeland, 1995). The test is designed to provide a first and a final count, with the first count basically done to determine seed vigour, and the final count also providing maximum time limits that even weak seeds are given every chance to germinate (Byrum and Copeland, 1995).

Four categories of standards which are damaged seedlings, deformed seedlings, decayed seedlings and seedlings with unusual hypocotyl formation are classified as abnormal seedlings (ISTA, 2013). During laboratory germination tests where first count is used to determine seed vigour, most of the normal seedlings are generally expelled at first counts, but the evaluation of the several unsure and abnormal seedlings are finally done at the stage where the test is concluded, to ensure that less vigorous yet normal seedlings are not mistakenly characterized.

2.5.2 Moisture Content

The moisture content of a seed is the value of weight loss in the seed sample when it is dried. Moisture is expressed as a percentage of the mass of the genuine sample. It is one of the most significant factors with the aim of maintaining seed quality.

Seed moisture content directly relates to seed deterioration rates and moisture content, bacterial and fungal attack, level of insect infestation, seed storability, and susceptibility to mechanical damage (FAO, 2010).

Seed moisture content is directly linked to seed component and its function, including maturity, timing of the harvest, susceptibility to mechanical injury during threshing or handling, longevity in storage and injury due to heat, frost, fumigation, insects and pathogens. Against this background, moisture content seems to be the most significant factor in determining seed harvest time, post-harvest handling techniques, as well as how long the seed can maintain its quality (Elias *et al*., 2012).

In determining the moisture content of seeds, procedures can generally be categorized into direct and indirect methods or techniques.

2.5.2.1 Direct Method

Under direct method, the seed moisture content is calculated directly by fall or rise in seed weight.

These are:

- Karl Fisher's method
- Desiccation method
- Distillation method
- Phosphorus pentaoxide method
- Vacuum drying method
- Oven-drying method
- Microwave oven method
- Direct weighing balance

(Seednet, 2019).

2.5.2.2 Indirect Method

The indirect methods are not that accurate because estimation is approximate, however, they are expedient and fast to use. They are usually applied at seed processing plants, and are also employed to determine other physical parameters such as electrical resistance or electrical conductivity of the water contained in the seed. Measurement of values are done with the aid of seed moisture meters, after which the values are changed into seed moisture content with the support of calibration charts for every species, in comparison with basic reference method or standard air-oven method (Seednet, 2019).

Among all other reference techniques, the Karl-Fisher's technique is regarded as the most accurate and principal reference technique for standardizing different techniques employed to determine seed moisture. The only applicable technique recommended by ISTA and other seed testing associations to be routinely used to determine seed moisture in any seed-testing facility is the constant temperature oven drying technique (Seednet, 2019).

The constant temperature oven drying method has been categorized broadly into two groups:

- Low Constant Temperature Oven Method and
- High Constant Temperature Oven Method.

The low constant temperature oven technique is the technique that has been suggested for seeds rich in oil content or contain volatile compounds. In this technique, the already-weighed moisture bottles alongside seed material are set in an oven at a stabilized temperature of 103°C for 17 hours ± 1hour. The relative humidity of the surrounding air in the seed testing facility must be kept below 70% at the time seed moisture content is being determined (Seednet, 2019).

With the high constant temperature oven technique, temperature of the oven is kept at 130°C-133°C with no distinct prerequisite regarding the relative humidity of the surrounding air in the facility at the time seed moisture content is being determined. The drying period under this method varies with species; 4 hours for maize, 2 hours for other cereals, and 1 hour for other remaining species (Seednet, 2019).

2.5.3 Physical Purity Test

Physical purity test which is also known as analytical purity test is the fraction of the seed that is of an identical crop, but not necessarily the same crop variety.

Physical purity analysis refers to the determination of the percentage physical composition by weight of the sample being tested, and by inference, the composition of seed lot and the identity of various species of seeds and inert particles constituting the sample (Anonymous, 2009; ISTA, 2013).

This test is principally done to determine the percentage composition by weight of the sample being tested, and to identity the various seed species and inert particles present in a particular seed lot or sample. Pure seed refers to a constituent component obtained from sampled species stated by the applicant for seed purity analysis by a seed testing laboratory, or that component of a sample after analysis in the laboratory found to be predominant in the sample tested. It includes all botanical varieties and cultivars of that species (immature, undersized, shrivelled, diseased, or germinated seed of a particular species) unless transformed into visible fungal sclerotia, smut balls or nematode galls (ISTA, 2013). Pure seed also includes the following:

a) Intact seed units (commonly found as dispersal units i.e. achenes and similar fruits, schizocarp, florets etc.) as defined for each genus or species.

b) Pieces of seed units that are larger than one half their original size (ISTA, 2013).

The pure seed component together with seed germination capacity of a seed lot are used to determine the planting value of the seed (Rindels, 1995).

2.5.4 Incidence of Noxious Weed Seed

This is an extension of analytical test (purity test) to assess the degree of incidence of certain weed seeds which hugely affect productivity. This is done based on law or by official guidelines.

2.5.5 Seed Vigour Test

Byrum and Copeland (1995) defined seed vigour as the sum of those characteristics that determines the activity and performance of seed lots of acceptable germination in a wide range of environments. AOSA also provided an operational definition for seed vigour as those attributes of a seed which dictate the potential for quick, unvarying sprouting and development of seedlings with normal attributes under a broad range of environmental conditions (Copeland and McDonald, 2001). Seed vigour can thus be summarised as the capacity of a seed to survive, sprout and produce normal seedlings rapidly and uniformly, even under potentially stressful environmental conditions.

Vigour tests are therefore based on the germination rate, and the seedling growth rate. Vigorous seeds tend to utilise minimum nutrient supply within the seed, and or growth medium for quick sprouting with all essential parts intact. Less vigorous seeds are usually characterized by stunted growth and abnormalities in the developing shoot and root system, and subsequently affecting crop establishment (Caddick, 2007).

The essence of a seed vigour test is to obtain information on the planting value of seed lots under variable environmental conditions, and also determine the storage potential of the seed (ISTA, 2013).

2.5.6 Varietal Purity

According to FAO (2010), varietal purity is the percentage of the pure seeds that produce offspring exhibiting the exact features of that specific crop variety. Field inspection during seed production has been cited as the most appropriate period to evaluate varietal purity (FAO, 2010).

In situations where variety validation trial is demanded, seed samples are cultivated in plots alongside plots of the known crop variety (reference sample). Observations are made throughout the entire growth period to have a confirmation that the seed is truly of that specific crop variety in question (FAO, 2010).

2.5.7 Seed Health Test

According to FAO (2010), standard concepts and methodologies are adopted by mycologists and other phyto-pathologists to figure out the presence of seed borne pathogens.

Although the seed is relatively smaller in size, it has the capacity to harbour and transfer wide range of fungi, viruses, bacteria, and (at times) nematodes, majority of which are pathogenic, causing various plant diseases, and therefore described by Sinclair (1979) as a microcosm of microbes. It is therefore imperative that seeds are tested to ensure that they meet minimum health standards before they enter the distribution and marketing chain, and furthermore, during seed imports and exports in order to mitigate the spread of seed pathogens.

According to Gullino and Munkvold, (2014), three indispensable associations have the responsibility to publish standardized seed health tests, and they include:

- the International Seed Testing Association (ISTA),
- the International Seed Health Initiative (ISHI), and
- the U.S. National Seed Health System (NSHS).

In the quest to having an assurance that seed health tests are standardized and provide accurate and reproducible outcomes as per the given standards of the test techniques, strategies ought to go through a peer review system, in addition to cooperative investigation among seed testing laboratories.

ISTA technique approval fundamentally inspects a seed quality test procedure to guarantee that the execution of the procedure is clear and complete and that the method produces precise, reproducible and repeatable outcomes (Hampton, 2007).

2.6 Seed Certification

The seed industry is regulated in a system of certification of seeds that have been duly inspected and have met minimum standards (Lyon, 1999). Seed certification is a continuous process intended to ensure the availability and consistent supply of high-quality seeds of specific crop varieties (Vikaspedia, 2019).

It is the responsibility of seed certification officers to register seed growers and dealers, and also conduct inspection on seed growers' fields, so as to ensure that all seed regulations and guidelines are adhered to by the seed growers (Etwire *et al*., 2013). Seed certification thus can be described as a systematic process backed by legislation, whereby an independent agency conducts monitoring and supervision of all activities related to the production of seeds in accordance with minimum standards throughout the various stages of seed production.

According to Etwire *et al*. (2013), laboratory assessment of seeds to certify that they meet the minimum standards in terms of purity and germination is the core mandate of the Ghana Seed Inspection Division (GSID), a subsidiary of the Plant Protection and Regulatory Services Directorate (PPRSD) of the Ministry of Food and Agriculture (MoFA). Thus, seeds that have received certification from PPRSD have passed the minimum standards in accordance with the International Seed Testing Association (ISTA) rules (Plant and Fertilizer Act (Act 803), 2010). Seed certification is very important in crop production in the sense that it is one of the critical mechanisms that guarantees that farmers are supplied with seeds of good quality (Nishikawa, 2010). Moreover, since farmers lack the technical know-how to evaluate the physical and/or hereditary qualities of seeds prior to cultivation and crop development, seed certification plays a fundamental role by confirming the quality of seeds that farmers buy and also provide a means of seeking remedy or compensation if farmers' expected outcomes are not met (Alemu *et al*., 2010).

2.7 Classes of Seed

There are four classes of seeds that are recognized in the seed certification process. They are the breeder seed, foundation seed, registered seed, and certified seed (Carrillo, 2010; Badu-Apraku *et al.*, 2014). The registered seed class is mostly ignored, leaving only three seed classes which are the breeder, foundation, and certified (Carrillo, 2010) as seen in Ghana seed certification system.

The breeder seed is the purest variety and the highest seed class from which other seed classes originate, and is obtained directly from the plant breeder (Carrillo, 2010). The breeder seed usually originates from an individual plant breeder, a group of plant breeders in a sponsored breeding program, or research institutions such as CRI and SARI of CSIR, and universities. The breeder seed class must be genetically pure to guarantee the expected genetic purity standards of subsequent originating generation of seed classes *viz*. the foundation and certified seeds (Badu-Apraku *et al*., 2014).

The next highest seed class, which is the first generation from the breeder seed is the foundation seed (Carrillo, 2010). Previously, the Grains and Legumes Development Board (GLDB) was the only authorized institution that produced foundation seeds from the breeder seeds, but owing to the growth of the seed industry, and the continuous rise in demand for foundation seeds, research institutions and few authorized private seed companies have also been given the nod to produce foundation seeds (Etwire *et al*., 2013).

Certified seeds are produced from foundation seeds (Carrillo, 2010). Seed growers and seed companies obtain foundation seeds from appropriate sources to produce certified seeds which are sold to agro-input dealers, NGOs, or directly to farmers (Etwire *et al*., 2013). Certified seed class has the least genetic purity amongst all the seed classes since standards for its production is less strict as compared to that of breeder and foundation seeds (Badu-Apraku *et al*., 2014).

2.8 Seed Marketing

The pivot of a successful seed industry is seed marketing. In a well-structured system, seed marketing can be a straight transaction between a seed producer and a farmer, and at times through industry players including distributors, merchants and agro-dealers (ACB, 2012). Seed marketing thus integrates all players or actors in the seed business; government, breeders, producers, dealers and distributors, wholesalers and retailers, as well as the eventual end user, the farmer. According to Lyon (1999), agro-chemical shops are those that buy the chunk portion of certified seeds, and some of these enterprises buy in larger quantities at an early stage to have an assurance of continuous supply in case there is scarcity. It is thus not surprising that advocates of the Green Revolution, AGRA, claim that these agro-dealers have proved beyond doubts to be the most suitable channels by which seeds are marketed and thus claim to have trained over 15,000 agro-dealers in rural areas under its Programme for Africa’s Seed Systems (PASS) programme (AGRA, 2013). Apart from AGRA, another main actor in the industry, the International Fertilizer Development Centre (IFDC) is also embarking on projects on agro-dealer networks in thirteen (13) countries in Sub-Saharan Africa (SSA) (IFDC, 2015).

A two-way system is offered in seed marketing; there is a forward linkage and a backward linkage. The forward linkage flows from the breeders and seed producers to farmers, serving to transport the outcomes of research and extension to farmers. The backward linkage also serving to send feedback from the users (farmers) of the variety to the seed producers, breeders and extension agents on the helpfulness or otherwise of the product (National Seed Policy, 2013).

A number of attributes determine farmers' satisfaction and subsequent sustainability of a vibrant seed market. Some of these attributes are the price of the seed, timelines of availability, appropriateness of the size and packaging, varietal and physical qualities, need for and availability of complementary services, and yield potential of the variety (National Seed Policy, 2013).

In addition to the above, success cannot be achieved in any marketing endeavor without the use of the marketing mix, popularly referred to as the 4Ps (product, place, price, and promotion) as discribed by Al Badi (2015). Elaborating on the 4Ps, product refers to the goods or services offered to the customer; place describes distribution channels and where goods are chosen to be sold; price becomes the amount of money customers who desire a product or service pay in exchange for that product or service; and finally, promotion is any form of communication that create customer awareness about a particular product or service (Al Badi, 2015). In the application of the 4Ps in seed marketing, success will be achieved if an improved seed of high quality (product), is distributed through right channels to where it is needed (place), given a reasonable and flexible pay terms (price), and accompanied with appropriate forms of communication that create awareness of the improved seed to the farmer (promotion).

One significant and common practice acting as a constraint to seed marketing in Ghana is farmers' continuous use of their saved seeds. The few farmers who patronize marketed certified seeds also encounter several issues. For instance, marketing of seeds should aim at satisfying the farmers' request for a dependable and continuous supply of improved seed varieties at affordable prices (Sirisha and Babu, 2014). Furthermore, farmers' motive for going for certified seeds is undoubtedly, the assurance of seed quality. On the contrary, after certification, some dealers end up selling grains that are packaged in certification bags with certification labels (Lyon and Afikora-Danquah, 1998), and this deters victims and other farmers from patronizing certified seeds. Furthermore, farmers do not promptly purchase enhanced seeds in light of the fact that a large portion of them cannot afford to pay the cost of these quality guaranteed seeds. One other deterrent to the buying of enhanced seeds is the farmers' powerlessness to purchase the chemical fertilizer required for the enhanced seeds to achieve the full yield potential (Tahirou *et al*., 2009). Alhassan and Bissi (2006) however, argued that continuous education of farmers on the use of improved seeds has achieved some level of adoption.

According to the Ghana Seed Policy (2013), seed marketing in Ghana faces a lot of challenges. Some of these challenges are:

i. Instability in prices of seeds and grains
ii. Personnel and logistical support to facilitate effective monitoring of seed inspection certification are inadequate
iii. Inadequate seed storage facilities
iv. Unavailability of unadulterated certified seeds at locations convenient to farmers
v. Lack of requisite education on identification of seed from grain as there exists no system for identification.

If these and the rest of the seed marketing challenges enshrined in the Ghana Seed Policy, 2013 are addressed by all stakeholders, seed marketing in Ghana will be worthy of emulation by other developing nations.

2.8.1 Transportation and Distribution of Certified Seeds

Transportation of seeds may be simply described as the movement of seeds from one location to another by land, water, or air. Seed transport is important in the sense that it enables trade between parties; an essential tool for agricultural and economic development. It may be intra-country seed transport or inter-country seed transport. According to Section 39 of the Plant and Fertilizer Act, 2010 (Act 803), samples of seeds imported into the country shall be subjected to testing by PPRSD, and test findings forwarded to the Minister. The Minister then approves or prohibits the importation based on the test results. Likewise, seeds meant for exportation should meet international standards after being supervised, tested, and approved by PPRSD (Plant and Fertilizer Act (Act 803), 2010) not neglecting the fact that seed quality standards may vary among some countries.

Taking cognizance of the fact that the increasing movement of seed and other plant parts from one country to the other creates an avenue for the spread of plant diseases and pathogens (Hampton and Tekrony, 1995), there are some phytosanitary measures put in place by countries across the world to minimize this canker.

The probable returns from the distribution and usage of improved quality seeds are overwhelming, and the access to seeds of improved varieties is essential for improved livelihoods among farmers, and ensuring food security in Ghana. Low cost of production, minimal incidence of disease and pest outbreak, and higher incomes are some of the instant returns achieved by farmers (Wright and Tyler, 1994).

Seed distribution can be described as making improved and certified seeds available to the farmer. This may either be directly done by the seed producer or seed company, or indirectly through government agencies, NGOs, and most especially, agro-input dealers. Distribution of certified seeds should ideally be done using cold vans or improvised with air-conditioned vans. On the contrary, the use of ordinary vans for certified seed distribution in Ghana has become a common practice.

2.8.2 Certified Seed Retailing

The purpose of seed producers is to get their certified seeds to farmers. Tripp (2001) therefore stated the pivotal factor that controls the agribusiness industry is the commercial aspect. Moreover, the promotion aspect of the marketing mix is a crucial link that exists between the seed markets and the eventual end-users of the seeds which are the farmers (OMaliko, 1998).

Generally, farmers' easiest source of obtaining certified seeds is through retailers (Sirisha and Babu, 2014). Fruitful supply of certified seeds involves appropriate transport of good inputs and assistance to create seed accessibility in the farming communities, and creating farmer networks (NSS, 2000).

One clear set-back in the retail of certified seeds is that, most retailers are ignorant about characteristics of the seeds they retail. They are therefore unable to provide farmers who buy their seeds with the right information with regards to complementary inputs and right agronomic practices to increase their productivity (Tahirou *et al*., 1994).

2.8.2.1 Temperature and Relative Humidity at Retailers' Shops

Seeds of economic crops are mainly stored to make them available for subsequent cropping seasons (Alhamadan *et al*., 2011). In general terms, temperature and relative humidity at retailers' shops and warehouses have been cited as the two most important factors that can cause a decline in seed quality or total seed deterioration (Alhamadan *et al*., 2011). The general principle is that, the lower the temperature and relative humidity, the higher the storability and maintenance of the seed quality (Demir *et al*., 2016).

As a medium-term type of storage, marketed certified seeds should be stored at a room temperature of 14-15 ^{0}C and relative humidity of 40-60% (Demir *et al*., 2016). Unfortunately, commercial seed retailers in Ghana store seeds at temperatures between 18-38.5 ^{0}C and air relative humidity that are at times very high (Eshun, 2017).

It is generally assumed that the high seed respiration at high temperature is in some way related to rapid loss in germination (Harrington, 1972). High temperature increases seed embryo respiration resulting in moisture production. High relative humidity also increases seed moisture content as the seed absorbs water from the surrounding air. This increase in moisture content in and around the seed may cause a decline in the seed quality, or cause mouldiness which may eventually lead to total seed deterioration. Certified seed retailers should therefore provide cold storage for seeds to help maintain their quality.

2.8.2.2 Retailing of certified seeds with agro-chemicals

Retailing of seeds and agrochemicals together has become a common practice in many agro-input shops in Ghana. This is a bad practice as agrochemicals can have adverse effects on seeds especially when they are planted.

It has been reported that the application of fungicide on coffee reduced its wax content and altered its physical features, causing some cracks and loss of crystalloids which increased its susceptibility to diseases, withering, and being fed upon by herbivores (Lichston *et al*., 2006). Another research conducted by Dane and Dalgic (2006) also revealed that solutions prepared from Benomyl, a fungicide, was able to cause many anomalies in mitotic cell divisions in the root tips of onion during germination and growth.

Legume seeds treated with herbicides resulted in reduction in nodules formation, thereby reducing the rate of nitrogen fixation (Isoi and Yoshida, 1990; Schnelle and Hensley, 1990). Adding to this, it has again been reported that agrochemicals such as Bentazone, Chlorsulfuron, Glyphosate, and Mancozeb have inhibited the development of nodules (Martensson, 1992). Finally, Buts *et al*., (2013) have also confirmed that Bavistin concentration just above 0.5% negatively affected growth and yield of mung bean (*Vigna radiata*).

Retailers are thus advised to store seeds and agrochemicals separately since the volatility of some of these chemicals as well as possible spillage of chemicals on seeds may cause biochemical alterations in the seeds and render them useless for their purpose.

2.8.2.3 Repackaging of certified Seeds at Retailers' Shops

According to the Cambridge dictionary, repackaging means "to put a product in a new container or to sell a product or service in a new package or market it in a new way". One alarming practice by retailers that has caught little or no attention by GSID, but could have adverse effects on the quality of seeds sold to farmers, is repackaging of the sealed certified seeds mostly into smaller transparent plastic bags. Retailers might have several reasons for repackaging their sourced certified vegetable seeds. Perhaps, some vegetable farmers need smaller quantities of seeds for backyard gardening. Other peri-urban vegetable farmers also do not plant on a large scale and thus require smaller quantities of seeds, especially, of those that are packaged and sealed in cans and larger plastic bags. Another probable cause might be the inability of small-scale vegetable farmers to afford the cost of these seeds in cans and larger sachets. Farmers might also have challenges with storage of larger quantities not used. Nonetheless, these reasons do not provide justification for this act since it is against seed quality control and Ghana seed laws which are reviewed below.

Quality control measures in seed production are carried out so that minimum standards for seed certification and labelling are met. Thus, the seed certification process ends with grant of certificate and certification tags, tagging, and finally, sealing (Malhotra and Vashishtha, 2007). One important activity of seed inspectors after supervising the seed production process is to oversee the filling and sealing of seed bags for the producers and companies (Poku *et al*., 2018). This presupposes that, certified vegetable seeds that are mostly packaged and sealed in cans and paper or plastic sachets are not to be opened or tampered with within the distribution and marketing chain until they reach the end user (farmer) for cultivation.

Furthermore, Section 42 of the Plant and Fertilizer Act, 2010 (Act 803) makes provision for labelling of seed packages and it states: "*Seeds produced or marketed in this country shall be packed in containers which shall be securely closed and labelled with an approved label which states the*

(a) species;

(b) variety name;

(c) lot number and seed class;

(d) minimum moisture content;

(e) germination rate in percentage;

(f) date of analysis;

(g) purity percentage;

(h) weight;

(i) year of production;

(j) name and address of the grower;

(k) code of the analyst;

(l) warning text or symbol where the seed is treated; and

(m)variety registration" (Plant and Fertilizer Act (ACT 803), 2010).

With reference to the above provisions, legal action could be taken against any person or group of persons or any company that violates this clearly defined seed law especially when the repackaging containers are not securely sealed and well labelled as prescribed by the act. Repackaging of certified seeds at retailers' end may also expose seeds to high relative humidity and temperatures which may reduce seed quality or cause seed deterioration. Repackaged seeds may further mix up with seeds of other varieties or other crop species, weed seeds, and inert matter, thus reducing seed purity which is also an attribute of seed quality. Lastly, seeds may also be infected by air-borne pathogens during the repackaging process, hence, affecting seed health quality.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Site

The study comprised a field survey conducted from December, 2018 to March, 2019, and laboratory analyses which was undertaken from April to May, 2019.

The field survey was conducted in the Ashanti Region of Ghana. The Ashanti Region is a cosmopolitan region sited within the middle belt of Ghana and lies between longitudes 0.15W and 2.25W, and latitudes 5.50N and 7.46N (Gyasi-Agyei *et al*., 2014). Occupying a total of 24,389 square kilometers of land area, the Ashanti Region represents 10.2% of Ghana's total land area (Gyasi-Agyei *et al*., 2014). The region currently has 43 metropolitan, municipal and districts (MMDs) with Kumasi, the second biggest city in Ghana, as its capital (Ghana Districts, 2018; Boamah, 2010). The Ashanti Region shares boundaries with six of the sixteen (16) administrative regions in Ghana; Eastern Region to the east, Central and Western North regions to the south, Ahafo and Bono regions to the west, and Bono East Region to the north.

The region has a total population of 4,780,280. This figure represents 19.4% of Ghana's total population making it the most populous region in the country (GSS, 2010). The Ashanti Region has 412,055 agricultural households, representing 36.6% of the total households in the region, and 16.5% of all agricultural households in Ghana (GSS, 2010).

3.2 Sampling Techniques and Tools Used for Field Survey

3.2.1 Laboratory Evaluation

Laboratory experiments to test the quality of certified vegetable seeds that were on sale were also conducted at the National Seed Testing Laboratory (NSTL) of the Ghana Seed Inspection Division

(GSID) at Pokuase in the Greater Accra Region. GSID is a subsidiary of Plant Protection and Regulatory Services Directorate (PPRSD) of the Ministry of Food and Agriculture (MoFA). Pokuase is located off the Accra-Kumasi highway in the Ga West Municipality of the Greater Accra Region.

3.2.2 Sampling of Certified Vegetable Seed Retailers/Respondents

Information from the leadership of Ghana Agricultural Inputs Dealers Association (GAIDA) revealed that majority of seed retailers were located in the capital, Kumasi, while others were also mostly located in markets and lorry stations of municipal/district capitals.

The regional capital, Kumasi was selected using purposive sampling since majority of the retailers were located within the Kumasi Metropolis. Twelve (12) other municipal/district capitals were additionally selected using simple random sampling. These were Atwima Foase, Mankranso Obuasi, Konongo, Ejisu, Tepa, Asante Mampong, Manso Nkwanta, New Edubiase, Nkawie, Asante Bekwai and Ejura.

Each district capital produced varying number of retailers or respondents. However, no certified vegetable seed retailers were identified in three municipal/district capitals namely, Ejura, Atwima Foase, and Mankranso at the time of visit. In all, twenty-five (25) retailers/respondents were sampled (Table 3.1). (Refer to appendix 2 for the list of retailers' shops and their locations)

Table 3.1: Metropolitan/Municipal/District, Capital and Number of Retailers

Metropolitan/Municipal/District	Capital	Number of Retailers
Kumasi Metropolitan	Kumasi	9
Bekwai Municipal	Bekwai	3
Mampong Municipal	Mampong	1
Atwima Nwabiagya Municipal	Nkawie	1
Obuasi Municipal	Obuase	3
Ejisu Municipal	Ejisu	1
Asante Akim Central Municipal	Konongo	1
Adansi South District	New Edubiase	2
Amansie West District	Manso Nkwanta	1
Ahafo Ano North Municipal	Tepa	3
Ahafo Ano South West District	Mankranso	-
Atwima Kwanwoma District	Atwima Foase	-
Ejura-Sekyedumase Municipal	Ejura	-
Total: 10	**Total: 10**	**Total: 25**

3.2.3 Tools Used for Survey

The vegetable seed retailers were interviewed one-on-one with the aid of a pre-tested questionnaire. The questionnaire was a 5-page document with questions that were relevant to the objectives of the study. The questionnaire centred mainly on retailers' sources of seed and delivery methods, day to day atmospheric conditions for seed storage, practice of repackaging of sourced seeds, storage of seeds with agrochemicals and other seeds, feedback from farmers (buyers), retailers' marketing challenges among others (See Appendix 1 for questionnaire).

An IN-OUT Thermo-Hygrometer was used in recording the storage temperature and relative humidity at all the commercial retail shops sampled.

3.3 Certified Vegetable Seed Sampling

Seed samples were purchased from 22 out of the 25 retail shops visited. The 3 other shops had run out of stock because they reported that their customers were rain dependent and thus, they only enter into business when the rains set in. Vegetable seed samples that were purchased were duly certified by PPRSD presupposing that before the vegetable seeds entered the seed distribution and marketing channels, they had passed the minimum seed certification standards and seed laws applicable in Ghana. Seed samples weighed from 25g to 100g depending on the seed size, and the type of packaging. Samples were rightfully labelled based on the name of seed, town from which they were sampled, and whether they were in original package or were repackaged.

3.3.1 First Sampling

Thirty (30) certified vegetable seed samples were purchased from 22 retail outlets from January February, 2019 to assess the general quality state of the seeds that were being sold to farmers. Samples were put into two (2) groups of fifteen (15). One group had vegetable seed samples that were in their original package (Table 3.2), and the other also had vegetable seed samples that had been repackaged into transparent plastic bags at the retailers' end (Table 3.3). Seed samples were selected using simple random sampling.

Table 3.2: Fifteen (15) vegetable seed samples in original packs purchased from various retail outlets

Vegetable/Variety	Retail Outlet	Label
Eggplant *var*. Black Beauty	Agyass Seeds	EP-MB-O
Hot pepper *var*. Shito Adope	Best and Less Agrochemicals	HP-KN-O
Onion *var*. Red Creole	K. Badu Agrochemicals	ON-BT-O
Tomato *var*. Rio Grande	Nanafico Enterprise	T-KJ-O
Cucumber *var*. Market More	Abronoma Agrochemicals	CU-BK-O
Lettuce *var*. Eden	I Sam 2:6-7 Agrochemicals	L-BK-O
African eggplant *var*. Kotobi	Anokye Agrochemicals	AEP-OB-O
Hot pepper *var*. Cayenne	Akuafuo Yiedie Fie	HP-NE-O
Okra *var*. Clemson Spineless	Agriseed Limited	OK-AN-O
Onion *var*. Ares	Agriseed Limited	ON-AN-O
Cabbage *var*. Tropical King	Owusu Agrochemicals	CB-NK-O
Carrot *var*. Amazonia	Grace Adom Agrochemicals	CR-TP-O
Sweet pepper *var*. Yolo Wonder	Yonko Do Agrochemicals	SP-AA-O
Carrot *var*. Amazonia	Kyeiwaa Agrochemicals	CR-MP-O
Tomato *var*. Heinze	Maconi Enterprise	T-OB-O

* *var* = variety

Table 3.3: Fifteen (15) repackaged vegetable seed samples purchased from various retail outlets

Vegetable/Variety	Retail Outlet	Label
Okra *var*. Labadi dwarf	Owusu Agrochemicals	OK-NK-R
Cabbage *var*. Oxylus	Maame Agrochemicals	CB-BK-R
Cabbage *var*. Oxylus	Amankwah Spare Parts and Seeds	CB-MB-R
Onion *var*. Ares	Maconi Enterprise	ON-OB-R
Cucumber *var*. Marketer	Divine Oppongsco Enterprise	CU-EJ-R
Tomato *var*. Roma	Divine Oppongsco Enterprise	T-EJ-R
Carrot *var*. Shakira	Akuafuo Adamfo	CR-OB-R
Tomato *var*. Tropimech	Dapsy Agro Products	T-MB-R
Sweet pepper *var*. Yolo Wonder	Dapsy Agro Products	SP-MB-R
Carrot *var*. Amazonia	Mansusu Agrochemicals	CR-MB-R
Lettuce *var*. Eden	Grace Adom Agrochemicals	L-TP-R
Lettuce *var*. Kaizer	Samofa Agrochemicals	L-NE-R
Hot pepper *var*. Carabeau	God's Time Agrochemicals	HP-TP-R
Cucumber *var*. Murano	Kyeiwaa Agrochemicals	CU-MP-R
Sweet pepper *var*. Yolo Wonder	Agyass Seeds	SP-MB1-R

**var*: variety

3.3.2 Second Sampling

Following the first sampling, nine (9) vegetable seed samples were also assembled from eight (8) retail outlets using purposive sampling (Table 3.4) in March, 2019. Samples comprised one variety each of sweet pepper, carrot, and cabbage. Each vegetable variety was in its original package, and had also been repackaged into transparent plastic bags across three (3) different retail outlets making a total of eighteen (18) treatments. Vegetable variety obtained from a particular shop was labelled as a single sample in two package types to enable comparison between samples, and package types across different retail outlets. The nine (9) samples were labelled as follows:

i. SP-MB, SP-MB1, and SP-MB2 for sweet pepper *var*. Yolo Wonder seeds obtained from three different retail outlets,

ii. CR-MP, CR-TP, and CR-MB for carrot *var*. Amazonia seeds obtained from three different retail outlets, and

iii. CB-BK, CB-MB, and CB-OB for cabbage *var*. Oxylus obtained from three different retail outlets (Table 3.4).

O and R were attached to treatment labels to distinguish between package types (O=original package, R= repackaged) of the same sample from a particular outlet (Table 3.4)

Table 3.4: Vegetable seed samples with their labels and corresponding retail outlets

Vegetable/Variety	Retail Outlet	Treatment Label
Sweet pepper *var*. Yolo Wonder	Agyass Seeds	SP-MB1-O
		SP-MB1-R
	Dapsy Agro Products	SP-MB-O
		SP-MB-R
	Mansusu Agrochemicals	SP-MB2-O
		SP-MB2-R
Carrot *var*. Amazonia	Kyeiwaa Agrochemicals	CR-MP-O
		CR-MP-R
	Grace Adom Agrochemicals	CR-TP-O
		CR-TP-R
	Mansusu Agrochemicals	CR-MB-O
		CR-MB-R
Cabbage *var*. Oxylus	Maame Agrochemicals	CB-BK-O
		CB-BK-R
	Amankwah Spare Parts and Seeds	CB-MB-O
		CB-MB-R
	Maconi Enterprise	CB-OB-O
		CB-OB-R

* *var*: variety

3.4 Quality Analyses on Seed Samples (Laboratory Experiments)

On arrival at the National Seed Testing Laboratory of GSID, the laboratory manager received the samples, verified that they were indeed certified by PPRSD and finally checked for the labelled seed quality parameters (eg. % germination, % purity, % moisture content) on the cans and sachets, and then the repackaged plastic bags (if any). Quality tests were conducted for seed germination percentage, percentage purity, moisture content, seedling vigour and seed health from April to

May, 2019, to evaluate these parameters after seeds had entered the distribution and marketing channel. All quality analysis mainly followed the ISTA Rules.

3.4.1 Experimental Design

Each group of the first sampled seeds (seeds in original package and repackaged seeds) was arranged in a Completely Randomized Design (CRD) with 4 replications. Each of the second sampled seeds (sweet pepper, carrot, and cabbage) was set up as a 2 x 3 factorial arranged in CRD with package type (original package, repackaged) and sample (three different sample sources (retail outlets)) as factors.

3.4.2 Seed Purity Tests

Purity test on vegetable seed samples submitted was carried out with the aid of the current ISTA (2017) rules and 3rd Edition (2013) ISTA handbook on pure seed definitions.

The Hand-halving method was used to divide submitted samples to obtain working samples. Working samples were then drawn into thin lines using spatula and each sample was individually examined to separate pure seed from other crop seeds, weed seeds and inert matter. A minimum of 15g of all submitted samples was used for this test. Various components were weighed in grams using a digital scale, and expressed as a percentage of the total weight. Percentage purity was calculated using the formula: $\%\ Purity = \frac{Pure\ seed\ weight}{Total\ weight\ of\ working\ sample}\ x\ 100$

3.4.3 Seed Moisture Content Tests

The constant temperature oven method was adopted to determine moisture content of the submitted vegetable seed samples (ISTA, 2007). The principle behind the constant temperature oven method is that the Moisture Content in a seed is determined by the loss in weight after the working sample has been dried for a specific time in a drying oven set at a specific temperature. The temperature and amount of time used is species dependent.

The equipment used for this analysis included:

- An oven with a stable and a high capacity capable of providing a uniform temperature.
- A well calibrated grinder/mill.
- A sensitive balance capable of weighing at least up to 3 decimal places.
- Containers made of a non-corrosive metal (stainless steel), with random numbers inscribed on their lids.
- Desiccators with plates at the bottom capable of holding samples after drying during cooling.

The desiccants are usually placed in the desiccator to absorb the moisture removed from the environment of the desiccator. This ensures samples cooled in a desiccator do not reabsorb moisture.

Before the process was started, the oven was turned on so as to build heat to the required temperature before the samples were placed in. With the oven building up heat, containers with their lids were first weighed and recorded on a moisture form. Vegetable seed samples were opened, mixed with spoon and three subsamples drawn at different positions with the spoon and placed in the container (Replicate A). The initial (wet) weight (container + sample + lid) was taken using the "COBOS precision" weighing balance and recorded. The above procedure was repeated in a replicate container called replicate B. Samples were placed in an oven with containers open, sitting on top of their lids.

Oven temperature was monitored, confirmed and recorded. A timer was set for the required drying period. At the end of the drying period, temperature was recorded. Samples were taken out of the oven, covered quickly with their lids and placed in a desiccator for 45 minutes after which the final (dry) weight (container + sample + lid) was recorded.

Each replicate was calculated separately using the formula:

$$\frac{(container\ \text{weight} + sample\ \text{weight}\ before\ drying) - (\text{Weight}\ of\ container\ and\ sample\ after\ drying)}{sample\ \text{weight}\ before\ drying} \times 100$$

Final moisture content was determined by finding the average of the replicates.

3.4.4 Seed Germination Tests

Seed germination potential was determined using the blotter paper (Top of paper) method at an incubation temperature of 25 ^{0}C. Four replications of 100 seeds each were used per each sample to ascertain seed germination potential. Final germination counts were done at 14 DAS to evaluate germination percentage of each seed sample (ISTA, 2013). For each replicate, normal seedlings (seedlings with all essential features intact) were separated from abnormal seedlings, and un-germinated seeds. Germination percentage was computed using the formula:

$$\%\ Germination = \frac{Normal\ seedlings}{Total\ number\ of\ seeds\ planted}\ x\ 100$$

3.4.5 Seed Vigour Tests

Seedling vigour tests were conducted for vegetable seed samples at 14 DAS using the seedling growth rate test. Seedling lengths (seedling root length + seedling shoot length) in centimetres were measured and recorded from 10 sampled seedlings from each replication using a ruler. Seedling length was used as an indicator of vigour because vigorous seedlings would grow faster and lengthier than less vigorous seedlings.

Seedling vigour index was then computed by finding the product of percentage germination of seed and average seedling length (Abdul-Baki and Anderson, 1973). Seed sample that had the highest seedling vigour index were ranked more vigorous.

3.4.6 Seed Health Tests

The Blotter method was used to conduct seed health tests (ISTA, 2013; Mathur and Kongsdal, 2003). Hundred (100) seeds were plated in 9 cm petri dishes lined with wet blotters for each tested sample. Twenty-five (25) seeds were plated per petri dish with 4 replications. Seeds were incubated under ultra violet light for 7 days under 12 alternating cycles (12 hours of light and 12 hours of darkness at 20 ^{0}C).

At the end of the incubation period, each seed was thoroughly examined under various magnifications of a stereomicroscope for fungal growth. Fungi were identified on the basis of habit characters; how individual fungi develop on seeds, as well as the morphological features of spores, fruiting bodies and conidia observed under the compound microscope.

Percentage fungal prevalence caused was determined using the formula:

% prevalence = $\frac{number\ of\ infected\ seeds}{total\ number\ of\ seeds\ plated}\ x\ 100$

3.5 Statistical Analysis

Data on percentage purity, percentage seed germination, percentage seed moisture content, seed vigour, and seed health were recorded accordingly. A general analysis of variance (ANOVA) for the various seed quality indices were conducted using GenStat statistical package 12th Edition. Mean separation was done by using Fishers' Protected LSD to compare the significant differences between treatments at 5 % level of significance.

Data on questionnaire were analysed using IBM SPSS Statistics 20.

CHAPTER FOUR

4.0 RESULTS

4.1 Profile of Certified Vegetable Seed Retailers and Retail Shops in the Study Area

4.1.1 Distribution of Retailers in the Ten (10) District Capitals

A total of twenty-five (25) certified vegetable seed retailers were identified in ten (10) of the thirteen (13) sampled district capitals in the Ashanti Region. The names of the district capitals, number of retailers and their corresponding frequencies and percentages are presented below (Table 4.1).

Table 4.1: Distribution of Retailers in the Ten (10) District Capitals

	Retailers	
District Capital	**Frequency**	**Percentage (%)**
Kumasi	9	36
Bekwai	3	12
Mampong	1	4
Nkawie	1	4
Obuasi	3	12
Ejisu	1	4
Konongo	1	4
New Edubiase	2	8
Manso Nkwanta	1	4
Tepa	3	12
Total	**25**	**100**

4.1.2 Demographic Characteristics of Retailers (Respondents)

4.1.2.1 Gender of Respondents

Results from the survey indicated that males were dominant (68%) in the vegetable seed retail business as compared to females (32%) (Figure 4.1).

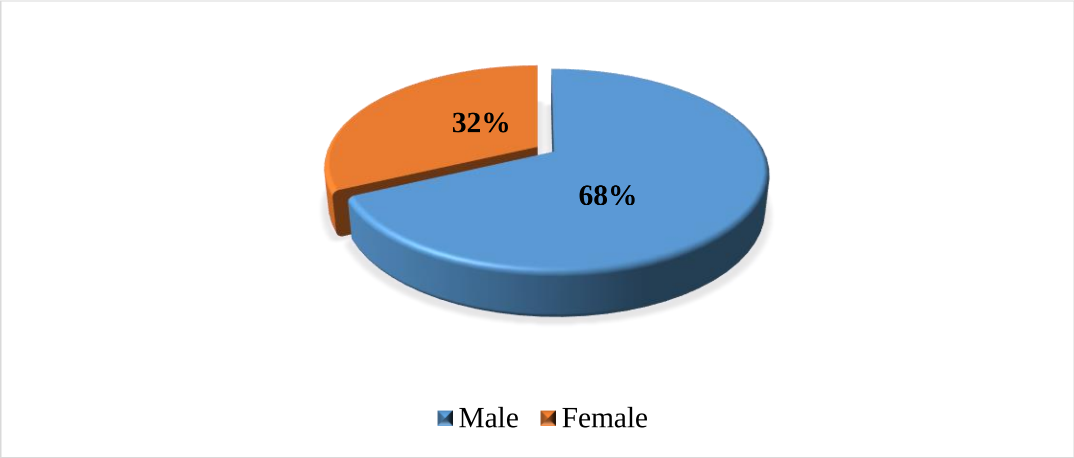


Figure 4.1: Gender of Respondents

4.1.2.2 Age Distribution of Respondents

Result analysis showed that majority (48%) of the retailers were above 36 years, followed by those whose ages ranged from 25 to 36 years (32%), with those below 25 years being the least age group (20%) (Figure 4.2).

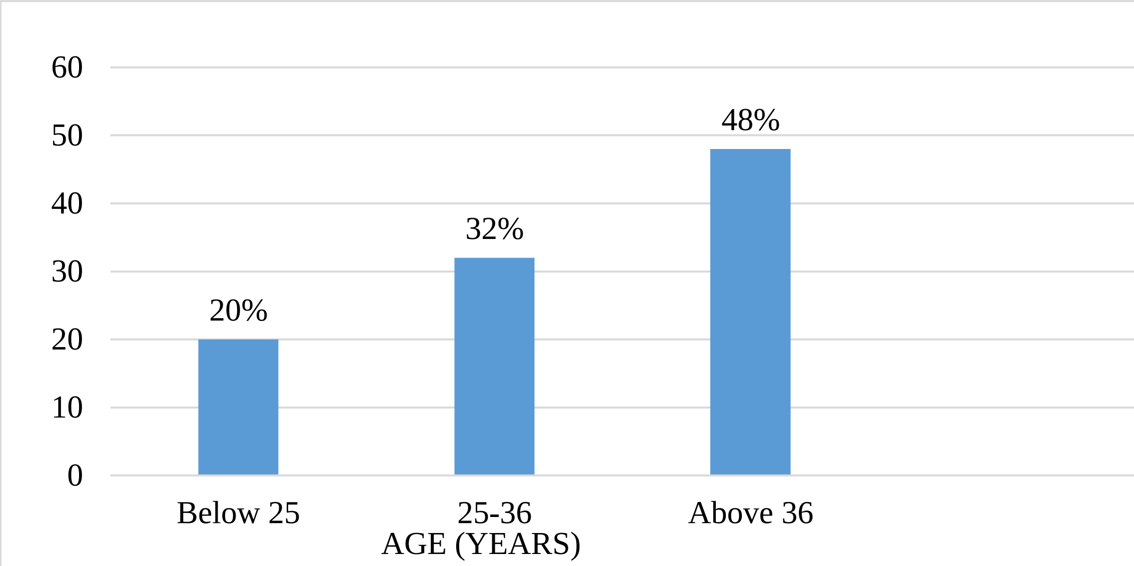


Figure 4.2: Age Distribution of Retailers

4.1.2.3 Educational Level of Retailers

Most of the retailers interviewed had completed S.H.S (48%). This figure was followed by Bachelor's Degree holders (20%), J.H.S leavers (12%), and Diploma holders (8%) in descending order of magnitude. Only one retailer, representing 4% of the total number of respondents had no formal education and the percentage was the same as HND and Master's degree holders (Table 4.2)

Table 4.2: Educational Level of Retailers

Level of Education	Frequency	Percentage (%)
B.E.C.E	3	12
W.A.S.S.C.E	12	48
HND	1	4
Diploma	2	8
Bachelor's degree	5	20
Master's Degree	1	4
No Formal Education	1	4
Total	**25**	**100**

4.1.3 Demographic Characteristics of Retail Outlets

4.1.3.1 Type of Business Organisation

Three business organisational types, namely, sole proprietorship, company, and co-operative were identified in the survey. Majority (80%) of the businesses fell under sole proprietorship. This was followed by companies which formed 16% of the total. Only one retail outlet, representing 4% of the total was a co-operative organisation (Figure 4.3).

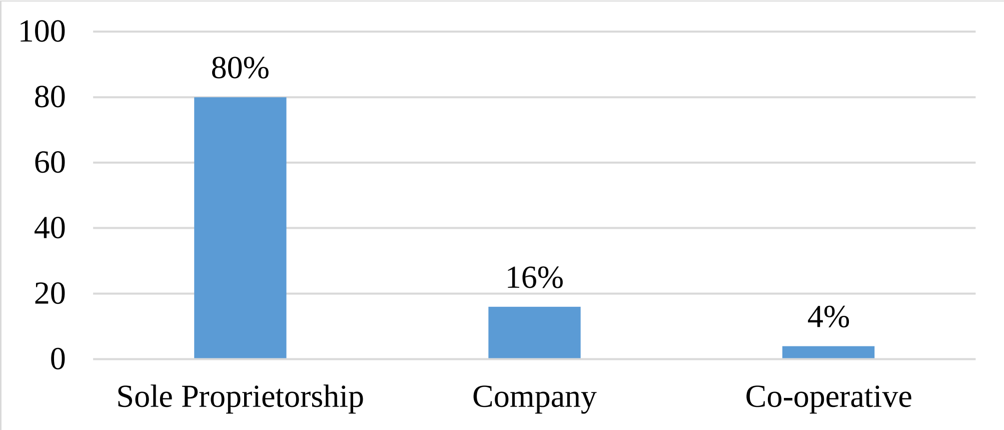


Figure 4.3: Type of Business Organisation

4.1.3.2 Number of Years in Business

The number of years retail shops had been in existence is reported in Figure 4.4. Majority (36%) of the shops had existed between 10 and 20 years. This was followed by those that had been in existence from 5 to 10 years (28%), and those that had existed for 20 years or more (20%). Retail shops that had been in existence for less than 5 years constituted the least with 16%.

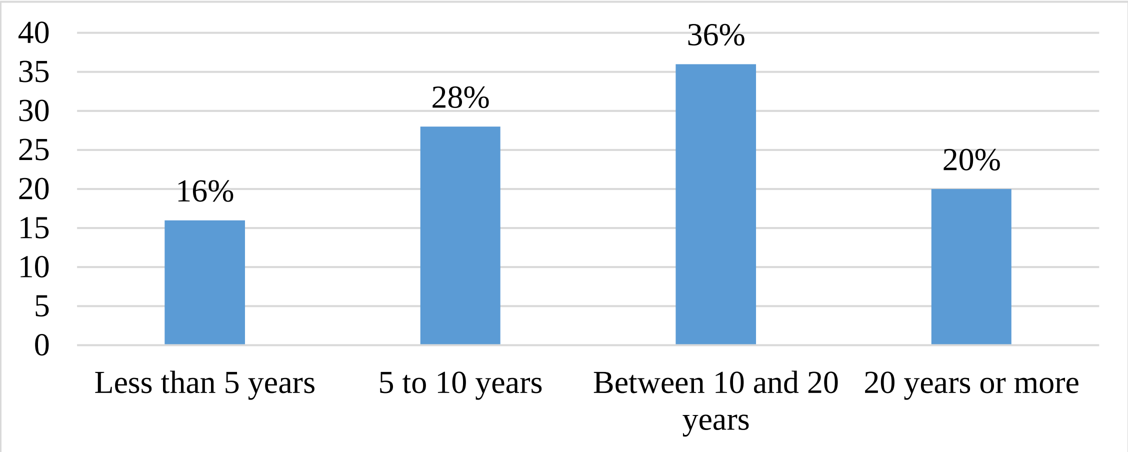


Figure 4.4: Number of Years in Business

4.1.3.3 Retail Shop Temperature

Results from the temperature recorded at the various retail shops indicated that majority (40%) of the shops had temperatures ranging from 31.0 ^{0}C to 32.9 ^{0}C. A temperature range of 29.0 ^{0}C to

30.9 ^{0}C followed with 28% whilst 20% of the shops had temperatures ranging from 33.0 ^{0}C to 34.9 ^{0}C. Eight percent of the shops recorded a temperature range of 35 ^{0}C to 36.9 ^{0}C whereas 4% had temperatures below 20 ^{0}C (Table 4.3).

Table 4.3: Temperatures of Retail Shops

Temperatures (^{0}C)	Frequency	Percentage (%)
Below 20	1	4
29.0 - 30.9	7	28
31.0 – 32.9	10	40
33.0 – 34.9	5	20
35.0 – 36.9	2	8
Total	**25**	**100**

4.1.3.4 Relative Humidity of Retail Shops

Results of the relative humidity measured at the various retail shops indicated that majority of the shops (32%) had relative humidity figures ranging from 60% to 64%. This was followed by shops that had relative humidity ranges of 55% to 59% (24%), 50% to 54% (20%), and 40% to 44% (16%). Shops that had relative humidity measuring from 45% to 49% had the least percentage (8%) (Table 4.4).

Table 4.4: Relative Humidity of Retail Shops

Relative Humidity (%)	Frequency	Percentage (%)
40 – 44	4	16
45 – 49	2	8
50 – 54	5	20
55 – 59	6	24
60 – 64	8	32
Total	**25**	**100**

4.2 Seeds Retailed, Certified Vegetable Seed Sources, Mode of Seed Delivery and Seed Packaging Materials.

4.2.1 Other Seeds Retailed

Results from retailers' response on the other types of seeds retailed aside vegetable seeds are shown in Table 4.5. The results indicated that most (56%) retailers sold only seeds of cereals in addition to vegetable seeds. This was followed by those who were also into retail of cereal and legume seeds (28%). Eight percent of vegetable retailers also sold seeds of cereals and fruits while 4% also dealt in seeds of fruits and ornamentals. Four percent of the vegetable seed retailers did not deal in other type of seeds.

Table 4.5: Other seeds sold by vegetable seed retailers

Responses	Frequency	Percentage (%)
Cereals only	14	56
Cereals and legumes	7	28
Cereals and fruits	2	8
Fruits and ornamentals	1	4
No other seeds	1	4
Total	**25**	**100**

4.2.2 Retailers' Most Sold Vegetable Seeds

Results from retailers' most sold vegetable seeds in terms of ranking are presented in Figure 4.5. Result analysis showed that, cabbage seeds were the most sold vegetable seeds for majority (44%) of the retailers. This was followed by okra seeds as 20% of the retailers indicated that okra was their most sold vegetable seeds. Tomato and Lettuce seeds followed up being ranked by the same percentage retailers as the most sold vegetable seeds. Sweet pepper, eggplant, and hot pepper also followed as they were ranked by the same percentage (4%) of retailers as most sold vegetable seeds.

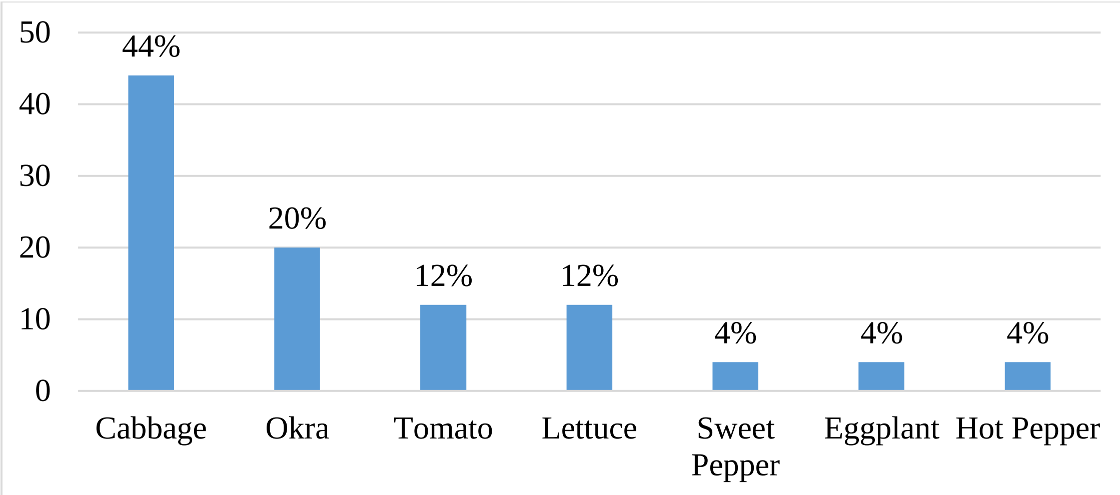


Figure 4.5: Retailers' Most Sold Vegetable Seeds

4.2.3 Receipts of Complaints from Buyers about Purchased Vegetable Seeds

Certified vegetable seed retailers' response as to whether they received complaints from buyers about purchased vegetable seeds showed that, 76% of them received complaints while 24% did not receive any complaints (Figure 4.6).

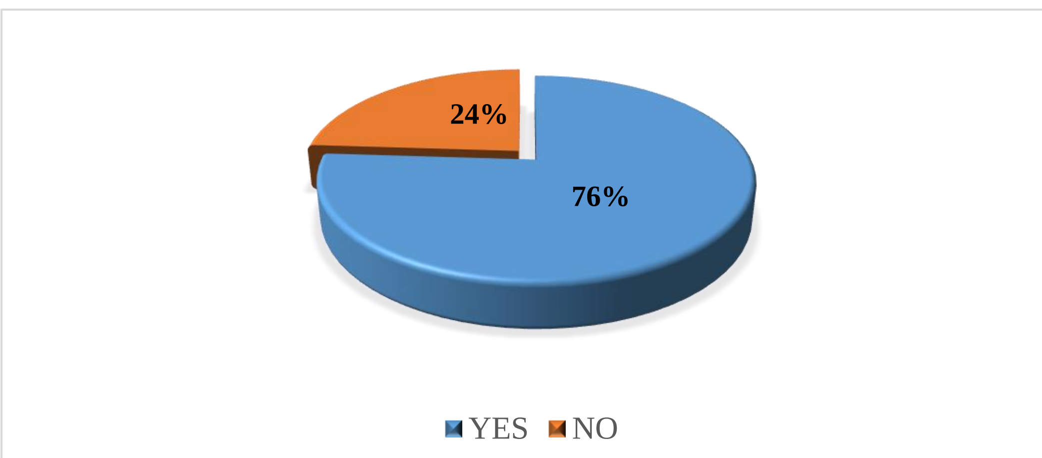


Figure 4.6: Percentage Respondents Indicating Receipts of Complaints from Buyers after Purchase of Vegetable Seeds

4.2.4 Specific Complaints Received by Retailers from Buyers

Multiple response analysis of specific complaints retailers received from buyers indicated that most (60%) complaints were about poor germination of the seeds. The next was about low plant establishment which formed 16.7% of the complaints. Presence of virus followed with 10% while presence of insects, and moulding completed the complaints with 6.7% apiece (Table 4.6).

Table 4.6: Specific Complaints Received by Retailers from Buyers

	Responses	
Complaints	**Frequency**	**Percentage (%)**
Poor germination	18	60
Presence of insects	2	6.7
Moulding	2	6.7
Presence of virus when planted	3	10
Low plant establishment	5	16.7
Total	**30**	**100.0**

4.2.5 Certified Vegetable Seed Suppliers

Response from retailers on their sources of certified vegetable seeds showed (100%) retailers indicating that they received their certified vegetable seeds from seed companies.

4.2.6 Mode of Seed Delivery to Retailers

With respect to how certified vegetable seeds were transported to retailers, most of the retailers (80%) indicated that seeds were transported to them by ordinary vans. 12% of the retailers also had their seeds transported to their end by air-conditioned vans. The least mode of seed transport was by cold vans as reported by only 8% of the retailers (Figure 4.7).

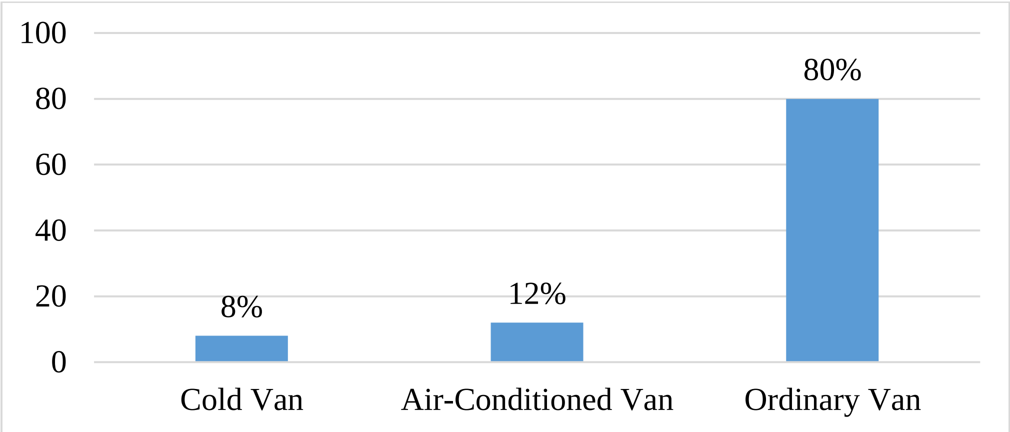


Figure 4.7: Percentage Respondents Indicating Mode of Seed Delivery to Retail Shops

4.2.7 Packaging Material of Purchased Certified Vegetable Seeds

Retailers' response on the type of packaging material used for their sourced certified vegetable seeds indicated that 51% were cans, 44.9% were paper sachets, and the remaining 4.1% being aluminium foil (Table 4.7).

Table 4.7: Packaging Materials of Certified Vegetable Seeds

	Responses	
Packaging Materials	**Frequency**	**Percentage (%)**
Cans	25	51.0
Aluminium foil	22	44.9
Paper sachets	2	4.1
Total	**49**	**100.0**

4.3 Retailers' Knowledge and Practices on the Storage and Handling of Certified Vegetable Seeds.

4.3.1 Retailers' Perception on Best Mode of Seed Delivery to Retail Shops

With respect to vegetable seed retailers' opinions about the best condition for transporting vegetable seeds to retail shops, 80% of them indicated that transporting seeds in air-conditioned vans was the best practice. This was followed by those who selected cold vans (16%) as the best mode of seed transport whereas only 4% opted for ordinary vans (Figure 4.8).

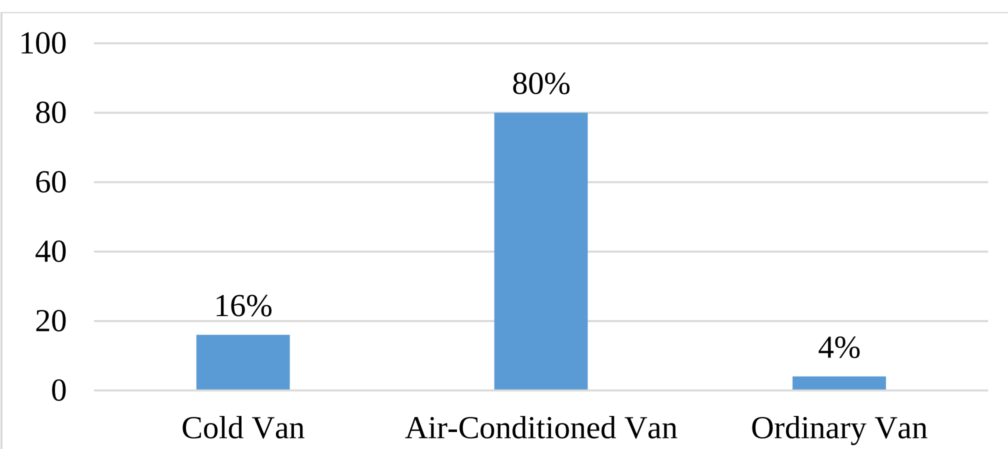


Figure 4.8: Retailers' Perception on Best Mode of Seed Delivery to Retail Shops

4.3.2 Retailers Response to Whether They Conducted Germination Test on Sourced Vegetable Seeds

Retailers' response to whether germination test was conducted on sourced vegetable seeds prior to retailing indicated that majority of them (56%) did not conduct any germination test on their seeds. The remaining 44% however conducted germination tests on sourced vegetable seeds before retailing (Figure 4.9).

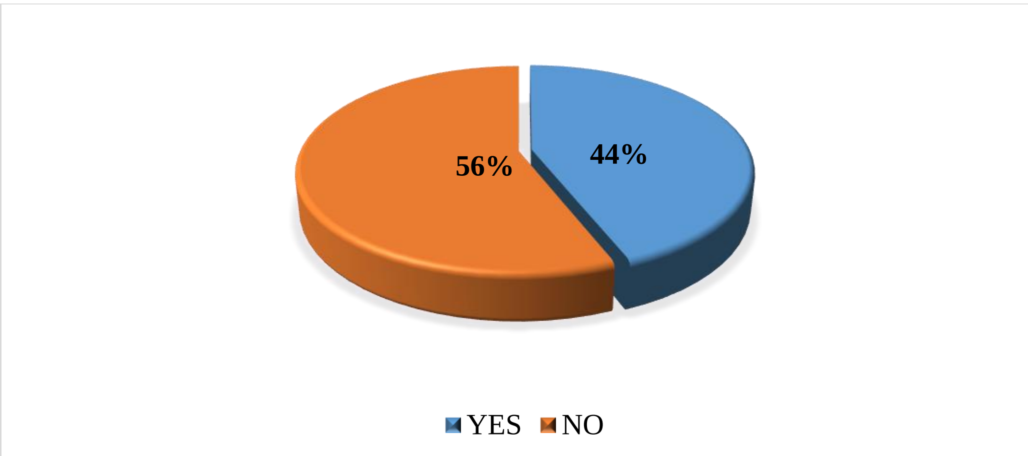


Figure 4.9: Retailers Response to Whether They Conducted Germination Test on Sourced Vegetable Seeds

4.3.3 Retailers' Storage Location of Received Vegetable Seeds

Majority (68%) of the retailers interviewed indicated that they kept their sourced vegetable seeds at their retail shops while the remaining 32% kept their sourced vegetable seeds in warehouses (Figure 4.10).

Figure 4.10: Retailers' Storage Location of Received Vegetable Seeds

4.3.4 Conditions under which Vegetables Seeds were Stored Over Time

Response from interviewed retailers showed that conditions under which almost all (96%) retailers stored their certified vegetable seeds over time was room temperature. The remaining 4% stored their seeds in cold rooms over time (Figure 4.11).

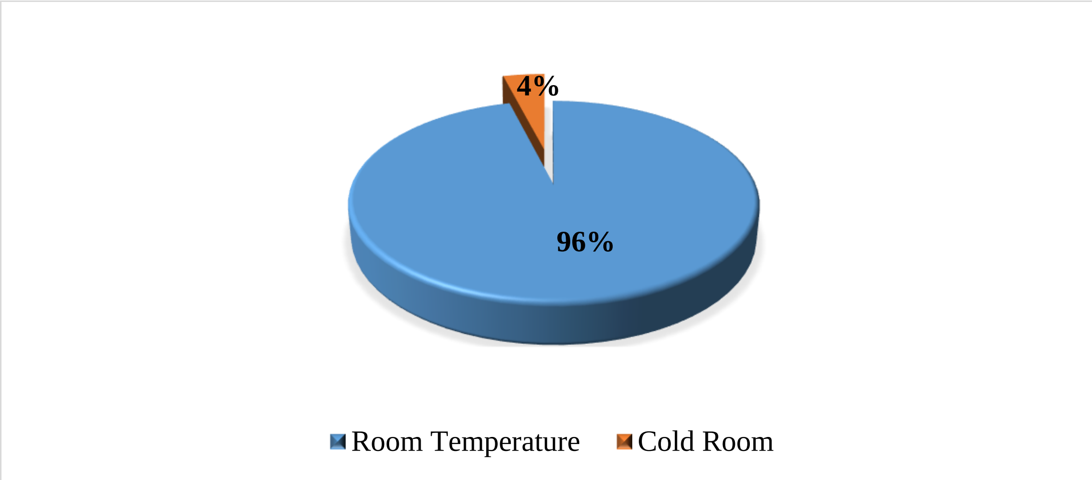


Figure 4.11: Conditions under which Vegetables Seeds were Stored Over Time

4.3.5 Storage Duration of Vegetable Seeds in Stock

Analysis of response by retailers on how long they kept vegetable seeds in stock showed that majority (44%) of them kept seeds in stock for a period of 1 to 3 months (Table 4.8). The same percentage of retailers (20%) followed with storage durations of 10 to 12 months and over 12 months (Table 4.8). Twelve percent of the retailers also kept seeds in stock for a period of 4 to 6 months while only 4% kept seeds in stock beyond 12 months (Table 4.8).

Table 4.8: Storage Duration of Vegetable Seeds in Stock

Duration (Months)	Frequency	Percentage (%)
1 – 3	11	43
4 – 6	3	12
7 – 9	1	4
10 – 12	5	20
Over 12	5	20
Total	**25**	**100**

4.3.6 Retailers' Perception on the Effect of Storage Duration on Vegetable Seed Quality

Retailers' response to whether the length of storage time had effect on vegetable seed quality is displayed in Table 4.9. Most retailers representing 87.5% out of 24 valid responses indicated that length of storage time had effect on vegetable seed quality; seed quality declined with time. However, 12.5% of the retailers indicated that storage time had no effect on seed quality; effect depends on storage conditions.

Table 4.9: Retailers' Response to whether the Length of Storage Time Had Effect on Vegetable Seed Quality

Response	Frequency	Percent (%)	Valid Percent (%)
Yes	21	84	87.5
No	3	12	12.5
Total	**24**	**96**	**100.0**
No response	1	4	
Total	**25**	**100**	

4.3.7 Effect of Storage Duration on Vegetable Seed Quality

Multiple response analysis of the effects of storage duration on vegetable seed quality as provided by respondents who were of the view that length of storage time had effect on vegetable seed quality is shown in Table 4.10. Majority (81.8%) of the respondents were of the view that long storage period resulted in poor germination of seeds. Poor plant establishment was cited by 9.1% of the respondents whereas 4.5% said seeds turned mouldy with time. The rest were of the view that seeds might expire with time.

Table 4.10: Effect of Storage Duration on Vegetable Seed Quality

Responses	Frequency	Percentage (%)
Poor germination	18	81.8
Poor plant establishment	2	9.1
Moulding	1	4.5
Expiry of seeds	1	4.5
Total	**22**	**100.0**

4.3.8 Retailers Awareness of Factors that Affect Vegetable Seeds in Storage

Analysis of results on whether retailers were aware of factors that affect vegetable seeds in storage indicated that most (92%) of the retailers were aware of at least one of such factors. The remaining 8% had no idea about such factors (Figure 4.12).

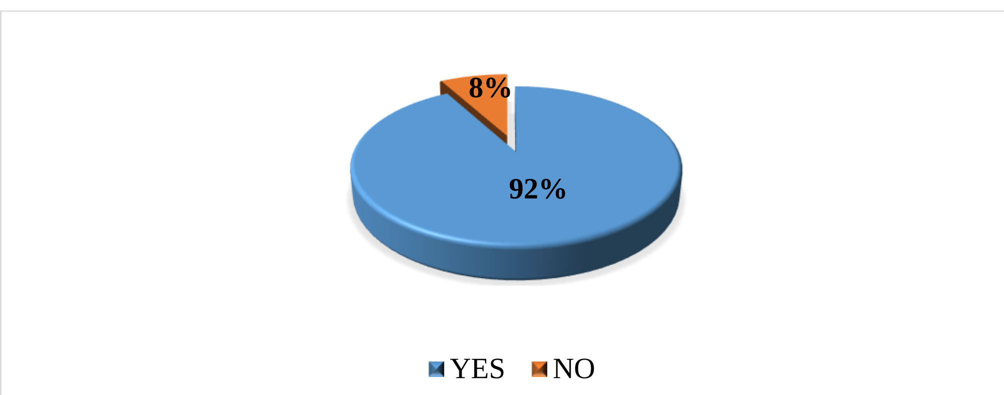


Figure 4.12: Retailers' Response to Whether They Were Aware of Factors That Affect Vegetable Seeds in Storage

4.3.9 Factors that Affect Vegetable Seeds in Storage

In multiple response analysis of factors that affect vegetable seeds in storage as indicated by retailers who were aware of such factors, storage temperature was the most predominant factor (64%) cited by retailers (Table 4.11). Moisture content and relative humidity followed with 11.8% each while pests and poor processing were the least mentioned factors with corresponding percentage of 5.9% each (Table 4.11).

Table 4.11: Factors that Affect Vegetable Seeds in Storage

	Responses	
Factors	**Frequency**	**Percentage (%)**
Storage temperature	22	64.7
Moisture content	4	11.8
Relative humidity	4	11.8
Pests	2	5.9
Poor processing	2	5.9
Total	**34**	**100.0**

4.3.10 Keeping of Vegetable Seeds together with Agrochemicals

Analysis of retailers' response to whether they kept vegetable seeds together with agrochemicals indicated that 84% of them kept vegetable seeds and agrochemicals in the same retail shop 16% of them did not (Figure 4.13).

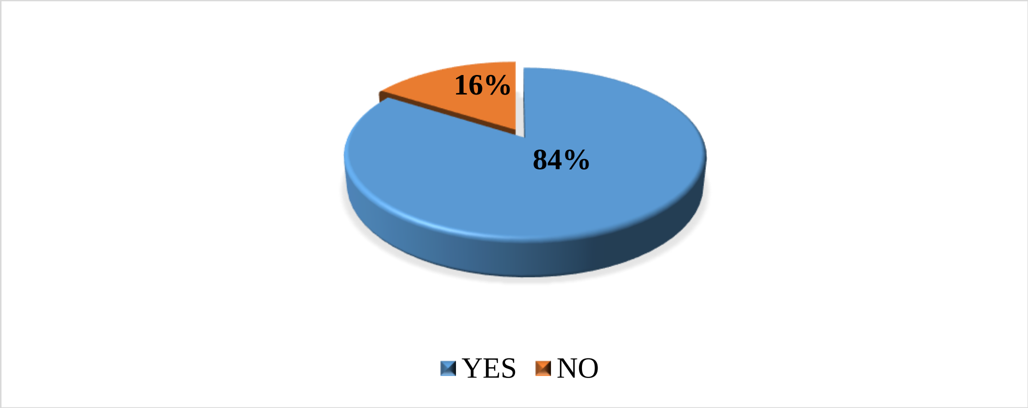


Figure 4.13: Response to Whether Retailers Kept Vegetable Seeds and Agrochemicals Together

4.3.11 Impact of Proximity of Agrochemicals on Vegetable Seeds in Retail Shops

Analysis of retailers' response to whether they had identified any negative impact of agrochemicals on vegetable seed quality as both were being kept in the same retail shop revealed that majority (76%) of them had not identified any such effects (Table 4.12). Only 8% of the respondents had witnessed some negative impacts while 16% did not provide any answer since they had not kept vegetable seeds with agrochemicals (Table 4.12).

Table 4.12: Retailers Response to whether they Had Identified any Negative Impact of Agrochemicals on Vegetable Seed Quality

Response	Frequency	Percent (%)	Valid Percent (%)
Yes	2	8	9.5
No	19	76	90.5
Total	**21**	**84**	**100.0**
No response	4	16	
Total	**25**	**100**	

4.3.12 Identified Negative Effects of Agrochemicals on Vegetable Seed Quality

Results analysed from retailers' response on identified negative impact of agrochemicals on vegetable seed quality indicated that only 8% had identified reduction in seed physiological quality (Table 4.13). The remaining 92% did not provide any response because they either did not keep seeds together with agrochemicals, or had not identified any negative effects of agrochemicals on seed quality when both were kept in the same retail shop (Table 4.13).

Table 4.13: Identified Negative Effects of Agrochemicals on Vegetable Seed Quality

Response	Frequency	Percent (%)	Valid percent (%)
Reduction in seed physiological quality	2	8	100
Total	**2**	**8**	**100**
No response	23	92	
Total	**25**	**100**	

4.3.13 Repackaging of Certified Vegetable Seeds at Retailers' Shops

Retailers response to whether they repackaged their sourced certified vegetable seeds indicated that 56% of them did repackage their sourced certified vegetable seeds whilst 44% of them did not (Figure 4.14).

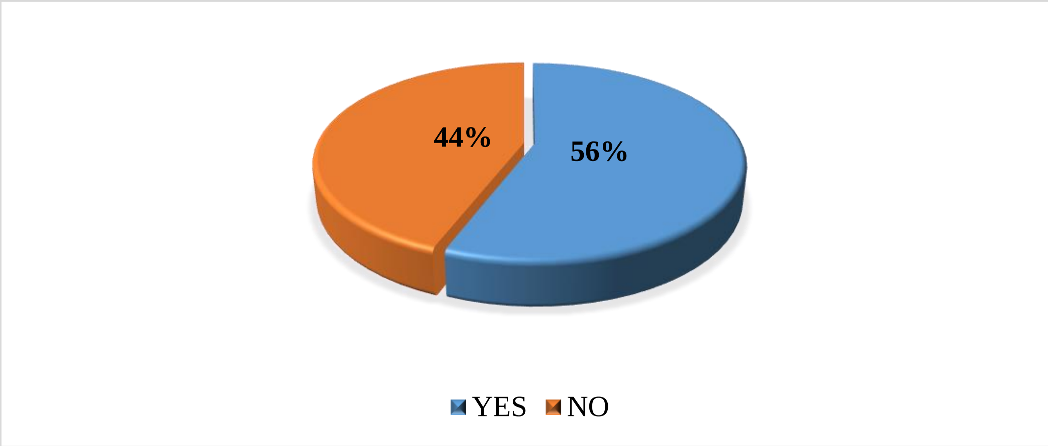


Figure 4.14: Retailers Response to whether they Repackaged Their Sourced Certified Vegetable Seeds

4.3.13.1 Material Used for Repackaging of Certified Vegetable Seeds

Analysis of results on the type of material employed for repackaging of certified vegetable seeds indicated that all (100%) the retailers who repackaged their sourced certified vegetable seeds used transparent plastic bags.

4.3.13.2 Reasons for Repackaging Certified Vegetable Seeds

Multiple response analysis on why retailers repackaged their sourced certified vegetable seeds indicated that, request for smaller quantities of seeds by small-scale vegetable farmers was the most cited reason (50%), followed by farmers' inability to afford the cost of seeds in larger containers (46.6%) (Table 4.14). The least cited reason was the request for small seed quantities for growth and yield tests of new varieties by large-scale vegetable farmers (4.6%) (Table 4.14).

Table 4.14: Retailers' Reason for Repackaging Certified Seeds

	Responses	
Reasons	**Frequency**	**Percent (%)**
Request for smaller quantities by small-scale farmers	14	50.0
Farmers' inability to afford cost of seeds in larger containers	13	46.4
Request for smaller quantities for growth and yield tests	1	4.6
Total	**28**	**100.0**

4.3.13.3 Impact of Seed Repackaging on Vegetable Seed Quality

Retailers' response to whether they had identified any negative impact of repackaging on vegetable seed quality showed that, 71.4% of retailers who repackaged their sourced vegetable seeds had not identified any negative effect of repackaging on the quality of the seeds. The remaining 28.6%, however, responded otherwise (Figure 4.15).

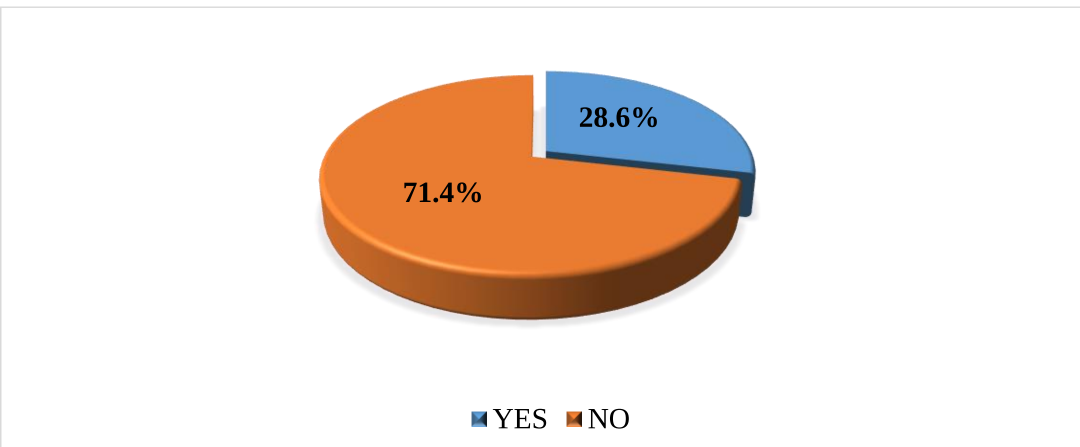


Figure 4.15: Retailers' Response to Whether They Had Identified any Negative Impact of Repackaging on Vegetable Seed Quality

4.3.13.4 Identified Negative Effects of Repackaging on Vegetable Seed Quality

Out of the responses provided by retailers who had identified negative impacts of repackaging on vegetable seed quality, poor germination was the most (42.9%) cited negative impact of repackaging on vegetable seed quality (Table 4.15). The next was entry of microbes (28.6%) as growth of moulds on seeds was observed, whilst reduction in seed shelf life and entry of inert matter also followed with 14.3% each (Table 4.15).

Table 4.15: Identified Negative Effects of Repackaging on Vegetable Seed Quality

	Responses	
Effects	**Frequency**	**Percent (%)**
Poor germination	3	42.9
Entry of microbes	2	28.6
Reduction in seed shelf life	1	14.3
Entry of inert matter	1`	14.3
Total	**7**	**100.0**

4.4 Vegetable Seed Marketing Challenges and Suggested Solutions by Retailers

4.4.1 Vegetable Seed Marketing Challenges

Multiple responses on marketing challenges encountered by vegetable seed retailers indicated that pricing was the major (37.9%) challenge faced by the retailers (Table 4.16). The next major challenges retailers faced were storage facilities and seed package sizes which formed 20.7% each of the total responses (Table 4.16). Access to credit facilities followed with 15.5% whilst late maturing, promotion, and access to good communication network followed with each recording 1.7% of the total responses (Table 4.16).

Table 4.16: Vegetable Seed Marketing Challenges

	Responses	
Challenges	**Frequency**	**Percent (%)**
Late maturing	1	1.7
Promotion	1	1.7
Storage	12	20.7
Access to credit facilities	9	15.5
Pricing	22	37.9
Seed package sizes	12	20.7
Access to good communication network	1	1.7
Total	**58**	**100.0**

4.4.2 Retailers' Suggested Solutions to Challenges with Vegetable Seed Marketing

Suggested solutions to vegetable seed marketing challenges included communicating with suppliers to package seeds in varying sizes to meet every farmer's specific requests, and provision cold storage facilities forming 35.1% and 29.7% respectively of the total suggested solutions (Table 4.17).

Table 4.17: Retailers' Suggested Solutions to Vegetable Seed Marketing Challenges

Suggestions	Responses	
	Frequency	**Percent (%)**
Mobilizing funds to increase business capital	3	8.1
Suppliers to package seeds in varying sizes to meet every farmer's demand	13	35.1
Provision of cold storage facilities to maintain seed quality	11	29.7
Government should cut down import duties on vegetable seeds to help reduce cost	2	5.4
Educating farmers on early maturing varieties to help them decide when to cultivate	1	2.7
Repackaging of seeds into smaller quantities to reduce cost	3	8.1
Reducing prices of seeds so that farmers can afford	1	2.7
Improving communication between actors in the seed business to identify challenges and provide appropriate solutions	2	5.4
Forming functional vegetable seed retailers' association to provide mutual assistance to members	1	2.7
Total	**37**	**100.0**

4.4.3 Retailers' Suggestions on what could be Done to Improve their Vegetable Seed Retailing Business

Responses pertaining to what could be done to improve the vegetable seed retailing business indicated that, financial support from government to retailers in the form of credit grants, and tax reductions was the most (35.5%) mentioned suggestion (Table 4.18). This was followed by access to cold storage to keep seeds over time (19.4%), and good price management by suppliers and retailers to make seeds affordable for farmers (12.9%) among others (Table 4.18).

Table 4.18: Retailers' Suggestions on What Can Be Done to Improve their Vegetable Seed Retailing Business

	Responses	
Suggestions	**Frequency**	**Percent**
Government should provide financial support to retailers in the form of credit grants, and tax reductions	11	35.5
Access to cold storage to keep seeds overtime	6	19.4
Increase in local seed production to reduce cost of importation	2	6.5
Conducting regular seed tests to ensure maintenance of seed quality	3	9.7
Good communication with farmers to get feedback after seed use	1	3.2
MoFA and other agencies should organize regular workshops for seed retailers on best practices on the handling and sale of certified seeds	1	3.2
Suppliers and retailers should practice good price management to make seeds affordable for farmers	4	12.9
Vegetable farmers should be supported with irrigation facilities to ensure all-year-round production	3	9.7
Total	**31**	**100.0**

4.5 Laboratory Tests Results

4.5.1 Quality Characteristics of Vegetable Seeds in Original Package Sampled from Various Retail Outlets

4.5.1.1 Physical Quality of Vegetable Seed Samples in Original Package

Results from the laboratory tests conducted on vegetable seeds in original package showed that there were significant differences ($p<0.05$) in mean percentage purity among the sampled seeds across the various retail outlets (Table 4.19). Seed samples showed high percentage purity with 87% of the samples recording mean percentage purity above 97% (Table 4.19). The highest mean percentage purity (99.98%) was recorded for Hot Pepper *var*.Shito Adope from Best and Less Agrochemicals (HP-KN-O), Okra *var*. Clemson Spineless from Agriseed Limited (OK-AN-O), and Sweet Pepper *var*. Yolo Wonder from Yonko Do Agrochemicals (SP-AA-O) whilst Carrot *var*. Amazonia from Grace Adom Agrochemicals (CR-TP-O) recorded the least percentage purity (92.30%) (Table 4.19).

The results also showed significant differences ($p<0.05$) in percentage moisture content of seeds sampled across the various retail outlets (Table 4.19). Sixty percent of the seed samples recorded mean moisture content above 8.0% with OK-AN-O and SP-AA-O recording the highest mean percentage moisture content of 10.50% (Table 4.19). The lowest mean moisture content of 6.50% was recorded for Tomato *var*. Heinze from Maconi Enterprise(T-OB-O) (Table 4.19).

Table 4.19: Physical Quality of Vegetable Seeds in Original Package

Treatments	Percentage Purity	Moisture Content
AEP-OB-O	93.40	10.00
CB-NK-O	99.95	6.60
CR-MP-O	99.95	10.00
CR-TP-O	92.30	10.20
CU-BK-O	99.95	10.00
EP-MB-O	96.00	9.50
HP-KN-O	99.98	8.00
HP-NE-O	98.80	8.50
L-BK-O	97.30	7.60
OK-AN-O	99.98	10.50
ON-AN-O	99.95	8.00
ON-BT-O	99.00	7.40
SP-AA-O	99.98	10.50
T-KJ-O	99.95	9.00
T-OB-O	98.43	6.50
LSD (0.05)	0.14	0.17
Grand Mean	98.43	8.82

**LSD: least significant difference*

4.5.1.2 Physiological Quality of Vegetable Seed Samples in Original Package

Mean germination percentages recorded for the tested seeds showed significant differences ($p<0.05$) among the sampled seeds across the various retail outlets (Table 4.20). More than 73% of the samples recorded mean percentage germination above 90% with Cucumber *var*. Market More from Abronoma Agrochemicals (CU-BK-O) recording the highest (98.50%) mean percentage germination (Table 4.20). Seed samples Onion *var*. Ares from Agriseed Limited (ON-AN-O) and Onion *var*. Red Creole from K. Badu Agrochemicals (ON-BT-O) also recorded percentage germination means of 82.25% and 80.25% respectively (Table 4.20). Hot Pepper *var*. Cayenne from Akuafuo Yiedie Fie (HP-NE-O) recorded a low mean percentage germination of 33.25% whilst seed sample HP-KN-O recorded no germination (Table 4.20).

Vigour index determined for the tested seed samples also showed significant differences ($p<0.05$) (Table 4.20). Seven of the fifteen samples had seedling vigour indices ranging from 10.52 to 22.18 with OK-AN-O recording the highest mean vigour index of 22.18 (Table 4.20). Six samples also recorded mean seedling vigour indices between 5.00 to 10.00 (Table 4.20). Seed sample HP-NE-O recorded a low mean seedling vigour index of 4.16 whilst HP-KN-O recorded nil mean seedling vigour index (Table 4.20).

Table 4.20: Physiological Quality of Vegetable Seed Samples in Original Package

Treatments	Percentage Germination	Vigour Index
AEP-OB-O	96.00	12.58
CB-NK-O	91.50	13.36
CR-MP-O	92.25	8.21
CR-TP-O	96.50	10.52
CU-BK-O	98.50	19.01
EP-MB-O	95.75	11.49
HP-KN-O	0.00	0.00
HP-NE-O	33.25	4.16
L-BK-O	95.75	5.36
OK-AN-O	97.25	22.18
ON-AN-O	82.25	8.97
ON-BT-O	80.25	8.99
SP-AA-O	96.50	8.49
T-KJ-O	97.25	9.35
T-OB-O	95.00	10.83
LSD (0.05)	3.02	0.37
Grand Mean	83.20	10.23

**LSD: least significant difference*

4.5.1.3 Seed Health Analysis of Vegetable Seed Samples in Original Package

Seed health results indicated that five (5) out of the fifteen (15) sampled vegetable seeds in original package showed fungal infections (Table 4.21). Two (2) fungal species, *Aspergillus niger* and *Aspergillus flavus*, were identified to be associated with the five (5) seed samples (Table 4.21).

Fungal prevalence was generally low with *Aspergillus niger* and *Aspergillus flavus* recording a prevalence of 16.67% and 16.00% respectively (Figure 4.16).

Table 4.21: Seed Health Status of Vegetable Seed Samples in Original Package

Samples	Presence of Fungi	
	Aspergillus niger	***Aspergillus flavus***
AEP-OB-O	✗	✗
CB-NK-O	✗	✗
CR-MP-O	✓	✓
CR-TP-O	✓	✓
CU-BK-O	✗	✗
EP-MB-O	✓	✓
HP-KN-O	✓	✓
HP-NE-O	✗	✗
L-BK-O	✓	✓
OK-AN-O	✗	✗
ON-AN-O	✗	✗
ON-BT-O	✗	✗
SP-AA-O	✗	✗
T-KJ-O	✗	✗
T-OB-O	✗	✗

* ✓ *= Present* ✗ *= Absent*

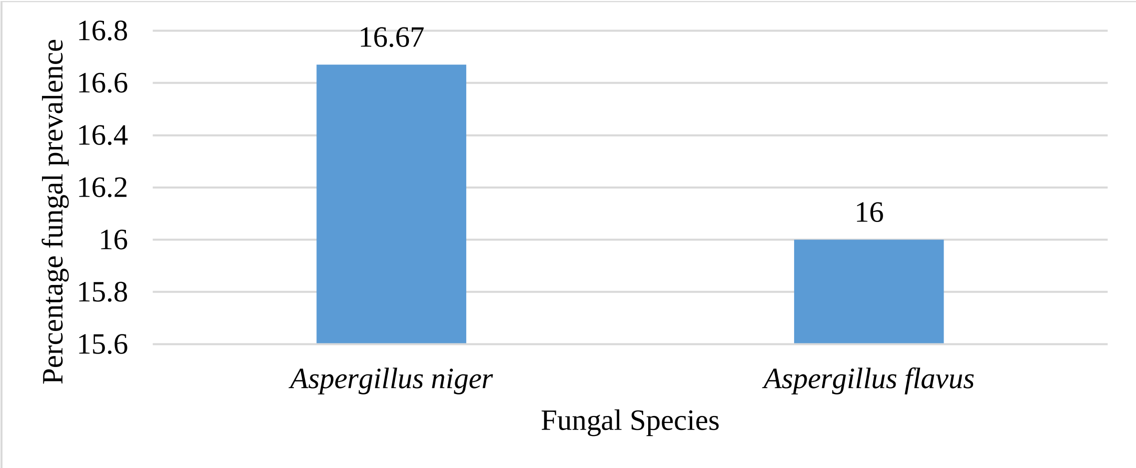


Figure 4.16: Percentage Prevalence of Fungal Species Associated with Seed Samples in Original Packs

4.5.2 Quality Characteristics of Repackaged Vegetable Seeds Sampled from Various Retail Outlets

4.5.2.1 Physical Quality of Repackaged Vegetable Seed Samples

Purity tests conducted on repackaged vegetable seeds showed significant differences ($p<0.05$) among seeds sampled from the various retail outlets (Table 4.22). Seed samples Cucumber *var*. Murano from Kyeiwaa Agrochemicals (CU-MP-R), Okra *var*.Labadi Dwarf from Owusu Agrochemicals (OK-NK-R), Onion *var*. Ares from Maconi Enterprise (ON-OB-R), and Sweet Pepper *var*. Yolo Wonder from Dapsy Agrochemicals (SP-MB-R) recorded the highest mean percentage purity of 99.98% whilst seed sample Cabbage *var*. Oxylus from Amankwah Spare Parts and Seeds (CB-MB-R) recorded the least percentage purity of 54.00% (Table 4.22). Thirteen out the fifteen samples had mean percentage purity ranging from 98.00% to 99.98% while the other two samples, Sweet Pepper *var*. Yolo Wonder (SP-MB1-R) and CB-MB-R, recorded mean percentage purity of 90% and 54.00% respectively (Table 4.22).

There were also significant differences ($p<0.05$) in moisture content among the repackaged seeds sampled from the various retail outlets (Table 4.22). Seed samples Carrot *var*. Shakira from Akuafuo Adamfo (CR-OB-R) and Cabbage *var*. Oxylus from Maame Agrochemicals (CB-BK-R) recorded the highest (10.50%) and lowest (6.50%) mean moisture content respectively (Table 4.22). Four seed samples *viz*. CB-BK-R, CB-MB-R, Lettuce *var*. Kaizer Samofa Agrochemicals (L-NE-R), and Lettuce *var*. Eden from Grace Adom Agrochemicals (L-TP-R) recorded mean moisture content below 8% whilst the other eleven samples recorded mean moisture content above 8% (Table 4.22).

Table 4.22: Physical Quality of Repackaged Vegetable Seed Samples

Treatments	Percentage Purity	Moisture Content
CB-BK-R	99.95	6.50
CB-MB-R	54.00	6.60
CR-MB-R	99.95	10.30
CR-OB-R	99.90	10.50
CU-EJ-R	99.95	10.00
CU-MP-R	99.98	10.00
HP-TP-R	98.80	8.30
L-NE-R	99.60	7.60
L-TP-R	99.00	7.50
OK-NK-R	99.98	10.00
ON-OB-R	99.98	9.00
SP-MB-R	99.98	8.90
SP-MB1-R	90.00	10.20
T-EJ-R	98.50	9.30
T-MB-R	98.00	9.00
LSD (0.05)	0.17	0.15
Grand Mean	95.78	8.91

**LSD: least significant difference*

4.5.2.2 Physiological Quality of Repackaged Vegetable Seed Samples

Germination test results showed significant differences ($p<0.05$) in mean percentage germination among repackaged seeds sampled across the various retail outlets (Table 4.23). Over 73% of the repackaged seed samples recorded mean germination percentages above 80% with Cucumber *var*. Marketer from Divine Oppongsco Enterprise (CU-EJ-R) recording the highest mean percentage germination of 99.75% (Table 4.23). Three samples, SP-MB1-R, SP-MB-R and L-NE-R recorded mean percentage germination below 80% with respective values of 72.25%, 42.75% and 27.25% (Table 4.23). Seed sample Hot Pepper *var*. Carabeau from God's Time Agrochemicals (HP-TP-R) recorded no germination (Table 4.23).

There were significant differences ($p<0.05$) in mean vigour indices recorded for the repackaged seed samples (Table 4.23). Six samples recorded mean seedling vigour indices above 10.00 with

OK-NK-R recording the highest vigour index of 20.75 (Table 4.23). Six samples also recorded mean vigour indices between 5.00 and 10.00 while SP-MB-R and L-NE-R recorded low mean vigour indices of 2.44 and 1.12 respectively (Table 4.23). Seed sample HP-TP-R recorded no vigour index (Table 4.23).

Table 4.23: Physiological Quality of Repackaged Vegetable Seed Samples

Treatments	Percentage Germination	Vigour Index
CB-BK-R	98.25	11.30
CB-MB-R	92.00	9.75
CR-MB-R	92.00	7.08
CR-OB-R	86.75	6.86
CU-EJ-R	99.75	20.45
CU-MP-R	86.75	18.39
HP-TP-R	0.00	0.00
L-NE-R	27.25	1.12
L-TP-R	96.75	5.03
OK-NK-R	96.50	20.75
ON-OB-R	84.75	9.49
SP-MB-R	42.75	2.44
SP-MB1-R	72.25	5.42
T-EJ-R	97.00	10.87
T-MB-R	92.75	10.20
LSD (0.05)	4.16	0.44
Grand Mean	77.70	9.28

**LSD: least significant difference*

4.5.2.3 Seed Health Analysis of Repackaged Vegetable Seed Samples

Seed health test conducted on the repackaged vegetable seed samples indicated that eight (8) out of the fifteen (15) samples showed fungal growth (Table 4.24). *Aspergillus niger* and *Aspergillus flavus* were the fungal species identified to be associated with the seed samples (Table 4.24). *Aspergillus niger* had a higher percentage prevalence of 21.33% in the seed samples compared to *Aspergillus flavus* which also recorded 14.67% prevalence (Figure 4.17).

Table 4.24: Seed Health Status of Repackaged Vegetable Seed Samples

Samples	Presence of Fungi	
	Aspergillus niger	*Aspergillus flavus*
CB-BK-R	✓	×
CB-MB-R	✓	×
CR-MB-R	×	×
CR-OB-R	✓	✓
CU-EJ-R	×	×
CU-MP-R	×	×
HP-TP-R	✓	✓
L-NE-R	×	×
L-TP-R	✓	✓
OK-NK-R	✓	✓
ON-OB-R	×	×
SP-MB-R	✓	×
SP-MB1-R	✓	×
T-EJ-R	×	×
T-MB-R	×	×

* ✓ = *Present* × = *Absent*

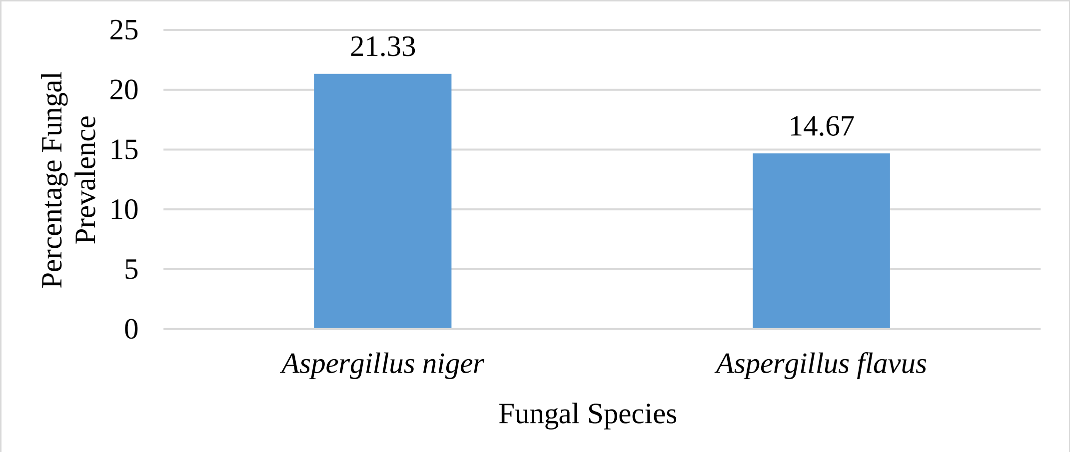


Figure 4.17: Percentage Prevalence of Fungal Species Associated with Repackaged Seed Samples

4.5.3 Comparison of Seed Quality Characteristics of Same Vegetable Variety in Different Packages Sampled from Three Different Retail Outlets

4.5.3.1 Seed Quality Characteristics of Sweet Pepper *var*. Yolo Wonder Seeds

Germination test conducted on seeds of sweet pepper *var*. Yolo Wonder showed significant differences ($p<0.05$) in mean percentage germination among the three samples (Table 4.25). Sample from Agyass Seeds (SP-MB1) had the highest (79.25%) mean percentage germination while sample obtained from Dapsy Agro Products (SP-MB) had the least (60.12%) mean percentage germination (Table 4.25). There was also significant difference ($p<0.05$) in mean percentage germination between seeds in original package and those that were repackaged with those in original package recording a higher (78%) percentage germination than those repackaged (64.42%) (Table 4.25).

There were significant differences ($p<0.05$) in mean seedling vigour indices among the three samples with sample purchased from Mansusu Agrochemicals (SP-MB2) and SP-MB recording the highest (6.22) and least (3.74) mean vigour index respectively (Table 4.25). Mean seedling vigour index of 5.72 recorded for seeds in original package was significantly different ($p<0.05$) from that (4.68) recorded for the repackaged seeds (Table 4.25).

Moisture test conducted revealed that there were significant differences ($p<0.05$) in mean moisture content among the three samples (Table 4.25). SP-MB recorded the least (8.43) moisture content while SP-MB2 recorded the highest (9.53) mean moisture content (Table 4.25). There was also significant difference ($p<0.05$) in mean moisture content between seeds in original package and the repackaged seeds, with those in original package recording a lower mean moisture content (8.38%) than the repackaged seeds which recorded a mean moisture content of (9.72%) (Table 4.25).

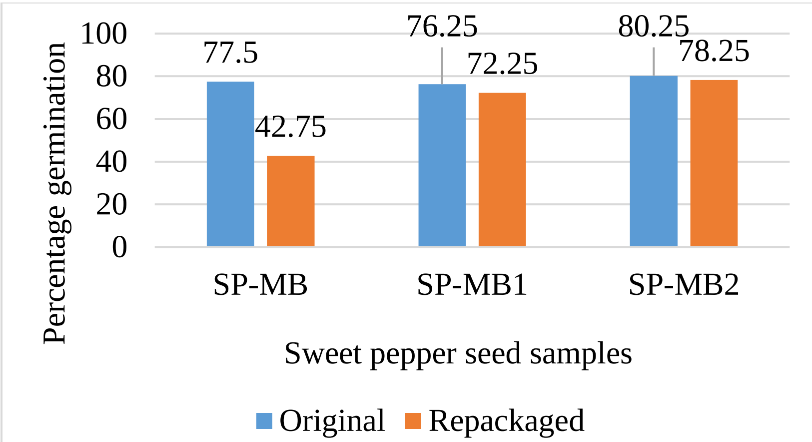
There were also significant differences ($p<0.05$) in mean purity percentage among the sampled sweet pepper seeds with SP-MB and SP-MB1 recording the highest (99.95%) and lowest (94.50%) percentage purity respectively (Table 4.25). Mean percentage purity values also showed significant differences ($p<0.05$) between sweet pepper seeds in original package and those that were repackaged (Table 4.25). Seeds in original package had higher mean percentage purity than the repackaged seeds with respective values of 99.63% and 96.62% (Table 4.25).

Interaction between sample and packaging had significant ($p<0.05$) effect on germination, seedling vigour index, seed moisture content, and seed physical purity (Figures 4.18. 4.19, 4.20, 4.21). The highest mean percentage germination (80.25%) and vigour index (6.26) were recorded for seed sample SP-MB2 in original package whilst repackaged SP-MB recorded the lowest mean percentage germination (42.75%) and seedling vigour (2.44) (Figures 4.18 and 4.19). SP-MB in original package recorded the least mean moisture content of 7.95 with repackaged SP-MB1 also recording the highest mean moisture content of 10.20 (Figure 4.20). Repackaged SP-MB1 recorded the least mean percentage purity of 90.00% whilst the remaining interactions produced percentage purity ranging from 99.00% to 99.95% (Figure 4.21).

Table 4.25: Seed Quality Characteristics of Sweet Pepper var. Yolo Wonder Seeds in Different Packages Sampled from Three Retail Outlets

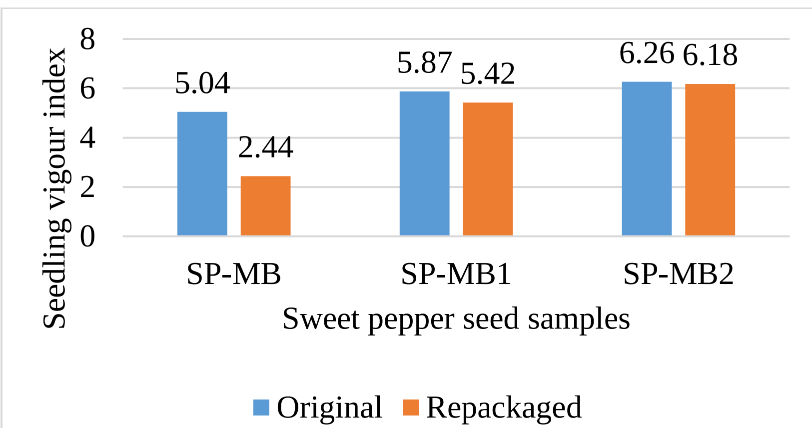
Factor Effect	Percentage Germination	Vigour Index	Moisture Content	Percentage Purity
Sample				
SP-MB	60.12	3.74	8.43	99.95
SP-MB1	74.25	5.65	9.20	94.50
SP-MB-2	79.25	6.22	9.53	99.93
LSD	2.72	0.20	0.13	0.09
Package Type				
Original	78.00	5.72	8.38	99.63
Repackaged	64.42	4.68	9.72	96.62
LSD	2.22	0.16	0.11	0.07

LSD: least significant difference



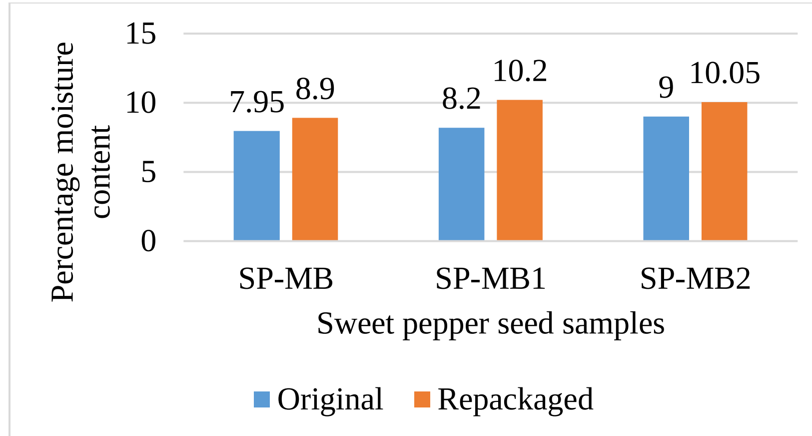
* *LSD (0.05) = 3.85* *LSD: least significant difference*

Figure 4.18: Effect of Sample and Package Type on Germination of Sweet Pepper Seeds



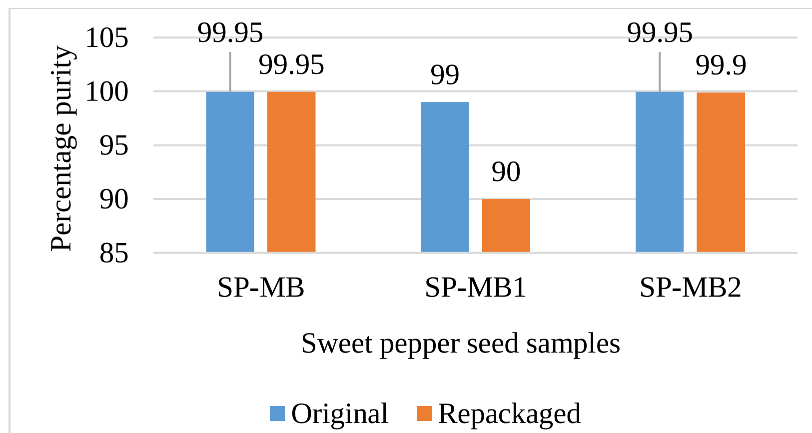
* *LSD (0.05) = 0.28* *LSD: least significant difference*

Figure 4.19: Effect of Sample and Package Type on Vigour of Sweet Pepper Seeds



* *LSD (0.05) = 0.18* *LSD: least significant difference*

Figure 4.20: Effect of Sample and Package Type on Moisture Content of Sweet Pepper Seeds



* *LSD (0.05) = 0.13* *LSD: least significant difference*

Figure 4.21: Effect of Sample and Package Type on Purity of Sweet Pepper Seeds

4.5.3.1.1 Health Analysis of Sweet Pepper *var*. Yolo Wonder Seeds from Three Retail Outlets.

After health analysis of sweet pepper seeds, *Aspergillus niger* was identified to be associated with two (2) of the three (3) samples (Figure 4.22). The fungal prevalence was 15.00% in sample obtained from Dapsy Agro Products (SP-MB) and 20.00% in sample from Agyass seeds (SP-MB1) while sample from Mansusu Agrochemicals (SP-MB2) recorded no fungal growth (Figure 4.22).

Sweet pepper seeds in original package recorded no fungal infections across the three retail outlets whereas the repackaged recorded growth of *Aspergillus niger* with percentage prevalence of 23.33% across the three retail outlets (Figure 4.23).

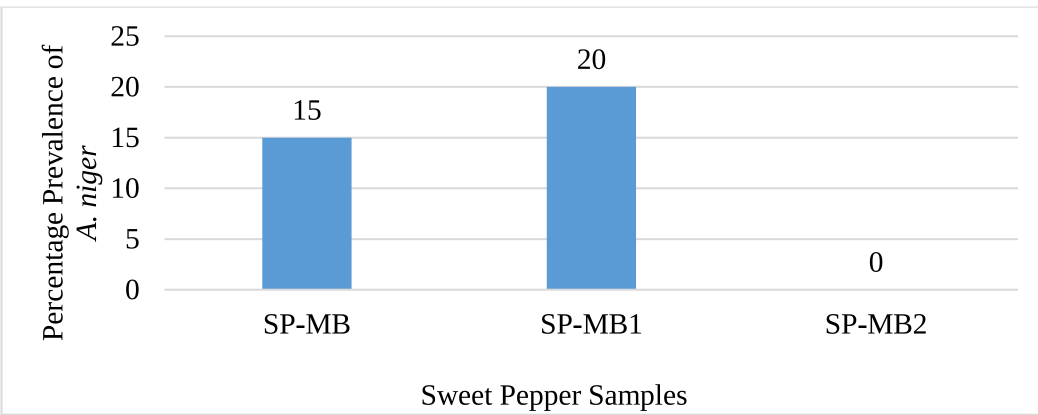


Figure 4.22: Percentage Prevalence of *Aspergillus niger* on Sweet Pepper Seed Samples from Three Retail Outlets

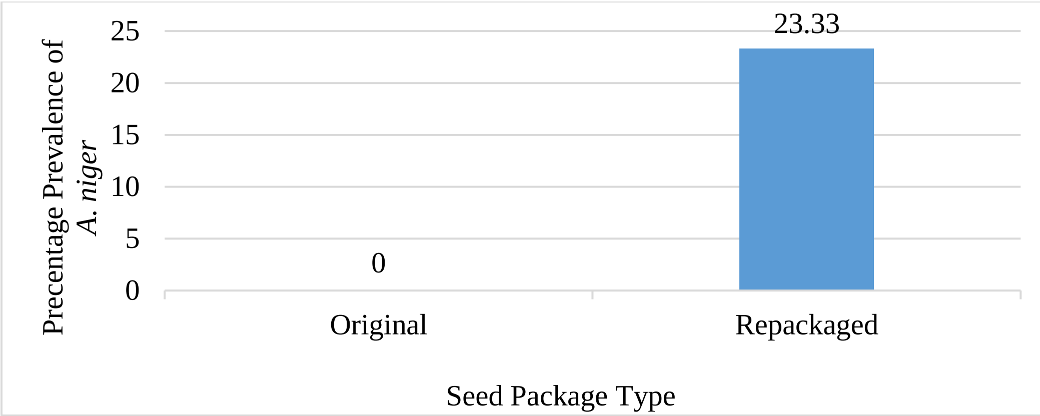


Figure 4.23: Percentage Prevalence of *Aspergillus niger* on Sweet Pepper Seeds in Two Package Types Sampled from Three Retail Outlets

4.5.3.2 Seed Quality Characteristics of Carrot *var*. Amazonia Seeds Sampled from Three Retail Outlets

Tests conducted on sampled carrot seeds showed that there were significant differences ($p<0.05$) in mean percentage germination across the retail outlets (Table 4.26). The highest mean percentage germination was 93.38% and was recorded for sample obtained from Grace Adom Agrochemicals (CR-TP) while sample purchased from Kyeiwaa Agrochemicals (CR-MP) also recorded the least mean percentage germination of 89.88% (Table 4.26). Seeds in original package had mean percentage germination of 93.25% which was significantly different ($p<0.05$) from mean germination percentage of 89.92% recorded for the repackaged seeds (Table 4.26).

Seedling vigour index calculated for the carrot seeds showed significant differences ($p<0.05$) among the sample means with CR-TP and sample from Mansusu Agrochemicals (CR-MB) recording the highest (9.86) and lowest (7.09) mean seedling vigour index respectively (Table 4.26). There was significant difference ($p<0.05$) between mean vigour index of seeds in original package and those that had been repackaged (Table 4.26). Seeds in original package had mean vigour index of 8.61 while the repackaged seeds recorded mean vigour index of 8.00 (Table 4.26).

Mean moisture content recorded for the carrot seed samples showed significant differences ($p<0.05$) across the retail outlets (Table 4.26). CR-MB recorded the lowest mean moisture content of 10.05% while CR-TP recorded the highest mean moisture content of 10.23% (Table 4.26). Mean moisture content of repackaged carrot seeds was 10.23% and it differed significantly ($p<0.05$) from those in original package which also recorded mean moisture content of 10.00% (Table 4.26).

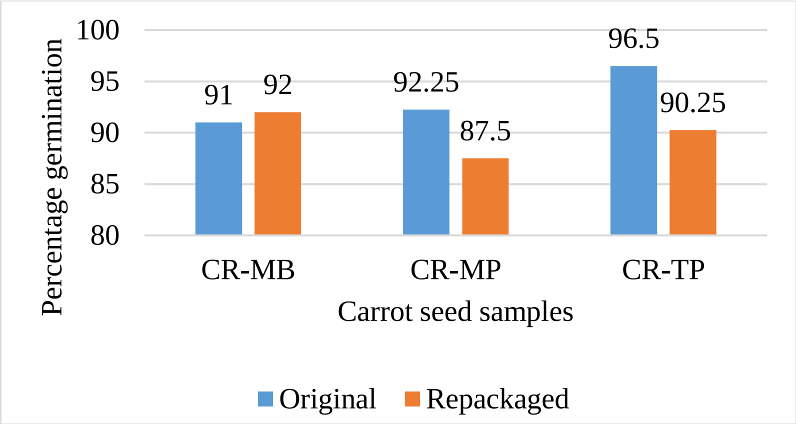
Purity test performed on the seeds showed significant differences ($p<0.05$) in sample means across the three retail outlets with CR-MB recording the highest (99.95%) mean percentage purity and CR-TP also recording the lowest (91.31%) mean percentage purity (Table 4.26). Carrot seeds in original package recorded a higher mean percentage purity of 97.40% which was significantly different ($p<0.05$) from the mean percentage purity of 95.93% recorded for the repackaged carrot seeds (Table 4.26).

All quality parameters described above were significantly ($p<0.05$) influenced by sample-packaging interaction (Figures 4.24, 4.25, 4.26, 4.27). Seed sample CR-TP in original package and repackaged CR-MP recorded the highest (96.50%) and lowest (87.50%) mean percentage germination respectively (Figure 4.24). The highest mean vigour index of 10.52 was attained by CR-TP in original package whilst repackaged CR-MB recorded the least mean vigour index of 7.08 (Figure 4.25). CR-MB in original package had the least (9.80%) mean moisture content whereas its repackaged form recorded the highest (10.30%) mean moisture content (Figure 4.26). Repackaged CR-TP recorded the least (90.33%) mean percentage purity whilst the remaining interactions recorded mean percentage purity ranging from 97.50% to 99.95% (Figure 4.27).

Table 4.26: Seed Quality Characteristics of Carrot *var*. Amazonia Seeds in Different Packages Sampled from Three Retail Outlets

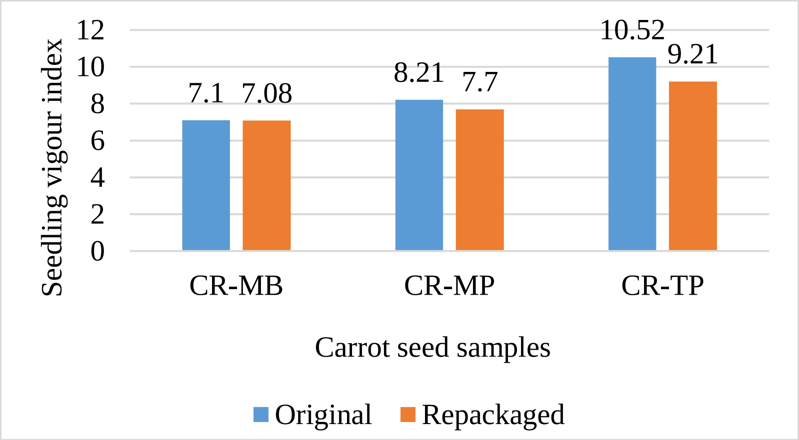
Factor Effect	Percentage Germination	Vigour Index	Moisture Content	Percentage Purity
Sample				
CR-MB	91.50	7.09	10.05	99.95
CR-MP	89.88	7.96	10.08	98.73
CR-TP	93.38	9.86	10.23	91.31
LSD	2.38	0.22	0.13	0.09
Package Type				
Original	93.25	8.61	10.00	97.40
Repackaged	89.92	8.00	10.23	95.93
LSD	1.94	0.18	0.11	0.07

* *LSD: least significant difference*



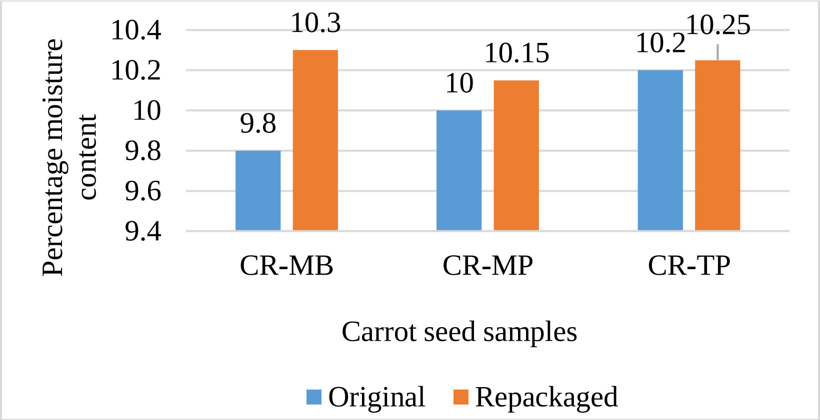
** LSD (0.05) = 3.36* *LSD: least significant difference*

Figure 4.24: Effect of Sample and Package Type on Germination of Carrot Seeds



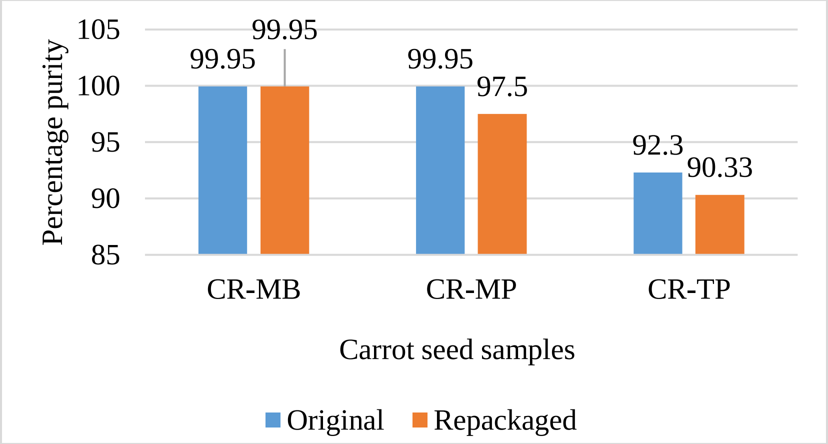
** LSD (0.05) = 0.31* *LSD: least significant difference*

Figure 4.25: Effect of Sample and Package Type on Vigour of Carrot Seeds



** LSD (0.05) = 0.19* *LSD: least significant difference*

Figure 4.26: Effect of Sample and Package Type on Moisture content of Carrot Seeds



** LSD (0.05) = 0.12* *LSD: least significant difference*

Figure 4.27: Effect of Sample and Package Type on Purity of Carrot Seeds

4.5.3.2.1 Health Analysis of Carrot *var*. Amazonia Seeds from Three Retail Outlets

Aspergillus niger and *A. flavus* were the fungal species identified to be associated with carrot seeds sampled across the three retail outlets (Figure 4.28). *A. niger* recorded 85.00% prevalence in seed sample from Kyeiwaa Agrochemicals (CR-MP) and 40.00% in sample obtained from Grace Adom Agrochemicals (CR-TP) (Figure 4.29). *A. flavus* was 90.00% prevalent in CR-TP and 45.00% prevalent in CR-TP (Figure 4.28). No infection was recorded for seed sample purchased from Mansusu Agrochemicals (CR-MB) (Figure 4.28).

A. niger was 36.67% prevalent within seeds in original package and 46.67% in repackaged seeds across the three retail outlets (Figure 4.29). *A. flavus* also showed 36.67% prevalence within seeds in original package and 53.33% in repackaged seed samples (Figure 4.29).

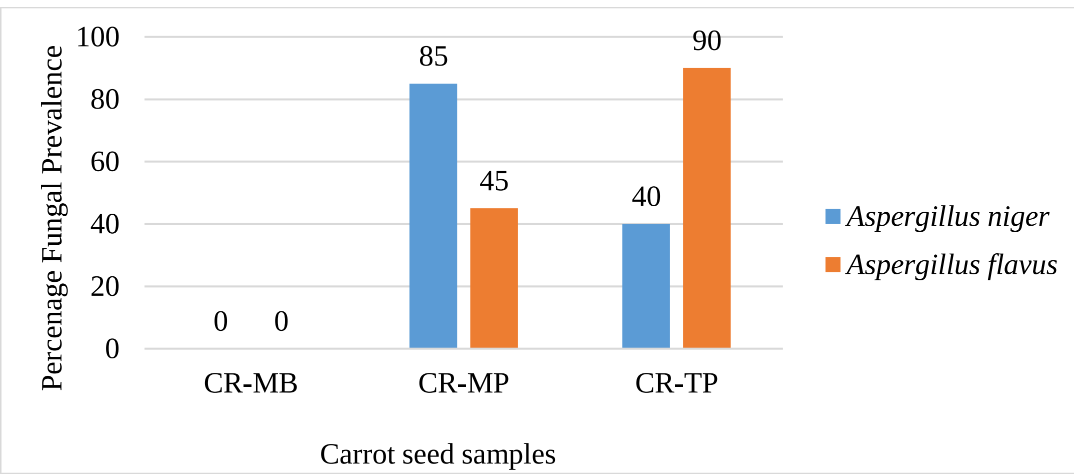


Figure 4.28: Percentage Fungal Prevalence on Carrot Seed Samples from Three Retail Outlets

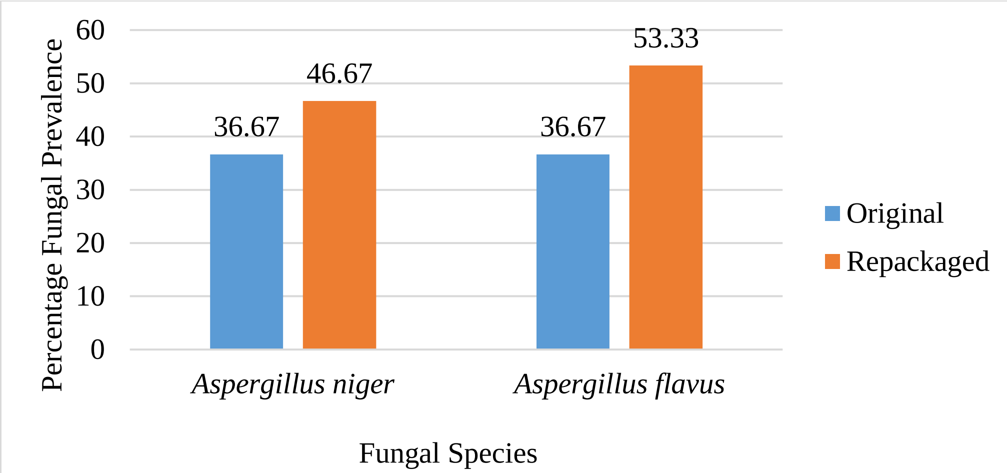


Figure 4.29: Percentage Fungal Prevalence on Carrot Seeds in Two Package Types Sampled from Three Retail Outlets

4.5.3.3 Seed Quality Characteristics of Cabbage *var*. Oxylus Seeds

Germination test conducted on cabbage seeds showed significant differences ($p<0.05$) in sample means across the three retail outlets (Table 4.27). Sample purchased from Maame Agrochemicals (CB-BK) recorded the highest (98.12%) mean percentage germination while sample obtained from Maconi Enterprise (CB-OB) also recorded the least (82.88%) mean percentage germination (Table 4.27). There was no significant difference ($p>0.05$) in percentage germination between the seeds in original package and those repackaged (Table 4.27).

There were significant differences ($p<0.05$) in mean seedling vigour indices recorded for the three sampled cabbaged seeds (Table 4.27). CB-BK and sample from Amankwah Spare Parts and Seeds (CB-MB) recorded the highest (11.39) and lowest (9.93) mean vigour index respectively (Table 4.27). Vigour index calculated also showed significant difference ($p<0.05$) between means of seeds in original package and those repackaged (Table 4.27). Seeds in original package recorded a better mean vigour index of 10.02 than the repackaged seeds which also recorded mean vigour index of 9.74 (Table 4.27).

Seed moisture content recorded showed significant differences ($p<0.05$) among sample means (Table 4.27). The lowest (6.49%) mean moisture content was recorded for CB-MB while the highest (7.46%) was recorded by CB-OB (Table 4.27). There was no significant difference ($p>0.05$) in mean moisture content recorded for cabbage seeds in original package and the repackaged ones (Table 4.27).

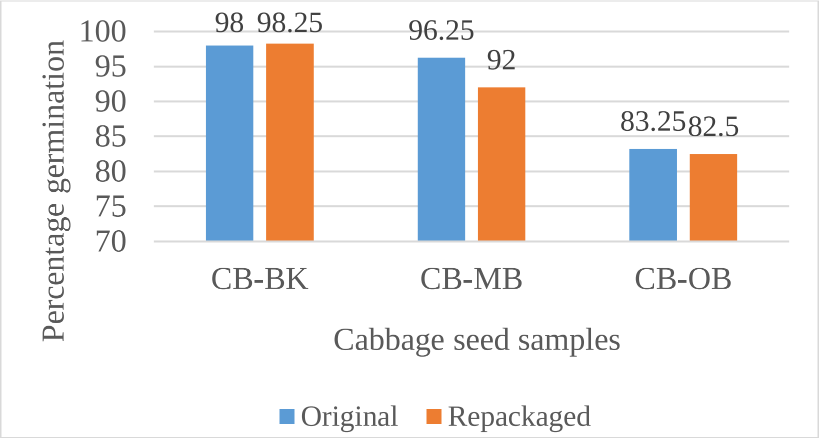
There were significant differences ($p<0.05$) in mean percentage purity recorded across the three different retail outlets (Table 4.27). The highest and lowest mean percentage purity were 99.95% and 76.38% and were respectively recorded for CB-BK and CB-MB (Table 4.27). Purity test conducted on cabbage seeds also showed significant difference ($p<0.05$) in mean percentage purity recorded for seeds in original package and the repackaged seeds (Table 4.27). Seeds in original package recorded a higher mean percentage purity of 99.22% while the repackaged seeds also recorded mean percentage purity of 84.29% (Table 4.27).

Germination, vigour index, and moisture content of the cabbage seeds were not significantly ($p>0.05$) affected by the interaction between the sample and type of package (Figures 4.30, 4.31, 4.32). Seed physical purity was however significantly ($p<0.05$) affected by the interactive effect of sample and package type (Figure 4.33). Repackaged CB-OB had the worst mean percentage purity of 54.00% whilst the remaining interactions recorded mean percentage purity within a range of 98.75% to 99.95% (Figure 4.33).

Table 4.27: Seed Quality Characteristics of Cabbage *var*. Oxylus Seeds in Different Packages Sampled from Three Retail Outlets

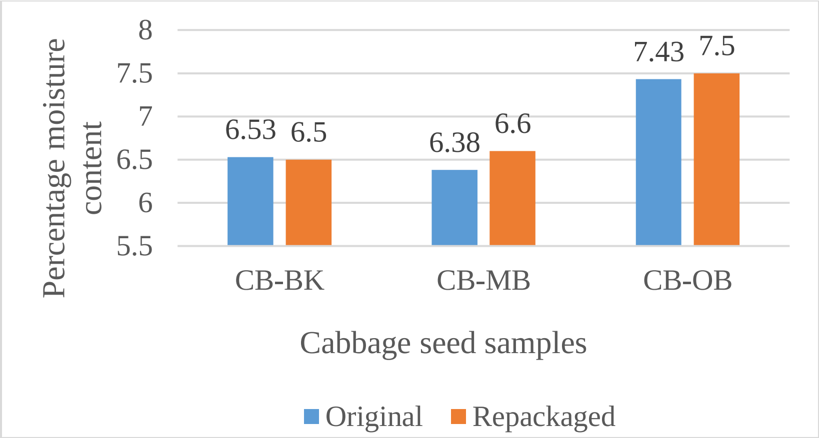
Factor Effect	Percentage Germination	Vigour Index	Moisture Content	Percentage Purity
Sample				
CB-BK	98.12	11.39	6.51	99.95
CB-MB	94.12	9.93	6.49	76.38
CB-OB	82.88	8.33	7.46	98.94
LSD	2.53	0.26	0.14	0.16
Package Type				
Original	92.50	10.02	6.78	99.22
Repackaged	90.92	9.74	6.87	84.29
LSD (0.05)	N. S	0.21	N. S	0.13

* *LSD: least significant difference; N.S: not significant*



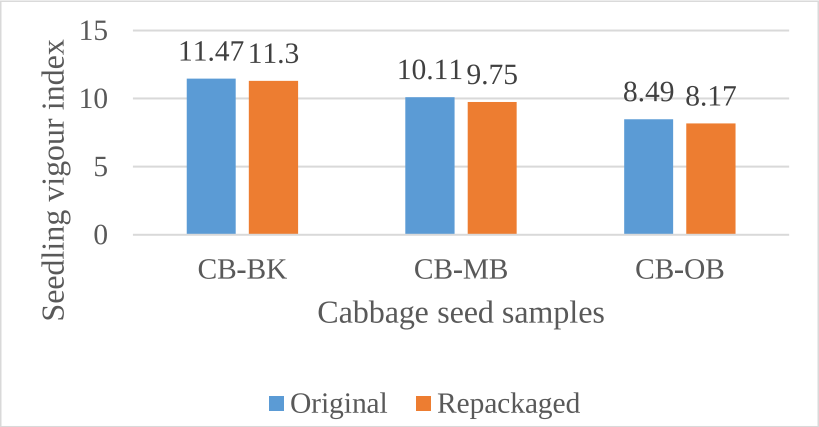
** Interaction not significant*

Figure 4.30: Effect of Sample and Package Type on Germination of Cabbage Seeds



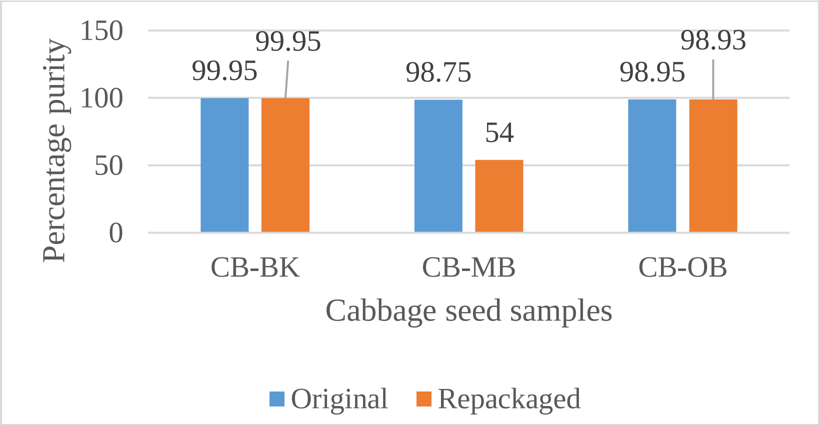
** Interaction not significant*

Figure 4.32: Effect of Sample and Package Type on Moisture Content of Cabbage Seeds



** Interaction not significant*

Figure 4.31: Effect of Sample and Package Type on Vigour of Cabbage Seeds



** LSD (0.05) = 0.23 LSD: least significant difference*

Figure 4.33: Effect of Sample and Package Type on Purity of Cabbage Seeds

4.5.3.3.1 Health Analysis of Cabbage *var*. Oxylus Seeds

Seed health tests carried out on cabbage seeds revealed that two out of the three samples had fungal infections (Figure 4.34). *Aspergillus niger* was the fungal species identified to be associated with the carrot seeds, recording a prevalence of 15.00% each in samples obtained from Maame Agrochemicals (CB-BK) and Amankwah Spare Parts and Seeds (CB-MB) (Figure 4.34). Sample purchased from Maconi Enterprise (CB-OB) recorded no fungal growth.

Across the three retail outlets, cabbage seeds in original package recorded no fungal infections but the repackaged carrot seeds recorded 20.00% prevalence of *A. niger* (Figure 4.35).

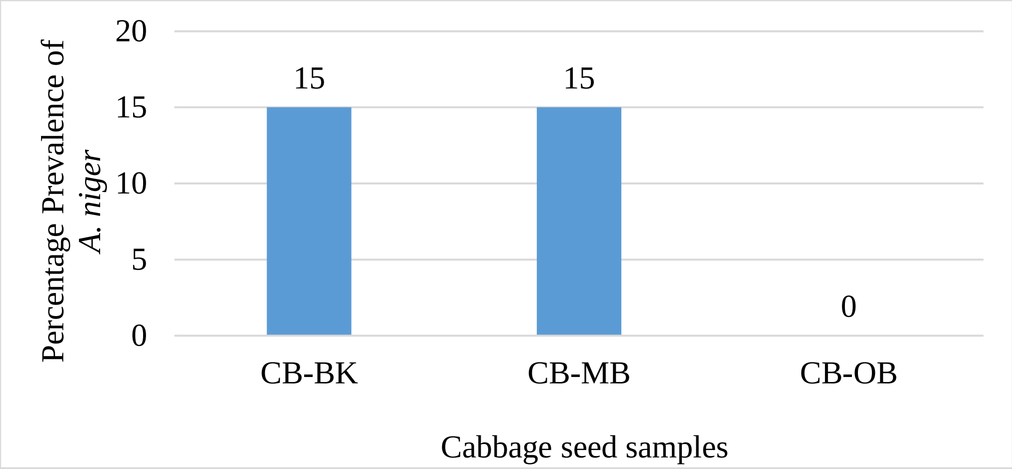


Figure 4.34: Percentage Prevalence of *Aspergillus niger* on Cabbage Seed Samples from Three Retail Outlets

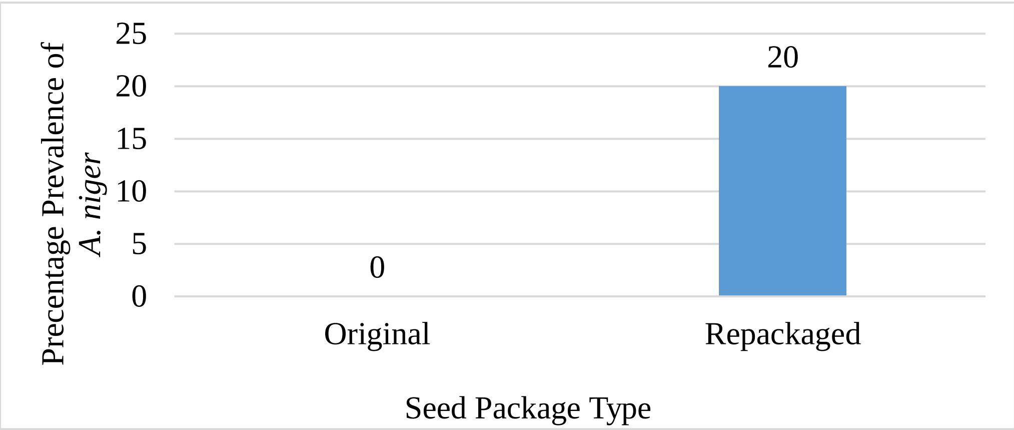


Figure 4.35: Percentage Prevalence of *Aspergillus niger* on Cabbage Seeds in Two Package Types Sampled from Three Retail Outlets

CHAPTER FIVE

5.0 DISCUSSION

5.1 Survey Results

5.1.1 Demographic Characteristics of Retailers

Survey results revealed that 68% of the retailers were males thus making seed retailing a male-dominated venture. This observation confirms an earlier report by IFPRI/IFDC (2009) where males formed 82% of the total agricultural input dealers surveyed in the Ashanti Region. Mabaya *et al*. (2017) also made similar observation where males accounted for 83% of the 3,153 agro-input dealers surveyed across Ghana. Male dominance in the retail of certified vegetable seeds may be attributed to a correlating male predominance in agriculture and other allied activities because Dave (2014) argues that agricultural activities are prima facie regarded as male-subjugated activities, and that, females involved in agricultural activities are just seen as helpers. Furthermore, agricultural development training programmes are usually targeted at men based on the argument that men as household heads, are the major decision makers for productive economic resources (Staudt, 1977). Despite women's active participation in processing and marketing of agricultural products as indicated by Aggarwal (2003), they are constrained with social and customary elements in addition to issues of land ownership, access to credit, and awareness of new technology (FAO, 2003; Dave, 2014). Dave (2014) further argues that females in agribusiness would be potentially efficient as males if they were given equal access to resources like their male counterparts.

The fact that most (48%) of the retailers were 36 years and over could lead to the belief that retailers' drive to set up certified vegetable seed trade business emanated from their previous organizational experiences, having worked in an agricultural firm, or institution, or a related field. Age plays a vital role in seed business owing to the fact that usually, seed retailers' interest in adopting new innovations diminishes as they get older (Malauni, 2009). The high involvement of the youth (below 36 years) might therefore be a good indication of their inclination to embrace and adopt new agricultural and seed trade innovations.

Vegetable seed retailers' literacy level and on-the-job experiences are essential for the growth of the seed industry. One reason being that, knowledge about the level of education of the retailers would serve as a guide in the planning and delivery of technical services (Malauni, 2009). As earlier reported by IFPRI/IFDC (2009) that only 4% of the agro input dealers sampled in the Ashanti Region had no formal education, this study also revealed that almost all (96%) the retailers interviewed were educated with most (84%) of them having gained a minimum of five years in the seed business. These revelations were evident as the retailers could assert logically their knowledge and experiences with respect to fundamental practices employed in the handling of certified seeds, as they were aware of the major factors that could cause decline in seed quality during seed storage. Adegbola and Gardebroek (2007) argued that actors in the seed business who were literate had a higher probability of being acquainted with information, and had better abilities in processing information and fishing out appropriate technological solutions to alleviate their challenges, especially, storage problems. The high literacy level among the retailers therefore suggests that they could easily search, or receive, and disseminate technical information on standard procedures and practices required for building and sustaining a robust seed industry.

5.1.2 Demographic Characteristics of Retail Shops

Although the formation of partnership has been reported to be an essential tool for increasing productivity and maximizing profits (Horne, 2009; Prasetyo *et al*., 2015), the survey results however showed that majority (80%) of the retailers were sole proprietors. This could be cited as a probable contributory factor to the numerous challenges faced by certified seed retailers, most especially, access to credit and storage facilities, leading to the stunted growth of the seed industry in Ghana. Since certified seed retailing is capital intensive, retailers could have accessed credits or mobilized funds to solve most of their challenges much easier if they had formed partnerships than to solely bear all operational costs. Furthermore, Syngenta (2017) reported that strong retail partnerships accelerated the dissemination of new technologies to the stakeholders in the seed industry, most especially, the farmers. The absence of partnership in this study therefore suggests that information about improved seeds could not be well disseminated to farmers leading to the low patronage of improved seeds by the farmers.

It should be noted that the high temperatures and high relative humidity figures recorded at the retail shops could not be attributed to ignorance on the part of the retailers since almost all the respondents did admit that cold storage was the best practice for the maintenance of seed quality. Retailers' response to why they kept seeds under ambient conditions was that high costs were involved in the procurement and maintenance of cold rooms which would eventually lead to a rise in seed prices. Temperature and relative humidity at retailers' shops and warehouses have been cited as the two most important factors that could cause a decline in seed quality or total seed deterioration (Alhamadan *et al.*, 2011; Mbofung *et al.*, 2013). According to Demir *et al*. (2016), the general principle for seed storage is that, the lower the temperature and relative humidity, the higher the storability and maintenance of the seed quality. Demir *et al*. (2016) further reported that in a short to medium term storage, certified seeds should be at least stored under a room temperature of 14-15^{0}C and relative humidity of 40-60%. High temperature increases seed embryo respiration resulting in moisture production. High relative humidity also increases seed moisture content as the seed absorbs water from the surrounding air to maintain moisture equilibrium in and around the seed. This increase in moisture content in and around the seed promote seed germination and fungal growth during seed storage, and may eventually lead to total seed deterioration. The prevailing high temperatures and high relative humidity values recorded at retail shops during the study could therefore cause a decline in seed viability and vigour. As reported by Vieira *et al*. (2001) that the rate of decline in seed viability is directly related to the moisture content of the seed which is also dependent on the relative humidity of the storage environment, the high relative humidity of the retail shops could lead to seeds picking up additional moisture which could lead to seed deterioration.

5.1.3 Seeds Retailed, Certified Vegetable Seed Sources, and Mode of Seed Delivery

Survey results indicated that cabbage seeds were the most sold vegetable seeds. This could be alluded to the popularity and high demand of cabbage among the populace of urban and peri-urban areas as reported by Timbilla and Nyarko (2004). Kondo *et al*. (2014) also reported that cabbage production was an important employment source for small-scale vegetable farmers which contributed significantly to food security and poverty alleviation. This could also be a contributory factor to the high demand for cabbage seeds.

All the respondents sourced their certified vegetable seeds from seed companies who mainly imported the seeds from either their sister companies, or their foreign suppliers. These findings corroborate the statement made by Saavedra *et al*. (2016) that most countries in Africa import most hybrid seeds. Seed companies tend to utilize the opportunity created as a result of the virtually non-existing local vegetable seed production industry and import a wide variety of vegetable seeds to be sold to farmers either directly, or through agro dealers. The lack of a robust local vegetable seed production industry may only not be attributed to the unavailability or limited number of vegetable seed breeders in Ghana, but also, the huge investments that would be required in the breeding and production of seeds of exotic vegetables under controlled environmental conditions. These factors have thus played a role in Ghanaian farmers and retailers' over-reliance on farmer-saved and imported vegetable seeds (Almekinders *et al*., 1994; Tripp, 2001; Saavedra *et al*. (2016).

Despite retailers' assertion that the use of custom-made air-conditioned vans for seed delivery to retail shops was the best practice, most (80%) of them however responded that they transported their sourced certified vegetable seeds by ordinary vehicles. Some of the retailers attributed this practice to the high cost of custom-made air-conditioned vans, and the unavailability of commercial cold vans. Other retailers were also of the view that, though cold seed transport was the best practice, it would be of no benefit since seeds would be eventually kept under ambient conditions present at their retail shops.

Most retailers confirmed receipts of complaints from farmers after purchase of seeds, with poor germination being the most received complaint. This was expected owing to the storage conditions witnessed at the retail shops during the study. As reported by various researchers, storage of seeds under high temperatures and relative humidity leads to a decline in seed viability, and eventually, absolute seed deterioration (Alhamadan *et al*., 2011; Mbofung *et al*., 2013; Demir *et al*., 2016).

5.1.4 Retailers' Certified Vegetable Seed Storage Practices

Interactions with retailers revealed that most (56%) of them did not conduct simple germination tests to ascertain seed germination capacity before selling to farmers. This could be due to fact that farmers did not request for seed test results as they perceived that since seeds were certified, they were of good quality. This assumption is in line with the statement made by Nishikawa (2010) that seed certification is very important in crop production in the sense that it is one of the critical mechanisms that guarantees that farmers are supplied with seeds of good quality. Furthermore, some of the retailers were also of similar view that since seeds had passed minimum standards and given certification labels by appropriate regulatory bodies, it was not necessary to conduct germination tests on the seeds because it would be a waste of time and resources. However, seed certification may not provide adequate guarantee that the seeds would reach the farmer (end user) in the same state, as it moves through the various seed chains.

Interruptions and deferments in the event of seed conveyance, and how seeds are stored at the retailers' end could have significant negative impact on seed quality (FAO, 2010). It is therefore imperative for seed retailers to conduct germination tests on randomly selected seeds once in a while to ascertain seed percentage germination during the course of retailing.

Majority (87.5%) of the retailers affirmed that storage duration had negative impact on seed quality with a general assertion that, seed quality waned with time, especially when seeds were kept under ambient environmental conditions. Retailers further cited poor germination as the most (81.8%) identified negative effect of long storage periods on vegetable seeds. Interactions with retailers showed that most (43%) of them kept seeds in stock for only 1-3 months as they only purchased limited quantities of seeds at a time in order to avoid decline or loss of viability caused by long storage period. This is evident as germination tests on the 30 seed samples showed that only 6 samples had germination percentages below minimum quality standard of 80% (Appendix 2). This is in accordance with the assertion made by Schmidt (2000) that in order to prevent seeds from deteriorating, they should not be stored for lengthy periods under tropical conditions.

Vegetable seed retailers mostly (84%) kept vegetable seeds and agrochemicals in the same retail shop because they claimed that agrochemicals (fertilizers, pesticides, weedicides) were supplementary inputs required for the certified seeds to achieve their full growth and yield potential when cultivated on the field. This corroborates the findings by Tahirou *et al*. (2009) who argued that, most seed retailers were agro dealers who sold improved seeds alongside other agricultural inputs. This finding further confirms claims by Lyon (1999) who revealed that agrochemical shops were those that bought the chunk portion of certified seeds, and AGRA (2013) who also reported that agro dealers had proven beyond doubts to be the most suitable channels by which seeds were marketed. This practice clearly suggests that for reasons of economic benefits, retailers have ignored the possible effects of agrochemicals on seeds especially in case of chemical spillage on seeds. Retailers however claimed they had not identified any negative effect of agrochemicals on seeds when asked. This claim by the retailers however contradicts the findings by various researchers on the effects of agrochemicals on seeds. A research conducted by Dane and Dalgic (2006) revealed that solutions prepared from Benomyl, a fungicide, was able to cause many anomalies in mitotic cell divisions in the root tips of onion during germination and growth. Legume seeds treated with herbicides also resulted in reduction in nodules formation, thereby reducing the rate of nitrogen fixation (Isoi and Yoshida, 1988; Schnelle and Hensley, 1990). It has again been reported that agrochemicals such as Bentazone, Chlorsulfuron, Glyphosate, and Mancozeb have inhibited the development of nodules (Martensson, 1992). Finally, Buts *et al*. (2013) also confirmed that Bavistin concentration just above 0.5% negatively affected growth and yield of mung bean (*Vigna radiata*). Vegetable seed retailers should therefore isolate seeds from agrochemicals to prevent a possible accidental spillage of a chemical on seeds which might cause biochemical alterations in the seeds and render them useless for their purpose.

5.1.5 Repackaging of Certified Vegetable Seeds

Whilst 44% of the sampled retailers did not repackage their sourced certified seeds as they claimed it would facilitate decline in seed quality, 56% of them however repackaged their sourced vegetable seeds into smaller transparent plastic bags and made them available for sale to farmers. The practice of repackaging however contradicts the statement made by Malhotra and Vashishtha, (2007) that seed certification process ends with grant of certificate and certification tags, tagging, and finally, sealing. Poku *et al*. (2018) also reported that one important activity of seed inspectors after supervising the seed production process is to oversee the filling and sealing of seed bags for the producers and companies. These assertions presuppose that, packaged and sealed certified vegetable seeds are not to be opened or tampered with in anyway within the distribution and marketing chains until they reach the end user (farmer) for cultivation. Repackaging of certified seeds at retailers' end further goes against provisions made for labelling of seed packages enshrined in Section 42 of the Plant and Fertilizer Act (Act 803) which states that seeds produced or marketed in Ghana shall be packed in containers which shall be securely closed and labelled with an approved label.

Retailers' most mentioned reasons for repackaging the seeds were the request for smaller quantities of seeds by small-scale vegetable farmers, and farmers' inability to afford the cost of seeds in larger containers. When asked about any identified negative effect of repackaging on the quality of the seeds, most (71.4%) of them claimed they had not identified any negative impacts. Repackaged seeds were neither securely closed nor properly labelled with an approved label. It could be deduced that retailers were either unaware of seed regulations or were just being adamant. Repackaging of certified seeds at retailers' end might only not expose seeds to high relative humidity and temperatures and cause a decline in seed quality, but might also lead to varietal mix up, entry of inert matter, and exposure of seeds to air-borne pathogens during the repackaging process. Effective communication and collaboration between regulatory bodies, seed producers/companies, retailers, and farmers would be required to curb this menace.

5.1.6 Retailers' Marketing Challenges

The predominant marketing challenges stated by the retailers involved seed pricing, seed storage, seed package sizes, and access to credit facilities.

Retailers explained that though farmers were generally satisfied with the quality and field performance of the certified seeds, the latter however complained bitterly about prices of the seeds being too high. Most farmers could not afford and were thus repelled by the prices of the seeds leading to their over-reliance on farmer-saved seeds. Issues of seed pricing is in accordance with an assertion made in the National Seed Policy (2013) which states that a number of attributes determine farmers' satisfaction and subsequent sustainability of a vibrant seed market, one of which is the price of the seed. The National Seed Policy (2013) further outlines instability in seed prices as one of the challenges faced by seed marketing in Ghana. The high cost of seeds could be ascribed to the high dependence on seed importation which would usually come with import duties and other applicable taxes. Retailers therefore suggested that investments should be made in breeding and local vegetable seed production to reduce cost of importation. They further suggested a cut down on import duties paid on vegetable seeds to help reduce cost.

Retailers marketing challenges with respect to storage is in agreement with Etwire *et al*. (2013) who reported that a major problem facing Ghana's seed industry is inadequate storage facilities resulting in loss of seed viability with time. The National Seed Policy (2013) also cited inadequate seed storage facilities as one of the challenges faced by the country's seed marketing industry. Retailers indicated that though cold storage of seeds was the best practice, they could not afford its establishment and maintenance. They further made an indication that the use of a cold storage would result in a rise in seed price as its establishment and maintenance would add up to the cost of seeds. Retailers' suggestion to manage this menace was to form a vibrant seed retailers' association and request for a central seed storage facility from government which would grant all members access to affordable cold storage.

Addressing seed package size as a marketing challenge, retailers explained that, farmers usually made complaints that seed package sizes were too small for the price the latter paid to purchase them. Some farmers also complained that seed package sizes were too big since they required smaller quantities for cultivation. The National Seed Policy (2013) also cited appropriateness of the size and packaging of marketed seeds as one attribute that determines farmers' satisfaction which subsequently leads to a sustainable vibrant seed market. With respect to how this challenge could be managed, retailers suggested that effective communication and discussions between suppliers, retailers, and farmers would be required to resolve the issue.

Retailers' challenge with access to credits could be attributed to the fact that most of them were sole proprietors. Although sole proprietorship is easier to form, one significant disadvantage is that the owner is solely liable for all business costs and liabilities. Retailers could have therefore pulled resources together to solve their financial challenges if they had formed partnerships. This approach would have been beneficial as the formation of partnership has been reported to be an essential tool for increasing productivity and maximizing profits (Horne, 2009; Prasetyo *et al*., 2015). Suggestions by retailers to solve their challenges included the formation of functional vegetable seed retailers' association to mutually assist members. Others too were of the view that government should provide financial support to retailers in the form of credit grants, and tax reductions.

5.2 Laboratory Assessment of Vegetable Seed Quality

5.2.1 Quality of First Sampled Seeds

5.2.1.1 Seed Moisture Content

With reference to seed quality standards for emergency activities based on FAO Quality Declared Seed (QDS) (Appendix 2), the maximum percentage moisture content for vegetable seeds is 8 %, signifying that, moisture contents recorded for the various seed samples were generally high.

Although seed samples in original package recorded varied moisture content values, they collectively recorded an average moisture content of 8.82%. High seed moisture content recorded for seed samples could not only be attributed to improper drying of seeds, but also, poor storage conditions since seeds were stored under predominantly high temperatures and high relative humidity. McCormack (2004) reported that high temperature and high relative humidity resulted in a rise in seed moisture content during storage, eventually resulting in a decline in seed quality. As reported also by Vieira *et al*. (2001), moisture content of the seed is dependent on the relative humidity of the storage environment, thus the high relative humidity of the retail shops could have led to seeds picking up additional moisture. High temperature increases seed embryo respiration resulting in moisture production in the seed. High relative humidity also increases seed moisture content as the seed absorbs water from the surrounding air. On the contrary, the few seed samples in original package that had moisture content of 8.0% or below could also suggest proper seed drying coupled with proper storage practices.

In comparison with seeds in original package, repackaged seed samples recorded relatively higher moisture content values with an average of 8.92%. This could not only be attributed to improper seed drying and poor storage conditions, but also, repackaging of the seeds which could have also led to seeds absorbing additional moisture from the environment either through the repackaging process, or the improper sealing of the repackaged samples. Few repackaged seed samples however had moisture contents within FAO QDS standards which could only not be as a result of proper drying and storage practices, but also retailers repackaging seeds under appropriate environmental conditions supplemented with proper sealing of the samples.

Seed moisture content has been indicated by O'Hare *et al*. (2001) to be the most essential factor that influences seed longevity during storage. The generally high moisture content of the certified vegetable seeds was therefore alarming since seeds could lose their viability in the shortest possible time. Yanping *et al*. (2000) reported a decline in seed quality of Welsh onion seeds due to increased moisture. Vieira *et al*. (2001) also indicated that the rate of seed deterioration is directly related to the moisture content of the seed, the higher the moisture content of the seed, the faster the rate of seed deterioration.

5.2.1.2 Seed Percentage Purity

Percentage purity of seed samples were generally high and within FAO QDS standards. Seeds in original package recorded an average percentage purity of 98.43% which was above FAO QDS minimum standards. The high percentage purity of the seeds could be as a result of proper cleaning during seed processing, and retailers' employment of good seed handling techniques which might have also prevented seed breakages. In contrast, seed samples, African eggplant *var*. Kotobi from Anokye Agrochemicals (AEP-OB-O), Carrot *var*. Amazonia from Grace Adom Agrochemicals (CR-TP-O), and Eggplant *var*. Black beauty from Agyass seeds (EP-MB-O) had percentage purity below FAO QDS standards. This might be as result of improper cleaning during seed processing, or improper handling of seeds during storage which might have led to breakages within the seed lot.

Repackaged seed samples also had majority recording percentage purity within minimum standards. This could only not be attributed to proper seed cleaning and good seed handling practices, but also, probable precautionary measures taken by retailers during the repackaging process which might have prevented seed mix ups and entry of inert matter. Two samples, repackaged Sweet pepper *var*. Yolo Wonder seeds from Agyass seeds (SP-MB1-R) and cabbage *var*. Oxylus from Amankwah Spare Parts and Seeds (CB-MB-R), however had percentage purity of 90.00% and 54.00% respectively which were below FAO QDS minimum standards. These findings could only not be ascribed to poor seed processing, and bad seed handling at retailers' shops, but also, repackaging of the seeds that might have caused seed mix ups, and entry of inert matter.

5.2.1.3 Seed Percentage Germination and Vigour

Significant differences in mean percentage germination and vigour indices among samples could not be attributed solely to variations in retailer storage conditions, but also, genetic differences among vegetable samples. Simic *et al*. (2007) reported that even different varieties of the same plant species may exhibit different storing abilities owing to genotypic variations.

Germination tests conducted on seed samples that were in original package generally showed high germination with a mean percentage of 83.20% which was above FAO QDS minimum standards. Seed viability has been reported to be affected by storage conditions and duration of storage (Coolbear, 1995; Adam *et al*., 2017). High germination exhibited by seed samples therefore could not only be as a result of proper storage conditions, but also due to the fact that retailers were not keeping seeds in stock for lengthy periods. On the contrary, Cayenne from Akuafuo Yiedie Fie (HP-NE-O) recorded poor percentage germination of 33.25% with Shito Adope from Best and Less Agrochemicals (HP-KN-O) also losing viability completely. The poor germination and loss of viability could have been as a result of poor storage conditions, seeds being kept in stock for lengthy periods, or challenges in the value chain as samples were local materials.

Though repackaged seed samples collectively recorded percentage germination of 77.70% which was lower than FAO QDS minimum percentage germination of 80%, individually, most of the seeds had percentage germination within FAO QDS standards. Three of the repackaged seed samples (Lettuce *var*. Kaizer from Samofa Agrochemicals (L-NE-R), Sweet pepper *var*. Yolo Wonder samples from Dapsy Agro Products (SP-MB-R) and Agyass Seeds (SP-MB1-R)) recorded very low germination with one sample (Hot pepper *var*. Carabeau from God's Time Agrochemicals) showing no germination. These observations could not only be due to poor storage conditions and lengthy storage periods, but also, repackaging of the seeds that might have directly exposed seeds to harsh environmental conditions. Maina *et al*. (2017) reported significant effects of storage material on seed quality during storage of jute mallow. In this study, the use of transparent plastic bags for seed repackaging resulted in a decline of seed viability.

It is worth noting that two seed samples that had completely lost viability (HP-KN-O and HP-TP-R) were both chillies corroborating the report by Kumari *et al*. (2014) that chilli seeds with their thin seed coat exhibit rapid deterioration in prevailing hot and humid climate in India. They further indicated that studies on film coating techniques on chilli seeds were being conducted to combat the situation.

Though seeds in original containers exhibited high vigour compared to those that were repackaged, seed vigour indices computed for both sample groups were generally high. There was a high correlation between seed percentage germination and seedling vigour which confirmed report by was by Tokpah (2010) that seeds with high germination percentages usually had corresponding high vigour. According to McDonald (1980), AOSA defined seed vigour are those attributes of a seed which dictate the potential for quick, unvarying sprouting and development of seedlings with normal attributes under a broad range of environmental conditions. This definition thus suggests that seeds tested would generally survive even when environmental conditions were unfavourable. Seed samples that recorded poor vigour indices could be associated to poor storage conditions, particularly, high temperature and high relative humidity leading to accelerated ageing of seeds as indicated by Heatherly and Elmore (2004).

5.2.1.4 Seed Health

Seeds in original containers showed low fungal prevalence for the two fungal species, *Aspergillus niger* and *Aspergillus flavus,* found to be associated with five of the fifteen seed samples. The detection and identification of few fungi species at low prevalence amid high storage temperature and relative humidity might be as a result of the pre-treatment of seeds with fungicides, mainly, Topsin and Thiram. Furthermore, the use of blotter method in the detection and identification of fungi could also be a limiting factor because the agar plate method has been reported to be better in obtaining more mycoflora associated with seeds than the blotter method (Dauda Palnam, *et al*., 2017).

Few samples that however showed fungal infections could be as a result of the high seed moisture content and the prevailing high temperature and relative humidity at retailers' shops. Niaz *et al*. (2011) reported that increased temperature and moisture increased mycoflora infection on maize seeds. High seed moisture content resulting from improper drying, moisture production through seed embryo respiration owing to high storage temperature, and absorption of moisture by seeds stored in humid environment creates suitable conditions for fungal growth. FAO (2018) further indicated that the spores of these storage fungi could easily not be gotten rid of during seed cleaning and are able to germinate during seed storage when seed moisture increases. The identification of the two *Aspergillus* species in this study is in accordance with Abdelwehab *et al*. (2014) who identified the genus *Aspergillus* as being the most prevalent fungi on vegetable seeds imported in Sudan.

Repackaged seeds relatively showed higher fungal prevalence than seeds in original containers. *A. niger* and *A. flavus* were found to be associated with eight of the fifteen repackaged seed samples. Mycoflora association with the repackaged vegetable seeds could only not be linked to the prevailing high temperatures and relative humidity at retail shops but also via the repackaging process. FAO (2018) stated that *Aspergilli* are storage fungi with air-borne spores. Rojas *et al*. (2002) also identified air-borne spores of *A. flavus* and *A. niger* in all screened environments at Havana University. Thus, spores might have therefore gained entry into seed samples in this situation during the repackaging process.

A. flavus and *A. niger* have been reported to cause a reduction in germination and seedling vigour index of mung bean (Chaudhari *et al*., 2018). Ratnarajah and Mikunthan (2015) also identified a reduction in percentage germination of chilli seeds. Thus, the loss, or decline in germination of infected seed samples, Hot pepper *var*. Shito Adope (HP-KN-O), Hot pepper *var*. Carabeau (HP-TP-R), and repackaged Sweet pepper *var*. Yolo Wonder (SP-MB-R and SP-MB1-R) could be attributed to the presence of the *Aspergillus sp*.

5.2.2 Comparison of Quality Characteristics of Selected Vegetable Seeds in Different Package Types Sampled Across Three Retail Outlets

5.2.2.1 Comparison of Quality Characteristics of Sweet Pepper *var*. Yolo Wonder Seeds

Sweet pepper seeds sampled from the three retail outlets recorded germination percentages below FAO QDS standards with corresponding low vigour indices indicating poor storage practices by retailers. Rindels (1995) made it known that seed viability was dependent on storage factors. Significant differences in mean percentage germination and mean vigour indices across the various outlets pointed out variations in retailers' conditions. Interaction between sample and package type significantly affected germination and vigour in samples obtained from Dapsy Agro Products (SP-MB) and Agyass Seeds (SP-MB1). Germination and vigour indices were significantly reduced when samples SP-MB and SP-MB1 were repackaged. The transparent plastic bags used for repackaging the seeds might have also allowed light penetration, resulting in increased seed respiration and subsequent decline in seed viability and vigour. This observation is similar to that of Maina *et al*. (2017) who reported significant effects of storage material on seed viability of jute mallow. Sample-package type interaction had no significant effect on germination and vigour in sample obtained from Mansusu Agrochemicals (SP-MB2) which indicates probable good seed handling and storage practices might have annulled the adverse effects of repackaging.

Moisture content recorded for sweet pepper seeds were generally high and did not meet FAO QDS standards. Retailers were observed to be storing seeds under high relative humidity. Similar reports were made by McCormack (2004) and Vieira *et al*. (2001). Certified seeds thus faced loss of or decline in seed viability with time because high seed moisture content has been reported to affect seed longevity (Yamping *et al*., 2000; O'Hare *et al*., 2001; Vieira *et al*., 2001). Repackaging significantly increased moisture content of seeds in all three samples. The repackaging process probably exposed seeds to moist environment resulting in seeds picking up additional moisture. The transparent plastic bags employed for seed repackaging, coupled with improper sealing of repackaged seed samples might have also accounted for the increase in seed moisture content. Adam *et al*. (2018) reported that sweet pepper seeds retain over 70% viability in short and medium-term storage if seeds are stored inside moisture-proof packaging materials like aluminium cans.

Seed percentage purity of SP-MB and SP-MB2 were higher than FAO QDS minimum standards and were not significantly different from each other. This indicates that both retailers were similarly handling seeds well. SP-MB1 however had percentage purity below FAO QDS standards indicating that seeds were mishandled leading to seed breakage and entry of foreign materials. Only the interaction between SP-MB1 and package type showed significant difference where repackaging reduced purity significantly. These findings showed that though repackaging could reduce seed purity, proper seed handling and precautionary measures taken by retailer during the repackaging process could maintain seed purity.

Health tests conducted on sweet pepper seeds revealed the association of *Aspergillus niger* on SP-MB and SP-MB1 while SP-MB2 recorded no fungal infections. The absence of fungal association with SP-MB2 could not only be as a result of proper seed cleaning followed with treatment with effective fungicides, but also, careful repackaging process that prevented entry of air-borne fungal spores. *A. niger* was only identified on the repackaged versions of SP-MB and SP-MB1, suggesting that, fungal association might have occurred during the repackaging process since *Aspergilli* have been reported by FAO (2018) to be storage fungi with air-borne spores. *Aspergillus sp*. have been reported by Chaudhari *et al*. (2018) and Ratnarajah and Mikunthan (2015) to cause a reduction in germination of mung bean and chilli seeds respectively. Thus, the decline in germination of SP-MB and SP-MB1 could also be attributed to the association of *A. niger* with the seed samples.

5.2.2.2 Comparison of Quality Characteristics of Carrot *var*. Amazonia Seeds

Carrot seeds tested showed high vigour indices and corresponding high germination percentages which met FAO QDS minimum standards. This could suggest retailers' good storage practices or the fact that seeds had been stored for a short period (Coolbear, 1995; Adam *et al*., 2017). Germination and vigour were significantly reduced in samples obtained from Kyeiwaa Agrochemicals (CR-MP) and Grace Adom Agrochemicals (CR-TP) when they were repackaged suggesting adverse impact of repackaging on carrot seed viability and vigour. Sample and package type interaction however did not affect germination and vigour in sample obtained from Mansusu Agrochemicals (CR-MB). This indicated that proper seed handling practices that might have been carried out by the retailer during the repackaging process might have neutralized possible adverse influence of repackaging.

Moisture contents of the seed samples were generally high and could not meet minimum standards. High relative humidity recorded across the three shops might have played a role in the gain in moisture by the seed samples. Though package type and sample interaction had no significant effect on moisture contents of CR-MP and CR-TP, moisture content of CR-MB was however increased significantly when repackaged. The repackaging of CR-MB might have led to moisture gain by seeds due to seed exposure to the humid environment present at retailer's shop.

All but CR-TP had percentage purity within FAO QDS minimum standards which suggests that both retailers were handling seeds with care. Mishandling of CR-TP might have resulted in seed breakages and entry of foreign materials that led to decline in seed physical purity. Physical purity of CR-MP and CR-TP were significantly reduced when repackaged. The repackaging process might have allowed entry of inert matter and other seeds identified in the said seed samples during purity analysis.

Two *Aspergilli* species, *A. flavus* and *A. niger* were associated with seed samples CR-MP and CR-TP whilst CR-MB recorded no fungal infections. CR-MB might have been well cleaned, treated, and handled with care during the repackaging process resulting in zero fungal occurrence. The occurrence of *A. flavus* and *A. niger* on CR-MP and CR-TP is similar to reports by Abdelwehab *et al*. (2014) who also reported *Aspergillus* genus as being the most prevalent fungi on imported vegetable seeds in Sudan. Germination of spores may have also been triggered by increased seed moisture following high relative humidity of storage environment as repackaged seeds were not in air-tight packs. Repackaging therefore significantly affected prevalence of fungal pathogens.

5.2.2.3 Comparison of Quality Characteristics of Cabbage Seeds

Cabbage seeds sampled from the three retail outlets recorded germination percentages, vigour indices, and moisture contents that met FAO QDS minimum standards. As reported by Coolbear (1995) and Adam *et al*. (2017), these observations might be the result of good storage practices or the maintenance of seed quality owing to short storage duration. Seed samples obtained from Maame Agrochemicals (CB-BK) and Maconi Enterprise (CB-OB) recorded purity percentage values that met minimum standards whilst sample from Amankwah Spare Parts and Seeds (CB-MB) could not meet minimum purity standards. CB-BK and CB-OB might have been well cleaned during seed processing and repackaged with high expertise compared to CB-MB leading to variations in physical purity.

Interaction between sample and package type had no significant effect on germination, seedling vigour, and moisture content. This could be attributed to good storage conditions and proper seed handling practices during the repackaging process. Purity of CB-MB was however reduced significantly when repackaged. The varietal mix ups and entry of inert matter observed during the purity analysis of CB-MB might have occurred due to low expertise in the repackaging process at retailer’s end.

While seed sample CB-OB showed no fungal infections, *Aspergillus niger* was however identified to be associated with CB-BK and CB-MB. CB-OB recording no fungal growth could be ascribed to proper seed cleaning followed with seed treatment with effective fungicides, and also, precautionary measures taken by the retailer in the course of seed repackaging that averted the possible entry of air-borne fungal spore. Since fungal associations were only identified on CB-BK and CB-MB that were repackaged, it could be said that the association might have occurred during the repackaging process because *Aspergilli* have been reported to be storage fungi with abundant air-borne spores (Rojas *et al*., 2002; FAO, 2018).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the study conducted, the following conclusions can be made:

I. Vegetable seed retailers in the Ashanti Region were found to be educated to at least B.E.C.E level, and had adequate knowledge and experience in the handling of certified seeds. They could assert logically their knowledge and experiences with respect to fundamental practices employed in the handling of certified seeds, and were aware of the major factors that could cause decline in seed quality during seed storage. Retailers were however not demonstrating good storage practices because they could not afford the purchase and maintenance of cold storage facilities.

II. Retailers' major marketing challenges were

- seed pricing in relation to farmers' dissatisfaction with the cost of seeds,
- lack of cold storage facilities,
- farmers' dissatisfaction with seed package sizes being too small for the amount paid to purchase them, or too large for the quantity required, and
- poor access to credit facilities.

III. With the exception of African eggplant *var*. Kotobi from Anokye Agrochemicals (AEP-OB-O), Carrot *var*. Amazonia from Grace Adom Agrochemicals (CR-TP-O), and Eggplant *var*. Black Beauty from Agyass Seeds (EP-MB-O), seeds in original package had high physical purity. Seeds in original package also showed high physiological (germination and seedling vigour) quality with the exception of Hot pepper *var*. Shito Adope from Best and Less Agrochemicals (HP-KN-O) and Hot pepper *var*. Cayenne from Akuafuo Yiedie Fie (HP-NE-O). The few samples that had lost, or declined in quality in terms of germination, vigour, and purity was due to poor storage practices, and extended storage periods.

IV. Repackaged seed samples were not of inferior quality with most of them exhibiting high quality with respect to germination, seedling vigour, and physical purity. Few samples that had lost, or declined in quality with respect to germination, seedling vigour, and physical purity was due to poor storage conditions, coupled with repackaging process that exposed seeds to harsh environmental conditions, and also facilitated the entry of foreign materials into seed samples.

V. Seeds tested generally had high moisture contents with few samples meeting minimum standards. Increase in seed moisture content was due to high temperature and high relative humidity present at retail shops. High seed moisture content indicated that seeds could not be stored for long periods as they could lose their viability within a short time.

VI. Fungal prevalence was low in the tested samples. Two saprophytic fungi, *Aspergillus niger* and *Aspergillus flavus*, found to be associated with few samples was ascribed to high seed moisture, and seed repackaging that allowed entry of fungal spores into seed samples.

VII. Seeds in original package were generally better than the repackaged seeds in all seed quality parameters tested. Seed repackaging reduced seed viability and vigour, and increased seed moisture content. Seed physical purity was also reduced as repackaging resulted in varietal mix ups and entry of inert matter. Seeds were possibly infested with air-borne fungal spores during the repackaging process causing a reduction in seed health quality.

6.2 Recommendations

I. Vegetable seed retailers should form functional associations capable of soliciting for funds, and offering support to members, to help solve their challenges, especially, storage.

II. GSID should be well resourced to conduct regular and effective post-certification surveillance to ensure seed quality maintenance.

III. Seed producers and seed companies should package seeds in varying sizes to prevent seed repackaging.

IV. Should seeds be repackaged by retailers, care must be ensured by using specially designed stable environments and moisture proof packaging materials.

V. Retailers should be trained on how to conduct simple germination tests. This would help them ascertain seed percentage germination before selling to farmers.

VI. Future studies should employ the Agar plate method in seed health tests to help detect and identify fungi species that would require a nutrient medium to grow.

VII. The study should be replicated in the northern zone of Ghana to have a broader view of the state of marketed certified vegetable seeds in the country.

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APPENDICES

Appendix 1: Research Questionnaire

INTRODUCTION

I am **Johnson Antwi Adom**, an MPhil. Seed Science and Technology student from the West African Centre for Crop Improvement (WACCI) of the University of Ghana, Legon. As part of my research, I am conducting a survey on the topic **"Assessment of the quality of marketed certified vegetable seeds in original package and those repackaged at retailers' end in the Ashanti region of Ghana"** and I duly plead for your assistance and cooperation to achieve this task. Please answer the questions that follow by ticking the appropriate options (if provided) or writing unrestrictedly for open-ended questions. Please answer all questions freely but objectively.

The information is for **academic purposes** only and will be treated with the **strictest confidentiality.**

1. Name of respondent (Optional) ……………………………………………………
2. Sex: a. Male ☐ b. Female ☐
3. Age (years): a. Below 25 ☐ b. 26-35 ☐ c. Above 36 ☐
4. Highest Educational level attained
    a. B.E.C.E. ☐ b. WASSCE ☐ c. HND ☐ d. Diploma ☐

e. Bachelor's Degree ☐   f. Masters ☐   g. Other ☐

h. No Formal Education ☐

5. Name of Shop/Company……………………………………………………………………

6. Address/Location…………………………………………………………………………

7. Telephone No……………………………………………………………………........

8. Type of business:

   a. Sole Proprietor ☐   c. Partnership ☐   e. Company ☐

   b. Franchise ☐   d. Limited Liability ☐   f. Other ☐

9. How many years have you been selling vegetable seeds?

   a. Less than 5 years ☐   c. Between 5 and 10 years ☐

   b. Between 10 and 20 years ☐   d. 20 years or more ☐

10. Which other seeds do you retail?   a. Cereals ☐   b. Legumes ☐

    c. Grass seeds ☐   d. Fruits ☐   e. Other (Specify)………………………...

11. List in order the highest selling vegetable seeds from your shop

    a.……………………………….….   b.……………………………………

    c.……………………………….   d.……………………………………

    e.……………………………….   f.……………………………………….

12. Do you receive any complaints from buyers about vegetable seeds purchased?

    a Yes [ ]   b. No [ ]

13. If 'yes' to question 12, State a few of these complaints

Complaint(s)	Tick (where applicable)
Poor germination	
Presence of insects	
Discolouration	
Mould	
Presence of viruses when planted	
Low establishment	
Varietal mix up	
Presence of weeds when planted	
Other (please specify) ……………………………......... …………………………………..	

14. Who is/are your certified vegetable seed supplier(s)? a. Seed growers [ ]

    b. Cooperatives [ ] c. Seed companies [ ] d. Other (Specify)………………

15. How are the vegetable seeds delivered to you?

    a. Cold van [ ] b. Air-conditioned van [ ] c. Ordinary van [ ]

16. From question 15, which in your opinion is the best practice?

    a. Cold van [ ] b. Air-conditioned van [ ] c. Ordinary van [ ]

17. Where are the delivered vegetable seeds kept?

    a. Warehouse [ ] b. Retail Shop [ ] c. Other (Specify)………………………..

18. What sort of packaging material is used for your sourced vegetable seeds purchased?

    a. Aluminium foil [ ] b. Cans [ ] c. Paper Sachets [ ] d. Transparent plastic bags [ ] e. Transparent plastic containers [ ] f. Other (specify)………………

19. Do you re-package the sourced vegetable seeds into different packages?

    a. Yes [ ] b. No [ ]

20. If 'yes' to question 19, which packaging material do you use for the re-packaging?

a. Aluminium foil [ ] b. Cans [ ] c. Paper Sachets [ ] d. Transparent plastic bags [ ] e. Transparent plastic containers [ ] f. Other (specify)………………

21. Why do you re-package seeds into other packaging materials?

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

22. Have you identified any negative impacts of seed re-packaging on seeds?

a. Yes [ ] b. No [ ]

23. If 'yes' to question 22, what are these negative impacts?

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

24. Do you perform any germination test to ascertain seed quality standards as per the label? a Yes [ ] b. No [ ]

25. Under what condition(s) is/are your vegetable seeds stored over time?

a. Room temperature [ ] b. Cold room [ ]

c Air-conditioned room [ ] d. Freezer [ ]

26. How long do you keep the vegetable seeds in stock? a.1-3 months [ ]

b. 4-6 months [ ] c. 7-9 months [ ] d. 10-12months [ ] e. Over 12 months [ ]

27. In your opinion does the length of storage time affect vegetable seed quality?

a. Yes [ ] b. No [ ]

28. If 'yes' to question 27, How? ……………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

29. Are you aware of factors that affect vegetable seeds in storage? a. Yes [ ] b. No [ ]

30. If 'yes' to question 29, give examples.

a. Storage temperature [ ] b. Moisture content [ ] c. Humidity [ ]

d. Pests [ ] e. Poor processing [ ] f. Pathogens [ ]

31. Do you keep vegetable seeds together with agro chemicals? a. Yes [ ] b. No [ ]

32. If 'yes' to question 31, have you identified any negative effect of agro - chemicals on the seeds?

a. Yes [ ] b. No [ ]

33. If 'yes' to question 32, what are these observable effects of agro-chemicals on vegetable seeds? ....

…………………………………………………………………………………………..

…………………………………………………………………………………………..

34. What kind of marketing challenges are you facing with regards to supplying good quality vegetable seeds to farmers and dealers?

a. Early maturing [ ] b. Late maturing [ ] c. Promotion [ ] d. Storage [ ]

e. Access to credit facilities [ ] f. Pricing [ ] g. Package sizes [ ]

h. Access to good communication network [ ]

35. What are you doing to solve the problem(s) above………………………………………………………………………………………

………………………………………………………………………………………….

…………………………………………………………………………………………..

36. Is there anything that can be done to help improve your vegetable seed business?

…………………………………………………………………………………………

…………………………………………………………………………………………

Appendix 2: List of sampled retail shops and their locations

RETAIL SHOP	LOCATION
Kyeiwaa Agrochemicals	Mampong
Grace Adom Agrochemicals	Tepa
God's Time Agrochemicals	Tepa
Just Grace Agrochemicals	Tepa
Samofa Agrochemicals	New Edubiase
Akuafuo Yiedie Fie	New Edubiase
Akuafuo Adamfo	Obuasi
Maconi Enterprise	Obuasi
Anokye Agrochemicals	Obuasi
Maame Agrochemicals	Bekwai
Abronoma Agrochemicals	Bekwai
First Samuel 2: 6-7 Agrochemical Ent.	Bekwai
Divine Oppongsco Enterprise	Ejisu
Amansie West District Cooperative Muliti-purpose Union	Manso Nkwanta
Best and Less Agrochemicals	Konongo
Owusu Agrochemicals	Nkawie
Yonko Do Agrochemicals	Adehyeman Acheamfuor
Nanafico Enterprise	Kejetia
Perp Oma Agrochemicals	Kejetia
Agyass Seeds	Mbrom
Amankwah Spare Parts and Seeds	Mbrom
Mansusu Agrochemicals	Mbrom
Dapsy Agro Products	Mbrom
Agriseed Limited	Afful Nkwanta, Kumasi
K. Badu Agrochemicals	Bantama

Appendix 3: Seed Quality Standards for Emergency Activities - Based on FAO Quality Declared Seeds (QDS)

VEGETABLES	Varietal Purity (min. %)	Analytical Purity (min. %)	Germination (min. %)		Moisture Content (max. %)
			Local Tender	International Tender	
Amaranthus	98	95	70	80	8
Beetroot	98	95	70	80	8
Cabbage	98	98	70	80	8
Carrot	98	97	70	80	8
Cauliflower	98	98	70	80	8
Celery	98	97	70	80	8
Chinese Cabbage	98	98	70	80	8
Cucumber	98	98	70	80	8
Eggplant	98	98	70	80	8
Leek	98	97	70	80	8
Lettuce	98	97	70	80	8
Melon	98	98	70	80	8
New Zealand Spinach	98	97	70	80	8
Okra	98	98	70	80	8
Onion	98	97	70	80	8
Parsley	98	95	70	80	8
Radish	98	98	75	80	8
Spinach	98	97	70	80	8
Squash	98	98	70	80	8
Sweet Pepper & Chillis	98	98	70	80	8
Swiss Chard	98	95	70	80	8
Tomato	98	98	75	80	8
Turnip	98	98	70	80	8
Watermelon	98	98	70	80	8

Appendix 4: Sampled vegetable seeds (a) Seeds in original package (b) Repackaged seed samples

(a)

(b)

Appendix 5: Analysis of Variance (ANOVA) for percentage germination of seeds in original package

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	27.867	9.289	2.07	
Rep.*Units* stratum					
Sample	14	44713.600	3193.829	713.01	<.001
Residual	42	188.133	4.479		
Total	59	44929.600			

Appendix 6: ANOVA for seedling vigour index of seeds in original package

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.53767	0.17922	2.66	
Rep.*Units* stratum					
Sample	14	1653.83827	118.13131	1754.90	<.001
Residual	42	2.82723	0.06732		
Total	59	1657.20317			

Appendix 7: ANOVA for moisture content of seeds in original package

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.17733	0.05911	3.99	
Rep.*Units* stratum					
Sample	14	109.93600	7.85257	529.67	<.001
Residual	42	0.62267	0.01483		
Total	59	110.73600			

Appendix 8: ANOVA for percentage purity of seeds in original package

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.02050	0.00683	0.68	
Rep.*Units* stratum					
Sample	14	366.17933	26.15567	2603.17	<.001
Residual	42	0.42200	0.01005		
Total	59	366.62183			

Appendix 9: ANOVA for percentage germination of repackaged seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	5.400	1.800	0.21	
rep.*Units* stratum					
sample	14	50720.100	3622.864	426.10	<.001
Residual	42	357.100	8.502		
Total	59	51082.600			

Appendix 10: ANOVA for seedling vigour index of repackaged seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.05290	0.01763	0.19	
rep.*Units* stratum					
sample	14	2361.05337	168.64667	1778.07	<.001
Residual	42	3.98363	0.09485		
Total	59	2365.08990			

Appendix 11: ANOVA for moisture content of repackaged seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.06533	0.02178	1.93	
rep.*Units* stratum					
sample	14	100.30933	7.16495	633.98	<.001
Residual	42	0.47467	0.01130		
Total	59	100.84933			

Appendix 12: ANOVA for percentage purity of repackaged seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.01933	0.00644	0.44	
rep.*Units* stratum					
sample	14	7842.90333	560.20738	37908.77	<.001
Residual	42	0.62067	0.01478		
Total	59	7843.54333			

Appendix 13: ANOVA for percentage germination of sweet pepper seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	9.125	3.042	0.47	
rep.*Units* stratum					
sample	2	1574.083	787.042	120.93	<.001
package_type	1	1107.042	1107.042	170.10	<.001
sample.package_type	2	1348.083	674.042	103.57	<.001
Residual	15	97.625	6.508		
Total	23	4135.958			

Appendix 14: ANOVA for seedling vigour index of sweet pepper seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.05063	0.01688	0.48	
rep.*Units* stratum					
sample	2	26.98681	13.49340	387.54	<.001
package_type	1	6.53127	6.53127	187.58	<.001
sample.package_type	2	7.43176	3.71588	106.72	<.001
Residual	15	0.52227	0.03482		
Total	23	41.52273			

Appendix 15: ANOVA for moisture content of sweet pepper seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.10333	0.03444	2.38	
rep.*Units* stratum					
sample	2	5.11000	2.55500	176.88	<.001
package_type	1	10.66667	10.66667	738.46	<.001
sample.package_type	2	1.34333	0.67167	46.50	<.001
Residual	15	0.21667	0.01444		
Total	23	17.44000			

Appendix 16: ANOVA for percentage purity of sweet pepper seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.101667	0.033889	4.69	
rep.*Units* stratum					
sample	2	157.690000	78.845000	10917.00	<.001
package_type	1	54.601667	54.601667	7560.23	<.001
sample.package_type	2	107.403333	53.701667	7435.62	<.001
Residual	15	0.108333	0.007222		
Total	23	319.905000			

Appendix 17: ANOVA for percentage germination of carrot seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	16.833	5.611	1.13	
rep.*Units* stratum					
sample	2	49.083	24.542	4.93	0.023
package_type	1	66.667	66.667	13.39	0.002
sample.package_type	2	58.583	29.292	5.88	0.013
Residual	15	74.667	4.978		
Total	23	265.833			

Appendix 18: ANOVA for seedling vigour index of carrot seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.09502	0.03167	0.74	
rep.*Units* stratum					
sample	2	32.15797	16.07899	376.98	<.001
package_type	1	2.25707	2.25707	52.92	<.001
sample.package_type	2	1.71401	0.85700	20.09	<.001
Residual	15	0.63978	0.04265		
Total	23	36.86385			

Appendix 19: ANOVA for moisture content of carrot seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.02333	0.00778	0.49	
rep.*Units* stratum					
sample	2	0.14333	0.07167	4.54	0.029
package_type	1	0.32667	0.32667	20.70	<.001
sample.package_type	2	0.22333	0.11167	7.08	0.007
Residual	15	0.23667	0.01578		
Total	23	0.95333			

Appendix 20: ANOVA for percentage purity of carrot seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.081250	0.027083	4.22	
rep.*Units* stratum					
sample	2	349.472500	174.736250	27231.62	<.001
package_type	1	13.053750	13.053750	2034.35	<.001
sample.package_type	2	6.752500	3.376250	526.17	<.001
Residual	15	0.096250	0.006417		
Total	23	369.456250			

Appendix 21: ANOVA for percentage germination of cabbage seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	36.458	12.153	2.15	
rep.*Units* stratum					
sample	2	1000.333	500.167	88.48	<.001
package_type	1	15.042	15.042	2.66	0.124
sample.package_type	2	22.333	11.167	1.98	0.173
Residual	15	84.792	5.653		
Total	23	1158.958			

Appendix 22: ANOVA for seedling vigour index of cabbage seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.38975	0.12992	2.14	
rep.*Units* stratum					
sample	2	37.39021	18.69510	308.18	<.001
package_type	1	0.47602	0.47602	7.85	0.013
sample.package_type	2	0.04206	0.02103	0.35	0.713
Residual	15	0.90995	0.06066		
Total	23	39.20798			

Appendix 23: ANOVA for moisture content of cabbage seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.00792	0.00264	0.14	
rep.*Units* stratum					
sample	2	4.94333	2.47167	135.02	<.001
package_type	1	0.05042	0.05042	2.75	0.118
sample.package_type	2	0.06333	0.03167	1.73	0.211
Residual	15	0.27458	0.01831		
Total	23	5.33958			

Appendix 24: ANOVA for percentage purity of cabbage seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.02125	0.00708	0.31	
rep.*Units* stratum					
sample	2	2842.32583	1421.16292	61566.62	<.001
package_type	1	1336.53375	1336.53375	57900.38	<.001
sample.package_type	2	2668.59250	1334.29625	57803.45	<.001
Residual	15	0.34625	0.02308		
Total	23	6847.81958			