A COMPARISON OF THE CHANGES IN SEED GERMINATION VIGOUR WITH PROLONGED STORAGE TIME BETWEEN HOPE AND SIERRA MALTING BARLEY VARIETIES AT DELTA BEVERAGES, KWEKWE MALTINGS.

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A comparison of the changes in seed germination vigour with prolonged storage time between Hope and Sierra malting barley varieties at Delta Beverages, Kwekwe Maltings.

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DECLARATION

I, **Milford Mwazha**, hereby declare that I am the sole author of this dissertation. I authorize the Midlands State University to lend this dissertation to other institutions or individuals for the purpose of scholarly research.

Signature _____ Date _____

APPROVAL

This dissertation entitles **"A comparison of the changes in seed germination vigour with prolonged storage time between Hope and Sierra malting barley varieties at Delta Beverages, Kwekwe Maltings",** by **Milford Mwazha** meets the regulations governing the award of the degree of Food Science and Nutrition of the Midlands State University, and is approved for its contribution to knowledge and literal presentation.

Supervisor: Mr. Jombo Signature …….

Date …….

ABSTRACT

To increase the brewing yield and efficiency, malts with high extract values, high enzymatic activities, and good modification are essential. To produce malt that meets these requirements, the barley employed must have minimal post-harvest dormancy and be able to germinate rapidly and uniformly. The aims of this study were to compare the changes in seed germination vigour trends and the general storage stability of two Zimbabwean two-row malting barley varieties (Hope and Sierra) as the post-harvest storage time increased. Two samples of these commercially grown varieties were obtained and stored under room temperature laboratory conditions. At monthly intervals the samples had their germination index and energy determined using SAB Miller standards for malting barley analysis (controlled germination in an incubator at 18^oC – 21^oC for 72 hours). In addition other quality parameters (nitrogen content, screenings, moisture content, water sensitivity and insect damage index) necessary to assess the storage stability of both varieties were also analyzed on monthly intervals using the same analytical standards as for germination tests. On the basis of the results obtained during the 13 months of post-harvest assessments it was found out that Hope had its Germination Index improving as storage time increased meaning that , the variety's germination vigour improves with time. By the first month of the research the GI index for Hope was 8.7 and gradually it increased reaching 9.2 by the end of the research period. However on the other hand the seed germination vigour for Sierra gradually diminishes with time as indicated by the weak negative downhill correlation (r value = -0.24). As for other grain quality parameters (including moisture loss, insect damage index, germination energy and screenings) Hope proved to be more stable in storage than Sierra. Thus after considering germination performance and general storage stability it was concluded that Hope is a better malting barley variety than Sierra.

DEDICATION

I dedicate this fruit of my labor to my dearest mother, the most important woman in my life, my source of inspiration and motivation. God bless you Mama!

ACKNOWLEDGEMENTS

Firstly I give praise and honor to the infinitely perfect and forever loving God for His benevolent and enduring merciful love. I proceed to put on board my grateful appreciation to my project supervisor Mr. Jombo, together with all my lecturers and colleagues from the Midlands State University's department of Food Science and Nutrition. Very special thanks must go to Delta beverages Kwekwe Maltings, in particular the production and quality control departments for their unwavering support at every stage of this research. Further I express my gratitude to Capernaum trust which made this dream come true by funding my studies.

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CHAPTER ONE

INTRODUCTION

1.0 Introduction

The main thrust of this introductory chapter is to outline the background of the study so as to provide an overview of the research topic, statement of the problem and the objectives of this research. It will also cover the questions which the researcher attempts to answer through the study, definition of terms, limitations and delimitations of the study.

1.1 Background of the Study

Briggs (1998) defined malting as the directed manipulation of barley growth to attain a desirable extract and enzyme yield or in simpler terms it is the partial conversion of the grain endosperm. Malting includes the controlled germination of barley in which hydrolytic enzymes are synthesized and the cell walls, proteins, and starch of the endosperm are largely digested, increasing grain friability (Enari and Sopanen 1986; Bamforth and Barclay 1993). The quality of the malt is of primary significance in the manufacture of beer of excellent quality. To increase the brewing yield and efficiency, malts with high extract values, high enzymatic activities, and good modificatioQDUHHVVHQWLDO7RSURGXFHTXDOLWPDOWZKLFKPHHWWKHUHZHU¶VSH the barley employed must have minimal post-harvest dormancy and be able to germinate rapidly and uniformly (Riss and Bang-Olsen 1991; Woonton, Jacobsen, Sherkat and Stuart 2005). Thus desirable germination performance which includes high germination index and germination capacity forms the criterion for selecting malting barley (Swanston and Taylor 1990; Larsenet 1994; Briggs 1995; /X2¶%ULHQDQG6WXDUW2000; Munck and Moller 2004). Highly suited for malting is the barley which germinates rapidly and homogenously. The faster the rate of

germination the shorter the time required to attain desirable modification during malting (hence the fewer the hours required for the germination stage). As a result the germination vigor / rate of germination determine the time required for malting, hence the malting efficiencies. Kwekwe Maltings has established a backward integration contract scheme with local barley farmers in all the farming regions of Zimbabwe in an attempt to have sufficient barley stocks to enable malt production throughout the year. As a result the company has the potential of receiving over 40 000 tons of barley from a winter growing season inclusive of both Sierra and Hope malting barley varieties; hence a great need to have proper storage facilities which ensure barley retains its desirable malting qualities such as germination capacity and vigor during the prolonged storage prior to malting. According to the findings of the research done at the Carlsberg Research Laboratory , during prolonged storage, barley grain will slowly lose its vitality, causing a slower germination and even grain death, and will therefore be of less value for the malster (European Brewery Convention Congress / EBC 1989 and 1991).The rate at which barley loses its vitality is dependent on the storage conditions and the rate of the quality deterioration also depends on the differences of the genetic backgrounds of the varieties.

1.2 Problem statement

The storage time of malting barley at Kwekwe Maltings (KKM) is determined by the quantity of barley received from farmers for a particular growing season. For both the two varieties (Hope and Sierra) malted at KKM just as in other varieties they are great possibilities for the germination vigour to vary with time but at different rates due to possible varietal differences in their physiological characteristics. Consequently for the same reasons stability of other quality parameters will vary during storage. No systematic scientific study has been done to determine trends of changes in seed germination vigour with increase in storage time for the two varieties

and further to analyse their storage quality stability. As a result Kwekwe Maltings lacks adequate experimentally proved information to justify whether or not the barley varieties they malt retain their desirable germination attributes for the same length of storage time. Due to this knowledge gap the organisation cannot explain if the compromised germination performances evident in some instances when barley is malted after prolonged period of storage are a result of the failure to meet standard storage conditions or an effect of varietal differences. As a result the researcher has found it necessary to carry out: A comparison of the changes in seed germination vigour with increase in storage time between Hope and Sierra malting barley varieties.

1.3 Objectives of the study

Broad Objective

To determine the effect of storage time on seed germination vigour between Hope and Sierra malting barley varieties.

Specific objectives

- To determine how the extent and rate of germination for both Sierra and Hope barley varieties changes with increase in storage time.
- To determine the general quality storage stability of Sierra and Hope Malting Barley varieties.

1.4 Research questions

The researcher attempts to fulfil the requirements of the research topic by answering the following questions:

- What are the differences in changes of seed germination vigour between hope and Sierra Barley varieties?
- What positive and negative changes occur for various malting barley quality parameters in Sierra and Hope during storage?
- What is relationship between changes in the quality attributes of the barley varieties to the germination vigour patterns as the storage time increases?

1.5 Hypothesis

- H_0: There will be no significant differences in seed germination vigour with prolonged storage time between Hope and Sierra barley varieties.

- H_1: There will be significant differences in seed germination vigour with prolonged storage time between Hope and Sierra barley varieties.

1.6 Assumptions

The researcher assumed that:

- The storage conditions which the samples were subjected to are the same as those for grain in storage silos and also uniform for both varieties.

1.7` Significance of the study

Benefits to the Malster

- A knowledge gap exist in regard to the trends of seed germination vigour for the malting barley varieties therefore a successful completion of this research will close the knowledge gap.
- Germination vigour determines the time and conditions required for malting (thus has a direct effect on malting efficiencies) and hence the information comparing the trends of germination vigour of the two varieties is necessary for effectively determining processing cycles and conditions at various storage stages.
- The research findings will be used to determine which of the two varieties should be malted first or kept longer in storage depending on the rate at which germination vigour diminishes or improves with increase in storage time under optimum conditions.
- In the contractual farming in which Delta Beverages Kwekwe Maltings engage with the farmers, information to be obtained from the research findings is essential to determine the quantities of barley to be grown per each variety, so as to avoid growing of amounts of barley which cannot be malted in the time frame which the barley will be retaining high germination vigour.

Benefits to the Researcher (Student)

Successful completion of the research project will improve the research skills of the student and in addition the researcher will widen his understanding of malting science and technology. Also completing this research study will contribute to the partial fulfilment of the requirements of the Food Science and Nutrition Degree programme at the Midlands State University.

1.8 Limitations

- Information specific to the barley varieties (Hope and Sierra) which is necessary to be able to reach well informed academic conclusions and interpretation of the findings is limited.

1.9 Delimitations

The scope of the research was restricted only to the two malting barley varieties (Hope and Sierra), malted at Delta Beverages Kwekwe Maltings. Only the malting barley harvested from the 2012 winter growing season was used for the research. The primary samples for both varieties were kept at room temperature under laboratory conditions at Kwekwe Maltings which is the same laboratory all the experiments were carried out.

1.10 Acronyms and Definition of terms

GI:	Germination index
GE:	Germination energy
GC:	Germination Capacity
TCW:	Thousand corn weight
KKM:	Kwekwe Maltings
IR:	Infra-Red
FM:	Foreign Matter

Malting: Directed manipulation of barley growth aimed at attaining a specified extract and enzyme yields (or simply the conversion of barley to malt).

Barley: A cereal plant belonging to the genus Hordeum of the grass family having awned flowers that grows in tightly bunched spikes with three additional spikes at the node.

Cultivar/ Variety: Plants selected for desirable characteristics that can be maintained by propagation e.g. Sierra and Hope which have been selected for malting purposes

Germination vigour: The sum total of those properties of the seed which determine the level of activity and performance of the seed or seed lot during germination.

1.11 Summary

The chapter gave an introduction to the research project. The chapter also included key elements such as hypothesis and contextual definitions of key terms used in this chapter and those that are to follow. The chapter sought to show and explain the rationale used by the writer to build up his research project.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter intends to review related theory in an attempt to establish the link between this study and already existing knowledge. In this chapter the major concepts encompassed within the scope of this study are fully defined and clarified. The major theoretical aspects explained in this chapter include those concerning the quality attributes of malting barley (including the influence of varietal differences), overview of the malting process including the relevant biochemistry. Also considerable attention has been given in discussing the concepts of grain germination vigour and the germination performance determination techniques.

2.1 Malting definition and purpose

The directed manipulation of barley growth to attain a desirable extract and enzyme yield (Malting) is defined by Briggs (1998) as simply the limited germination of cereal grains or, occasionally, the seeds of pulses, under controlled conditions. More specifically referring to barley malt, Gupta, Abu-Ghannam, and Gallaghar (2010) defines malting as the controlled germination of cereals, to ensure a given physical and biochemical change within the grain, which is then stabilized by grain drying.

2.2 Malting barley

Naidu (2008) notes that barley (Hordeum vulgare) is a type of cereal that belongs to the grass family (Gramineae) usually grown in winter and one of the ancient domesticated crops. Worldwide, the greatest use of barley is for malting purposes, most specifically for the brewing

industry. However, in recent years, there has been a growing interest in incorporating barley into the human diet because it is wholesome, readily available, and relatively inexpensive (Keenan, Coulson, Shamliyan, Knutson, Kolberg and Curry, 2007). The barley used for malting is technically called malting barley. Despite barley being the most malted cereal ,Briggs (1998) also notes that other cereals such as wheat (triticum aestivum) and sorghum (Sorghum vulgare) are also malted in notable quantities (the latter in Africa), and in other countries small amounts of rye (Secale cereale), oats (Avena sativum) and millets (various spp.) are also used .According to Kunze (1999) barley selected for use in the malting industry must meet special quality specifications which are essential for the accepted malting barley varieties to modify evenly and produce finished malt whose properties lie within the brewer's specifications. The malt quality of a given barley variety is determined by its genetic background and the physical conditions during growth, harvest and storage (Kunze, 1999).

Figure 2.1: A general view of a fully grown barley plant (extracted from Briggs; 1998)

2.2.1 Characteristics of the barley grain

Malting can be understood only by reference to the grain structure and the interactions which occur between the tissues hence it is essential to discuss the grain physiology in this literature review. Given below are both longitudinal and transverse cross sections diagrammatic representations of the barley grain which are followed by a description of the barley structure.

Figure 2.2: A longitudinal cross section of the barley grain (Briggs, 1998).

Figure: 2.3 Transverse cross section of a barley grain (Briggs, 1998).

Figure 2.4: Transverse sections on the dorsal sides of grains. (a) A protein-poor (low nitrogen) grain; (b) a protein-rich (high nitrogen) barley grain. (Briggs, 1998).

According to the detailed structure of the barley grain given by Briggs, Boulton, Brookes and Stevens (2004) dimensions of the kernel ranges: lengths 6-12 mm, widths 2.7-5.0 mm, thicknesses 1.8- PP ,Q WKH VDPH WHW LW Q RWHG WKDW WZR malting barley grains may have one thousand corn dry weights (TCW) in the range 32-44 g, and some six-rowed barleys have values of about 30 g. Whole barley grain consists of about 65% to 68% starch, 10% to 17% protein, 4% to 9% -glucan, 2% to 3% free lipids, and 1.5% to 2.5% minerals (Czuchajowska, Klamczynski, Paszczynska, and Baik, 1998; Izydorczyk, Rossnagel, Labossiere, MacGregor, and Storsley, 2000 ; Quinde, Ullrich, and Baik, 2004).

The amylase content of barley starch varies from 0% to 5% in waxy, 20% to 30% in normal, and up to 45% in high-amylose barley (Bhatty and Rossnagel 1997). Mixed linked (1-3), (1-4)- -D-glucans constitute approximately 75% of the barley endosperm cell walls together with 20% arabinoxylans and protein. Both -glucans and arabinoxylans determine wort viscosity and beer filtration rates (Stewart, Freeman, and Evans, 2000), and form a barrier for hydrolytic enzymes attacking starch and protein within the cell walls and in many barley products cause potential health benefits such as prevention of constipation, reduction in risk of colorectal cancer (Bingham, 1990; Faivre and Bonithon-Kopp, 1999), lowering of blood cholesterol, and controlling diabetes management (Gallagher, Hassel, Lee, and Gallagher, 1993; Frost, Leeds, Dore, Maderios, Brading, and Dornhurst, 1999).

Barley endosperm protein is rich in prolamin storage proteins (hordeins) and has moderate nutritional quality (Newman and McGuire 1985). High-lysine barley mutants, which contain 2% to 3% greater lysine than normal lysine types could provide high-quality, protein-enriched barley grains for the human diet (high lysine content of 5% to 6% compared to 3% as normal ones), but however after the malting and brewing process not the same degree of nutrition is retained as the

proteins are denatured and other nutrients chemically converted from their natural state (Ullrich and Eslick 1978). Proteins are among barley components that are essential for the quality of malt and beer. First, high-protein contents decrease available carbohydrates, with a negative influence on the brewing process (Frost, Leeds, Dore, Maderios, Brading, and Dornhurst, 1999 ; Fox, Onley-Watson, and Osman, 2002) and second, proteolysis (protease hydrolysis producing amino acids and peptides from hordeins) during malting and mashing is necessary for yeast metabolism (Moll, 1979). Finally, soluble proteins are important in beer head retention and stability.

The kernel has different tissues, with each serving a purpose. Fincher (1989) explains that the husk and the pericarp serve to protect interior constituents of the grain from mechanical damage. Both the husk and pericarp provide barriers to gaseous exchange between the interior living tissues and the exterior and therefore can limit respiration. This mechanical protection of the grain offered by the pericarp and the husk safeguard the grain from physical damage by moving machinery and this is of great importance during processes such as conveyance and turning during the malting process. Underneath the pericarp is the testa consisting of two cuticularized layers between which polyphenolic proanthocyanidins (colour pigments) usually occur (Briggs et al, 2004).

The testa limits the inward diffusion of solutes which permeate the husk and the pericarp and also prevent the outward diffusion of amino acids, sugars and other essential soluble compounds in the grain (Briggs 1998).Briggs (1998) also notes that microbes though may be present in this region they can never penetrate the testa therefore it serves to separator the exterior from the interior regions of the grain for various important ways.

Another important functional region of the malting barley grain is the embryo. Brown and Morris, (1890) notes that the embryo is situated within the testa, at the base of the grain, and towards the dorsal side. According to Briggs et al (2004) the embryonic axis consists of the coleoptile (the maltster's acrospire) and the root sheath (coleorhiza). This appears at the end of the grain, at the onset of germination, as the `chit' and the embryo is the one which can grow into a plant by utilizing the reserves in the starchy endosperm. A thin layer called the scutellum shields the embryo from the starchy endosperm.

The starchy endosperm is a dead tissue of thin-walled cells packed with starch granules HPEHGGHGLQDSURWHLQPDWUL[7KHFHOOZDOO\gOXFDQV, with some pentosans and a little holocellulose (Briggs, 2004). This tissue contains most of the grain's reserves, although others are present in the embryo and in the aleurone layer .Briggs, (2004) further describes that the outer region of the starchy endosperm, the sub-aleurone layer, is relatively richer in protein LQFOXGLQJ-amylase) and small starch granules but poor in large starch granules. The starchy endosperm is surrounded by the aleurone layer which on average is about three cells thick. The cells are alive but do not multiply or grow during germination, have thick cell walls and contain reserves of lipids and protein, sucrose and possibly fructosans, as well as a full range of functional organelles but however do not contain any starch (Briggs, 2004).

2.2.2 Malting barley varieties

Since this research is focused on comparing two malting barley varieties (Hope and Sierra), in this section the researcher intends to discuss the concepts of barley classification and varietal identification , putting emphasis on the influence of varietal properties on malting. According to Anon (1996) thousands of barley varieties exist which differ in their suitability for malting

because of their differences in physiological compositions and enzyme systems. In barley the grains are arranged in rows on the head or ear of the plant and it is the number of rows which is used for classification with the varieties being either 2 rowed or 6 rowed and in addition to that they are also classified as either spring or winter type (Briggs et al, 2004). Since varieties differ in size, plumpness and thus composition, basing on morphological differences maltsters have to distinguish and evaluate cultivars for maltabilities and avoid mixing varieties to eliminate the malting complications of heterogeneous batches (Anon, 1996). Some of the differences mainly considered in determining the malting suitability include the compositions of the varieties, with two rowed barley generally having lower enzyme content, low protein content, more starch and a thinner husk than six rowed barley which on the other hand has a higher enzyme content for converting starch into fermentable sugars, more protein, less starch and a thicker husk than two row barley (Briggs et al, 2004). Malting barley varieties are usually soft, whereas non-malting varieties are usually hard. Psota, Vejrazka, Famera, and Hrcka (2007) also reported significant relationships between hardness of barley grain as assessed using the particle size index and hot water extract of malt as well as the malt quality index of barley malt. Other structural and compositional characteristics of barley endosperm could contribute to grain hardness, including proteins, starch, -glucan, and their interactions, and packing during grain filling (Henry; 1988). Generally, sound barley grain has a bright light yellow or off-white colour. Discoloured barley grain often develops undesirable flavours when malted and has poor germination energy and vigour (Li, Kaneko, Qin, Wang, and Wang 2003).The two varieties (Hope and Sierra) utilised in this research are both two row varieties which have been accepted for malting at Delta Beverages .ZHNZH 0DOWLQJV DQG PDQLSXODWHG E\WKH FRPSDQ¶ SURFHVVHV WR SURGXFH PDOW PHH brewer specified requirements, however this is achieved at different costs and efficiencies due to

their varietal differences and thus different malting behaviours . In addition to morphology Hope and Sierra also differ in agronomic quality characteristics. The comparison of the varietal agronomic characteristics outlined in the following table is based on the information which was obtained from the Delta Beverages Agricultural Services Division , whose primary mandate is to develop barley varieties meeting the needs of the barley chain i.e. farmers , maltsters and brewers.

Table 2.2: Comparison of the agronomic properties of Hope and Sierra

Variety	**Release Year**	**Variety Description**	**Variety Characteristics**	
			Strengths	**Weaknesses**
HOPE	2000	• 2 row variety of medium maturity (136 days). • High yield potential.	• High yield potential • Large plump grains • High malt extract • Good disease resistance	• Poor standability. • Low grain nitrogen. • Pregerminates on the head easily.
SIERRA	2006	• 2 row variety of medium maturity (136 days) • High yield potential	• Stiff strawed and excellent standability • Plump grain • Good disease resistance • Fair on	• Extract values slightly lower than hope

			pregermination • High malt extract • Ideal nitrogen 1.78-1.88	

2.2.3 Quality Requirements for Malting Barley

According to Kunze (1999) the malt quality of a given barley variety is determined by its genetic background and the physical conditions during growth, harvest and storage. The malting industry requires malt with high extract yield, high levels of enzyme activity and good modification to manufacture beer of excellent quality. The basic raw material for the production of beer is the malting barley whose quality is of primary significance. Therefore malting barley must be of good quality, able to germinate vigorously and be post-harvest mature to meet these requirements, Francakova, Liskova, Bojnaska and Marecek (2012). As a result before processing each batch of malting barley it is of paramount importance to assess a representative sample of each batch in order to verify its suitability for malting. As highlighted by Briggs et al (2004) the commonly assessed quality parameters in malting barley are moisture content , nitrogen content, screenings profiling, germinability and viability. Furthermore for best practise is done at Kwekwe Maltings they is need to determine the amount of foreign matter , corn damage index and estimate the degree of infestation. The Methodologies and significance of analysing these quality parameters in malting barley are covered in Chapter 3 of this research report.

2.2.4 Storage of Malting Barley

Barley just like other cereals in general, is amiable to storage for relatively long periods of time and the storage conditions determine grain quality (Woods et al. 1994; White et al. 1999). Barley, a winter crop, is harvested at relatively low moisture content and when stored out of the weather and from insects and rodents, easily store for several years. Storage time is increased if the grain is stored under ideal conditions which are low temperature and moisture. Kunze (1999) explains that since barley is alive and produces heat by respiration, the warmer the barley is, the faster the rate of respiration increases and together with it moisture content and temperature. As a result of such conditions microorganisms such as bacteria and fungi proliferates, and furthermore most of the insects will also find their ideal conditions for growth hence the need to control both temperature and moisture.

At Kwekwe Maltings barley is stored in 8 silos made of reinforced concrete with a capacity of 3500 tonnes each. According to Kunze (1999) such silos are have low conductivity, are fire proof and have maintenance costs as their advantages. Kunze (1999) also highlights the importance of aeration and recirculation of the stored malting barley in order to ensure even distribution of moisture and also prevent the building up of heat, both of which are natural products of respiration. At Kwekwe Maltings the silos lack mechanical stirrers and to compensate for this grain is circulated from one silo into another free silo or simply reticulated by moving it out of the silo and reloading it back into the same silo. To achieve the recommended temperature control at Kwekwe Maltings the barley is cooled by a suitable grain cooler called the granifigor which is connected from the bottom of the silos and blows cold air thus initially cooling the lowest layer of the barley .the air becomes warmed to the temperature of the grain and flows upwards through the silo to the top where it escapes through exhaust

vents. As a result any failure to control both the temperature and moisture during storage causing proliferation of microorganisms and insect infestation directly negatively impact on the germination performance of the grain during malting.

2.3 Overview of the malting process

Kunze (1999) defines the purpose of Malting as to produce enzymes in the barley kernel and to cause defined in its chemical constituents. Before discussing the theoretical concepts of the main stages of the malting process, given below is a flow diagram of giving a summary of the process steps at Kwekwe Maltings.

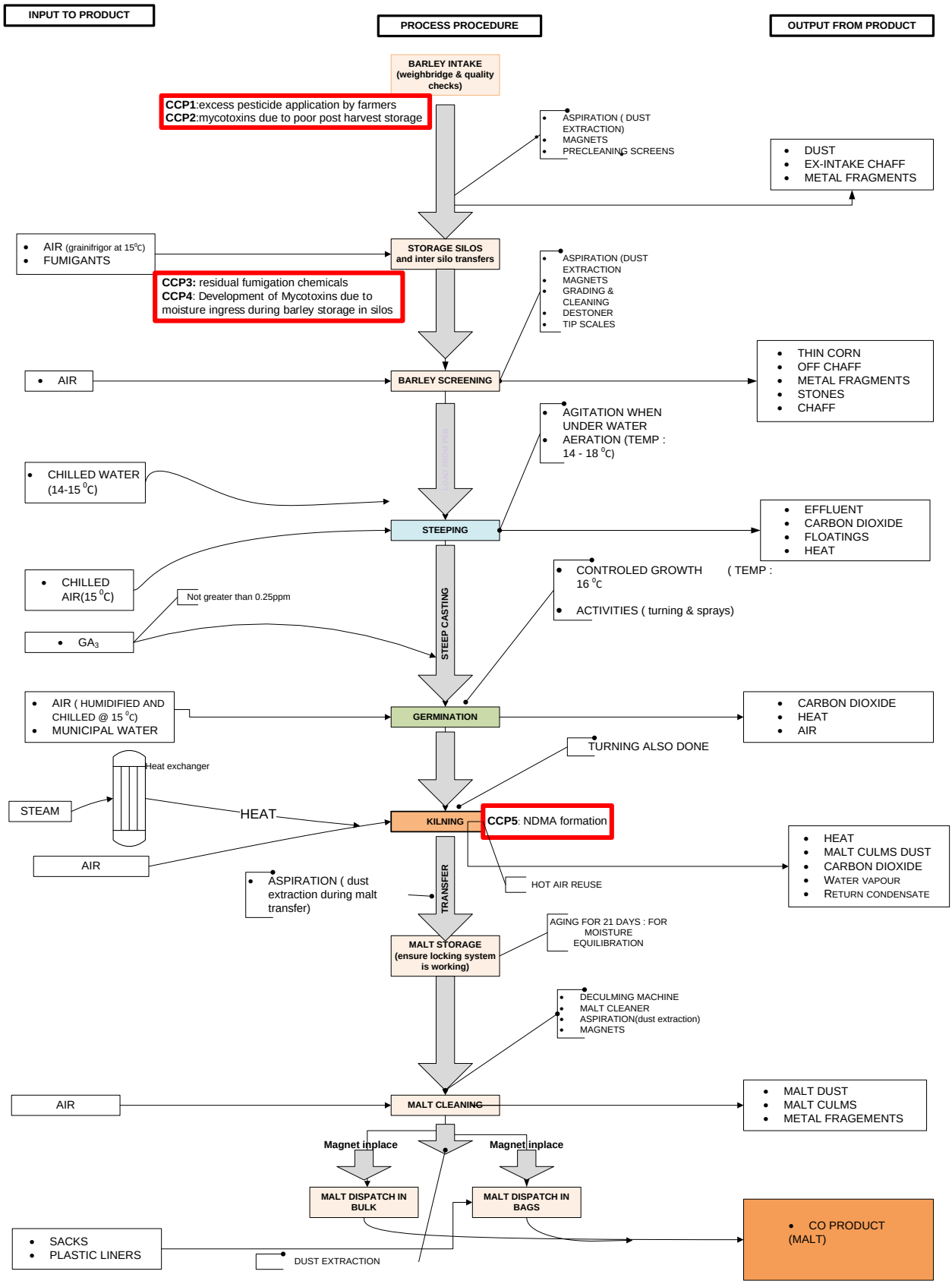


Figure 2.5 Kwekwe Maltings Process flow diagram prepared by the researcher.

2.3.1 Malting grain Preparation

Before the barley conversion operations are performed the barley delivered to the Maltings is first pre-cleaned prior to storage further undergoes cleaning and grading before processing. This is achieved through barley screening (cleaning) and grading operation. The cleaning of barley is achieved by passing it over vibrating sieves with air jets and magnets. The material that is removed includes twigs, leaves straw, stone, metal pieces and dust and collectively this is called dockage. The grading operation segregates the barley according to the differences in size. Kunze (1999) notes that different sized grains malt at different rates, leading to non-homogenous batches of poor quality malt. For instance small grains will hydrate and respire vigorously than ODUJHU JUDLQV 7KH VPDOOHU JUDLQV ZLOO EROW PDOWLQJ PRUH UDSLGO\ DQG PRGLI\ JUHDW in malt containing portions under-modified and over-modified grains. The by-products produced from these processes (thin corns chaff and off chaff) are bagged and sold as stock feeds.

2.3.2 Steeping

Belitz, Grosch, and Schieberle (2009) introduce steeping as soaking the grain in water to initiate hydration and thus inducing germination. According to Belitz et al (2009) steeping raises the barley moisture content from post-harvest moisture of around 12% to a moisture high as 45% and this process generally takes around 36 to 48 hours. The steep liquor should be of drinking water quality, without taints for they will be carried over to the final product affecting it quality and stability. The steep-water temperature should be controlled. At elevated temperatures water uptake is faster but microbial growth is accelerated and the grain may be damaged or killed (Kunze, 1999). The rate of water uptake will be affected by the following factors: steeping time (water uptake is high at first and slows down with time), steeping temperature (the warmer the

steep liquor the faster the uptake due to increased kinetic energy of the water molecules) and kernel size (the smaller the kernel the less the distance for the water to move hence the faster the hydration).In addition to hydration Kunze (1999) notes that steeping also aims to clean the grain by removing dust, micro flora, inhibitors ,removing all floating materials ,provide sufficient oxygen to corn respiration and remove produced carbon dioxide.

If the oxygen is not supplied intra-molecular respiration will occur (other compounds will replace oxygen) which may lead to death of the grains resulting in a dead steep. To avoid such effects the grain is aerated to certain intervals of the steeping regime. Briggs (2004) to prevent it packing tightly and wedging in the steep it may be loosened and mixed by blowing air into the base of the steeping vessel. This also adds oxygen to the steep liquor. The oxygen is rapidly taken up, both by the grain and by the microbes that multiply on the grain and in the liquor. Steeping is followed by the germination stage and through the process activity called steep casting the hydrated grain is transferred from the steep tank to the germination vessel. At Kwekwe Maltings during casting an important plant hormone, gibber relic acid (GA) is added to the grain. The effects of GA include breaking dormancy, shortening germination time, increasing extract yield by about 1%, increasing extract fermentability and friability and an improvement of malt consistency. GA initiates synthesis of alpha amylase and limit dextrinase, increases synthesis of alpha glucosidase, beta glucanase, beta glucan solubilase, pentosanases and proteinases and it has no effect on beta amylase and peptidase (Kunze, 1999).

2.3.3 Germination

Germination is a process in which physical modification of endosperm is carried out to increase the bioactive compounds (Madhujith and Shahidi ; 2007). As described by Belitz et al (2008) when the cereals reach the desired moisture content (which is around 42-45% at casting) and germination is started, they are allowed to germinate in germination vessels. Kunze (1999) notes that during germination a new plant develops by utilising energy and other molecular products of respiration and other metabolic processes.

In the germination vessel the grain is kept moist by aerating with cool air saturated with 100% humidity. Aerating also cools the grain and removes the carbon dioxide produced. It is of importance that the green malt is kept moist throughout germination because if it dehydrates, modification will cease, hydrolytic enzymes will not be able to progress through the endosperm and thus modification stops (Briggs and Hugh 1985).

Turners in the vessel are used to turn the germination bed regularly effecting aeration and cooling. This further also prevents matting of the rootlets which tend to entangle as they elongate. Germination lasts 3 ± 5 days at temperatures around 14 - 18°C and through applying fine sprays and turning the grain bed the moisture is raised up to 46% during germination (Belitz et al (2009). Respiration increases throughout the process and by the end, temperatures as high as 23°C are normal. The grain grows, producing a tuft of rootlets (culms) at the base of the grain and, less obviously, the coleoptile or `acrospires' grows along the dorsal side of the grain, beneath the husk. The extent of acrospires growth, expressed as a proportion of the length of the grain, is used as an approximate guide to the advance of the malting process. Variations in acrospires lengths indicate heterogeneity in growth. The living tissues respire and carbon dioxide and water are generated resulting in a loss of dry matter.

The energy liberated supports growth and is liberated as heat (Briggs et al, 2004). Kunze (1999) explains that germination is chiefly characterised by enzyme activation and synthesis. According to Briggs (1998) some of these catalyse the physical modification of the starchy endosperm. In the same text by Briggs (1998) it is noted that during initial stages of germination these hydrolases are released from the scutellum. However, after a short lag the embryo releases gibberellin hormones (gibberellic acid).These diffuse along the grain triggering the formation of some enzymes in the aleurone layer and the release of these and other enzymes into the starchy endosperm. Here they join the enzymes from the embryo in catalysing modification. As germination progresses the starchy endosperm softens and becomes more easily `rubbed out' between finger and thumb. The stages of physical modification are the progressive degradation of the cell walls of the starchy endosperm, which involves the breakdown of the troublesome glucans and pentosans, followed by the partial degradation of the protein within the cells and the partial or locally complete breakdown of some of the starch granules, the small granules being attacked preferentially (Briggs, 1998). In a summary the main enzymes synthesised and activated during this phase are starch degrading amylases, protein degrading proteolytic enzymes, cytolytic enzymes (glucanases and cytase), and phosphatases (Kunze, 1999). During brewing starch hydrolysis is carried out by the malt enzymes . -amylase, -amylase, limit dextrinase, and . -glucosidase (Manners 1985).Limit dextrinase is responsible for hydrolyzing the (1: 6)-. -glucosidic branch points in LMW branched dextrins formed by the action of . - and -amylase on starch components (Manners and others 1970). Starch granules can be encapsulated by a rigid protein matrix or by cell walls (Weurding and others 2001). . -Amylase can solubilize both amorphous and crystalline regions (Lauro and others 1993) of starch granules attacking the (. -4)- linkages of starch producing oligosaccharides. -Amylase also attacks (. -4)-linkages from

the nonreducing ends of amylose and amylopectin molecules (Bamforth and Quain 1989; Lewis and Young 1995). A range of fermentable sugars is produced from the action of these enzymes on starch during the mashing process. These include glucose, sucrose, fructose, and mainly maltose and also some low molecular weight dextrins (Slack andWainwright 1980; Lauro and others 1993).

Figure 2.6 Four successive stages of germination in the malting barley grains. Each pair of diagrams shows a vertical longitudinal section of the grain to one side of the sheaf cells, and the approximate extent of modification of the starchy endosperm, and a view of the exterior of the grain from the dorsal side. In (c) the grain is slightly under modified while in (d) it is overgrown or `overshot' and is known as a huzzar or a bolter. (Briggs, 1998.)

2.3.4 Kilning

Despite highlighting the biochemical changes occurring during this stage of malting LWVital to note that kilning is the most important stage in malting, in terms of operating efficiency. A Kunze (1999) state that about 80% of the total energy used in the malting plant is at this stage. After the green malt has modified to the extent specified by the brewer, it then becomes necessary to terminate the enzyme activities occurring within the endosperm. As discussed by Kunze (1999) the main objectives of kilning are discussed below:

Lowering the moisture content

To make the malt storable the moisture content should be decreased from over 40% to less than 5%.this is achieved by passing large amounts of hot air through the green malt. Enzymes which later be of use in the brew-house during mashing are easily destroyed in wet heat compared to dry heat so to protect them malt is first pre-dried at low temperatures before subjecting it to higher temperatures.

Termination of germination and modification

As a result of the removal of water, germination is stopped and consequently the rootlets do not grow any more. A major portion of the kernels are destroyed by the effect of heat and so the malt no longer respires. Modification thus ceases as respiratory metabolic changes cease resulting in no further breakdown processes and thus malt becomes a durable good.

Formation of colour and flavour compounds

At temperatures as high as 80°C attainable during kilning low molecular weight breakdown products react to form a number of colouring and strong flavour compounds. These reactions are complex and collectively referred to as maillard reactions.

Enzyme Inactivation

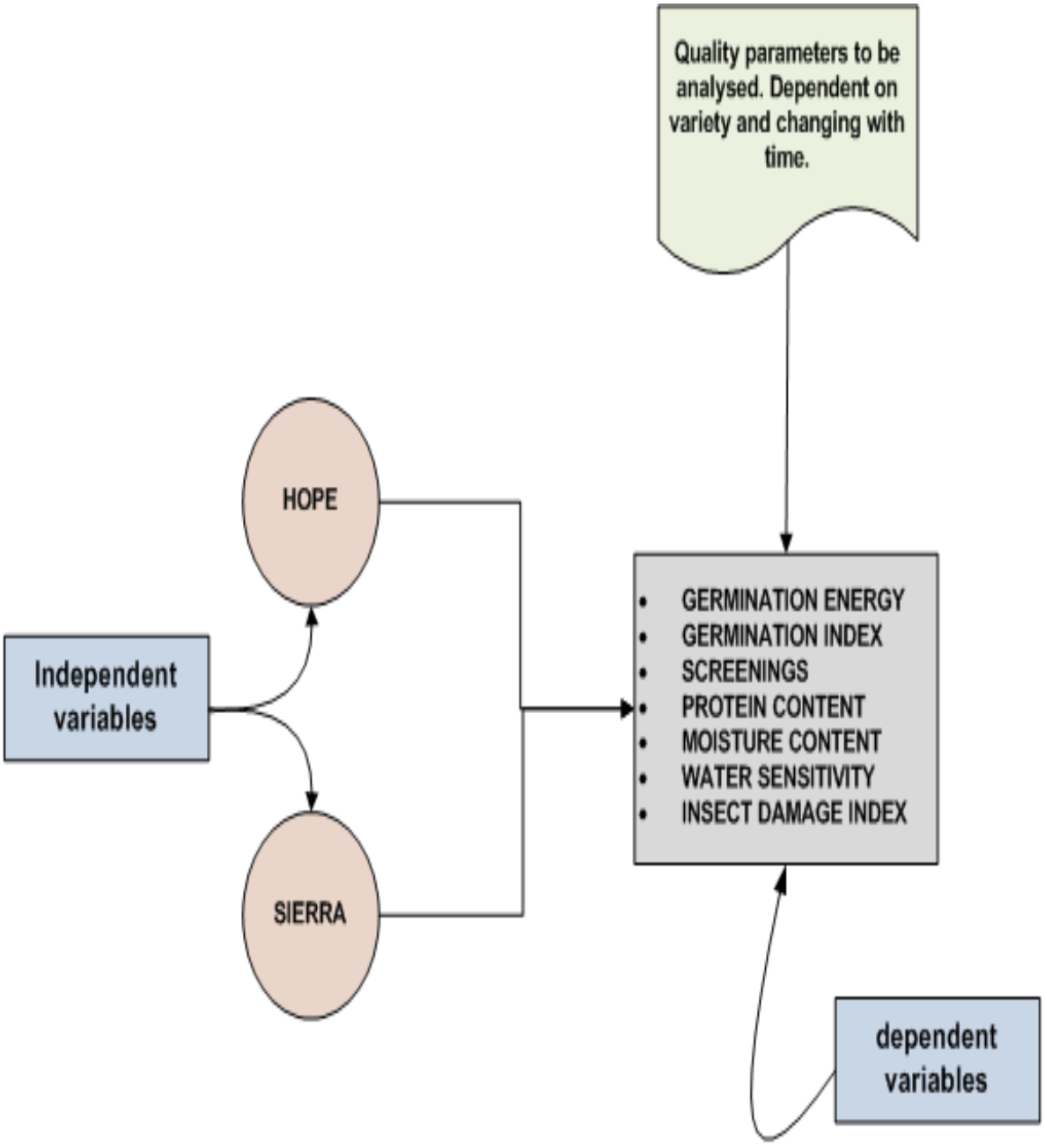
Enzymes are associated with high molecular weight proteins and as a result of the heating during kilning; the structures of the proteins are altered and become denatured. Denaturation however is dependent on the structure of the carrier proteins and hence affect enzymes to different extents. For instances in the early phases of kilning enzymatic activity of amylases increase and later GHFUHDVHDVNLOQLQJSURJUHVV,QSDUWLFXODUEWKHHQGRINLOQLQJ -amylase activity is about 15% PRUHWKDQLQJUHHQPDOW-ZKLOVW -amylase activity is 40% less than in green malt. In the case of the more sensitive enzymes such as glucanases the loss of enzyme activity is even greater up to IRUHQGR -glucanases and 70% IRUH[R -glucanases.

2.4 **The germination vigour concept** (According to Perry ,1984)

Seed vigour is an important quality parameter which is essential to determine performance of a seed lot during storage and processing. Perry (1984) defines seed vigour as the sum properties of the seed which determines the level of activity and performance of the seed or seed lot during germination or seedling emergency. Several factors like genetic constitution, environment and nutrition of the mother plant, maturity at harvest, seed weight and size, mechanical integrity, deterioration, ageing and microbes are known to influence seed vigour (Perry, 1984). The principle of seed vigour or growth tests is based on the reality that vigorous seeds grow faster

than seeds of poor vigour. Detail on the germination index test used to determine germination vigour in this research is given in Chapter 3 under the section on experimental procedures.

2.5 Conceptual Frame Work



2.6 Chapter Summary

This chapter covered the theoretical aspects concerning malting barley quality aspects and varietal influence on germination, the malting process, germination vigour concept and its methods of analysis. The literature discussed under this chapter is essential for effective interpretation, discussion of results, deriving academically factual conclusions, and recommendations. The next chapter will focus on research methodology.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

In this chapter a clear description of the methodology employed is given, highlighting all relevant procedures and activities done during the collection of data.

3.1 Research Design

In this study an experimental research design was adopted. An experimental research design has as its basis the elements of observation, inference, control and comparison which were required to adequately answer the research questions posed in this study. The researcher conducted experiments, observed quantitative measurements and recorded the data on simple work sheets designed to include all parameters that were experimentally examined. The experiments conducted included germination vigour and energy tests, determination of germination capacity, moisture content, protein content, water sensitivity, screenings, germination capacity and insect damage index.

3.2 Research Population and Sampling Technique

In this research study the research population comprised of the two malting barley varieties (Hope and Sierra) harvested from the 2012 winter growing season and stored in perforated sample bags under room temperature laboratory conditions at Kwekwe Maltings. In this research the simple stratified sampling technique was used, with the two barley varieties considered distinct strata and randomly creating average samples from each.

3.3 Experimental Procedures

3.3.1 Determination of the total Nitrogen content using the technicon method

Principle and scope

The technicon Infra analyzer is based on the Near Infrared Reflectance (NIR).This Technology relates the intensity of the diffuse reflectance as specific wavelengths from the surface of a sample to the composition of a sample. The various components of a given product have specific NIR absorption bands which will affect the reflectance of the sample as the concentration of each constituent changes.

Method

The nitrogen content was determined using Technicon infra analyzer 300 plus accessories (manufactured in 19977KHLQVWUXPHQW¶V FDOLEUDWLRQ VWDWXV ZDV YHULILHG DQG VHWXS have been done as per the instructions in the operation manual. The random sample was fed into the sample cell which was then plunged into the infra analyzer. Thereafter the machine would PRYH LQWR WKH ¾UXQ PRGH¶ DQG WKH UHVXOWV DUH GLJLWDOO\GLVSODHG LQ DERXW VHF Total nitrogen (and moisture if required) will be then recorded. The nitrogen content value was then multiplied with the conversion factor (6.25) to determine the total protein content.

3.3.2 Determination of the germinative energy of malting barley

Principle and Scope

In order to malt barley satisfactorily, the barley must be alive and also non-dormant. Dormant barley is one which although not dead, will not germinate. The germinative energy test is a

measure of the physiological readiness of barley to germinate at a particular point in time under specified conditions. In this study the steeping germination test outlined below was used.

Method

The germination tests were supposed to be carried out in the dark at $18^{o}C \pm 21^{o}C$.A random selection of 100 corns from the primary samples was done for both varieties. Filter papers (Whatman number 1) would be placed in the bottom half of each Petri dish (90mm diameter) .Thereafter Pipette $4cm^3$ of distilled water onto the papers and the 100 corns were then spread evenly on the filter papers. The top half of the Petri dishes was then placed into position and the corns were then germinated in the dark (thermostat / incubator) at $18^{o}C \pm 21^{o}C$ for 72 hours. Germinated corns were then removed at intervals of 24 hours. Recording of the total number of grains which would have germinated at 72 hours ± x% was done. It was useful to note also the grains which would have germinated at 24 and 48 hours for the determination of the germination Index as required by the formulae given below:

a. Calculation of % Germinative Energy = x%
b. Calculation of the germination index (GI) (EBC method):The germination index (GI), which is an indicator of the rate of seed germination was calculated from the results of the germination energy determination according to EBC method:

$$GI = 10 \times (n24 + n48 + n72)/ (n24 + 2n48 + 3n72)$$

Where: n24, n48, n72 ± numbers of germinated kernels at 24, 48, and 72 h

3.3.3 Determination of Water Sensitivity

Principle and Scope:

Water sensitive corns are those which exhibit a decreased ability to germinate in the presence of water in excess of the minimum required to promote germination .The degree of water sensitivity is assessed by carrying out Petri dish germination tests with $4cm^3$ and $8cm^3$ of water. The difference in percentage germination in the tests gives a measure of water sensitivity. A difference of > 20% indicates water sensitivity.

Method

The germination tests were supposed to be carried out in the dark at $18^oC \pm 21^oC$.A random selection of 100 corns from the primary samples was done for both varieties. Filter papers (Whatman number 1) would be placed in the bottom half of each Petri dish (90mm diameter) .Thereafter Pipette $8cm^3$ of distilled water onto the papers and the 100 corns were then spread evenly on the filter papers. The top half of the Petri dishes was then placed into position and the corns were then germinated in the dark (thermostat / incubator) at $18^oC \pm 21^oC$ for 72 hours. Germinated corns were then removed at intervals of 24 hours. Recording of the total number of grains which would have germinated at 72 hours ± x% was done.

Calculation

The water sensitivity was then calculated using the formulae outlined below:

% water sensitivity = % Germinative Energy * - x%.

i.e. % germinated in 4 cm^3 ± germinated in 8 cm^3 test

References: BIRF ± Studies in Barley and Malt ± JIB 1955, page 25

3.3.4 Determination of the germination capacity of barley

Principle and Scope

7KHJHUPLQDWLRQFDSDFLWWHVWGHWHUPLQHVWKHJUDLQ¶YLDELOLWZKLFKLVLWVSR

if the minimum requirements of germination are provided. This measure gives an indication of the degree of dormancy, and in the case whereby dormancy has already been broken the GC help determines whether or not the grain is still alive or dead.

Chemical reagents

2, 3, 5 ± triphenyl-tetrazolium chloride

Method

A random selection of 100 corns was made. The corns were soaked in tap water for about 5 minutes. Thereafter the corns were longitudinally sectioned and one half of each corn was discarded. The retained halves of each corn were then placed in test tubes according to the variety. The corns were covered with the 1.0 $_{2,\ 3,\ 5}$-triphenyl-tetrazolium chloride solution. The test tubes were then placed in a water bath set at 40^{o}C for about 30 minutes to allow the reaction to proceed. The excess tetrazolium solution was then poured off, the half corns emptied onto a piece of filter and classified as follows:

a. Corns in which the scutellum or aleurone layer and embryo are unstained are dead or if not dead will not modify during malting. (If the scutellum and /or aleurone cells are dead the enzymes produced by the embryo cannot be translocated to the endosperm for modification).

b. Corns in which the embryo, scutellum and aleurone have all stained a bright pink red colour. these corns are fully viable = x

Picture 3: The researcher adding tetrazolium solution to a sample during the determination of germination capacity.

3.3.5 Screenings characterisation

Principle and scope

Screening level is a measure of grain plumpness, with grain size being influenced by the amount of starch in the endosperm. Grain plumpness is presented as either the proportion that passes through or retained by 2.5mm screen. A low variation in grain size improves the processing of barley in the malting plant. High screenings affect the grain modification because small grains germinate faster than larger grains. Small grains also have different steeping requirements to

larger grains. High screenings are associated with reduced starch deposition relative to protein and hence thin grained barley is unacceptable for malting. In this study the results of the screening test will assist in establishing and analysing the relationship of the sample homogeneity to germination performance.

Method

Barley was differentiated by grain size in a shaking machine provided with three sieves having a slot of different widths. A Pfeiffer sieving machine (manufactured 1997) driven by an electric motor crank is used at Kwekwe Malting. The dimensions of the sieves were 43cm long and 15cm wide. The sieves were made of hardened brass. The width of the slots of the sieve 1 were 2.8mm, for sieve 2 are 2.5mm and sieve 3 2.2mm. The speed of shaking was 300 to 320 oscillations per minute and the total length of the platform is 18 to 22mm. 100-gram sample was taken from the primary sample and paced on the top sieve and the apparatus set in motion for five minutes. The weights of each fraction was determined and expressed as a percentage of the total weight.

3.3.6 Moisture content determination

Principle

This was done by a rapid moisture determination instrument (Brand Name: Pfeuffer, Model Number: He Lite). The Pfeuffer He Lite grain moisture meter (manufactured in 2010) determines the actual internal moisture content of the sample by grinding and appropriately compressing it.

Method

A random sample of the barley was put into the grinding chamber of the moisture meter. The sample was ground and immediately homogenised on the special grinding surface of the PRLVWXUH PHWHU LQVWUXPHQW¶V PHDVXULQJ FHOO $JHDGLQJ RI WKH PRLVWXUH FRQWHQ ZRXOGWKHQEHUHFRUGHGIURPWKHLQVWUXPHQW¶VGLJLWDOGLVSODXQLW

Picture 4: Pfeuffer Moisture determination meter used by the researcher.

3.4 Justification of the choice of experimental procedures.

All the experimental procedures carried out during this research were done according to the methodologies adopted by Delta Beverages Kwekwe Maltings from the SAB Miller Analytical manual for barley and malt analysis. Several reasons influenced the choice of the analytical procedures applied in this particular study. Firstly all these experimental procedures have already been validated and verified for effectiveness and efficiency by Delta Beverages Kwekwe

Maltings. Secondly the researcher from his industrial internship developed the required technical competences to carry out the procedures and interpret the results accordingly. Thirdly all the necessary laboratory facilities and equipment required for successful completion of the experiments were provided by the Delta Beverages Kwekwe Maltings Quality Control department. In addition to ensure the reliability and validity of the results all analytical equipment were checked before use to confirm if the calibration status were not overdue.

3.5 Summary

This chapter gives a detailed account of the research methodology. Elaborated in this chapter are the research design adopted, the sampling techniques and experimental procedures carried out to obtain the required data and also the justification of their selection. It should be noted that all the experimental methodologies highlighted in this Chapter and utilised in this particular research study were extracted from the barley and malt analytical techniques manual used by Delta Beverages Kwekwe Maltings.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This section will focus on data presentation, discussion and academic interpretation of the research findings. The data presented in this fourth chapter seeks to answer the research questions and also test the hypothesis outlined in earlier in chapter one of this research report. For effective presentation of the results tables, figures and text will be utilized. The results of the physiological changes which the malting barley varieties underwent during post-harvest were analysed by linear regression basing on the magnitudes of the r values which measures the strength and direction of correlation between the variables.

4.1 Results

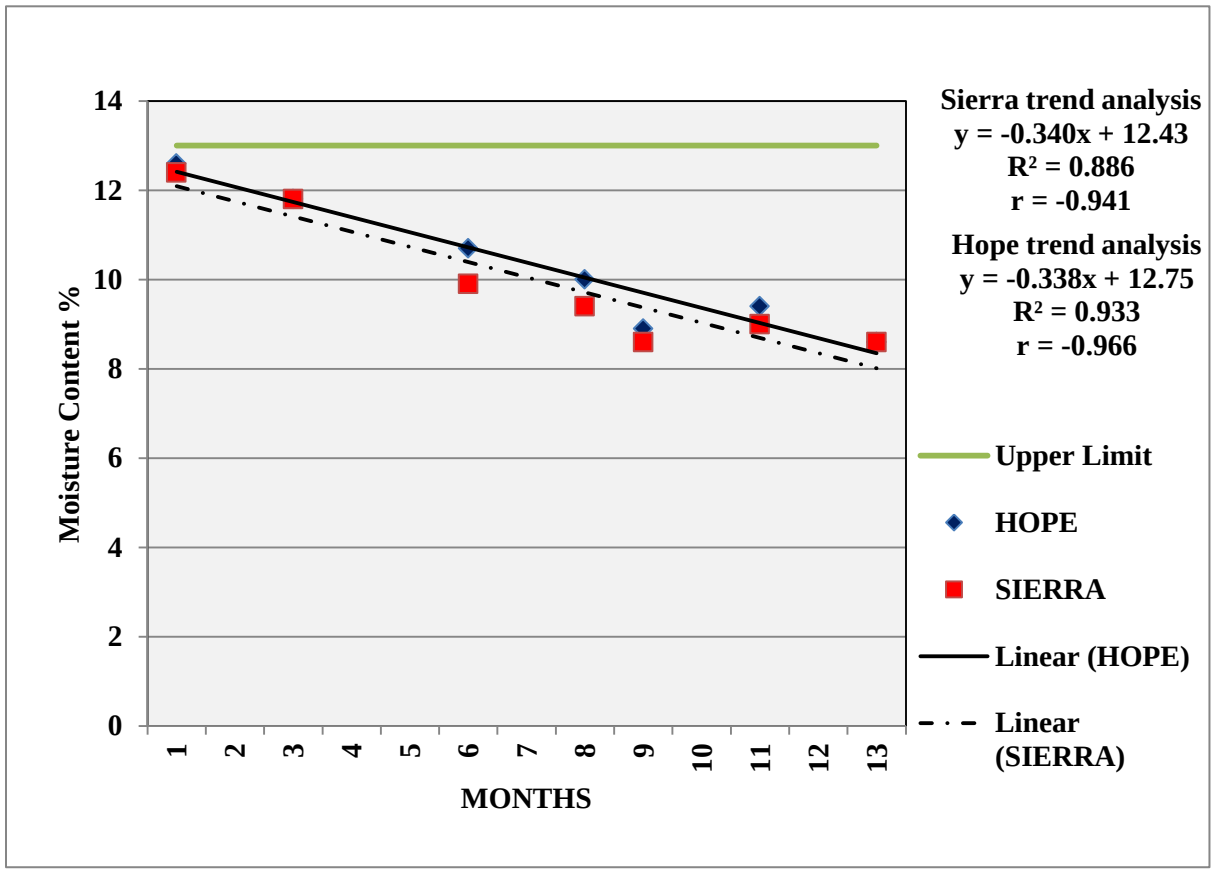


Figure 4.1: Comparison of moisture content trends

Fig 4.1 shows progressive moisture content loss for Hope and Sierra varieties. Hope and Sierra both recorded strong negative downhill correlations with r values of -0.966 and -0.941 respectively. In the first month the varieties had an average moisture content of 12.5%, which continued to decrease during storage down to an average of 8.6% by the 13th month.

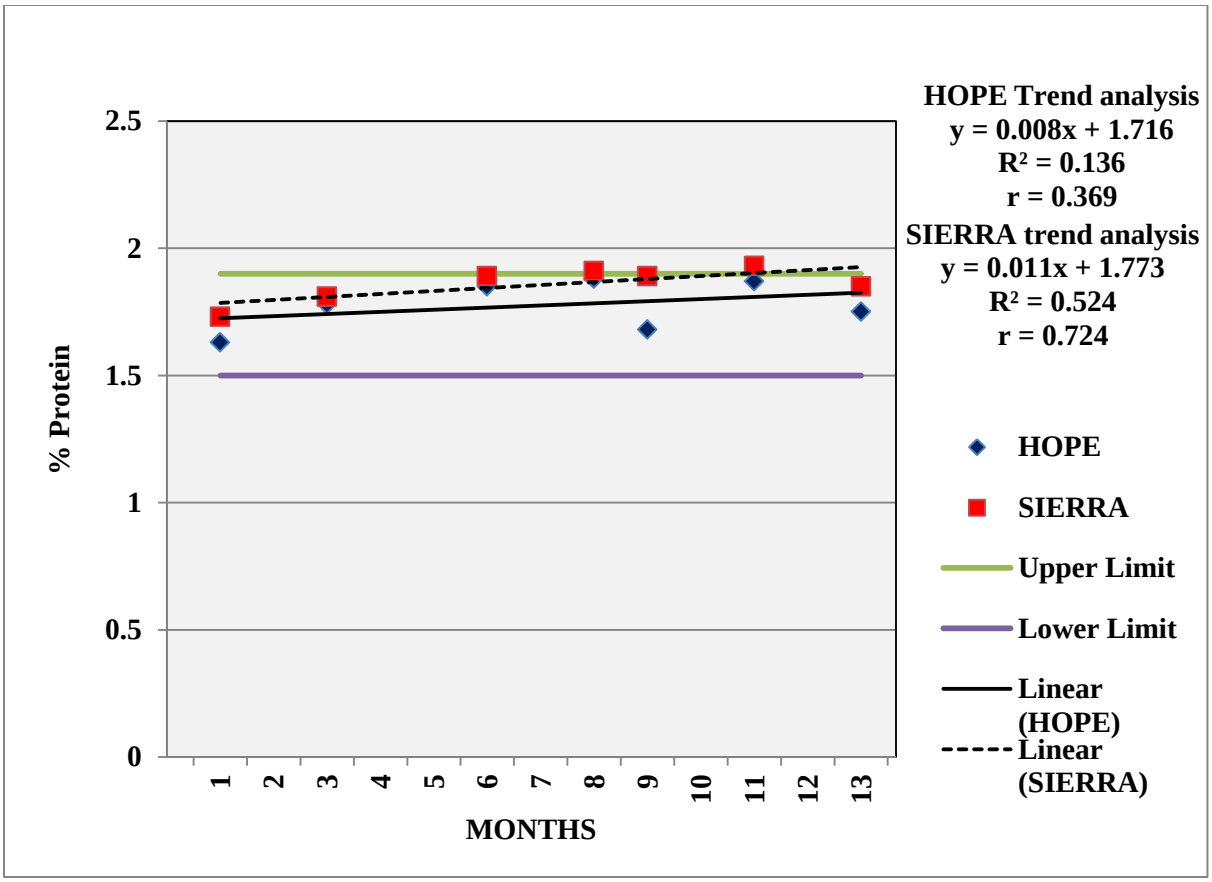


Figure 4.2 Comparison of the protein content trends

For the protein content, both Hope and Sierra recorded positive uphill correlation. Sierra had a strong positive correlation as denoted by the r value of 0.724 and Hope had a weak positive correlation as denoted by the r^2 value of 0.369.as presented in fig 4.2 the protein content of both varieties though changing with time remain within the acceptable limits with Sierra which naturally have higher nitrogen content reaching the upper limit at some point.

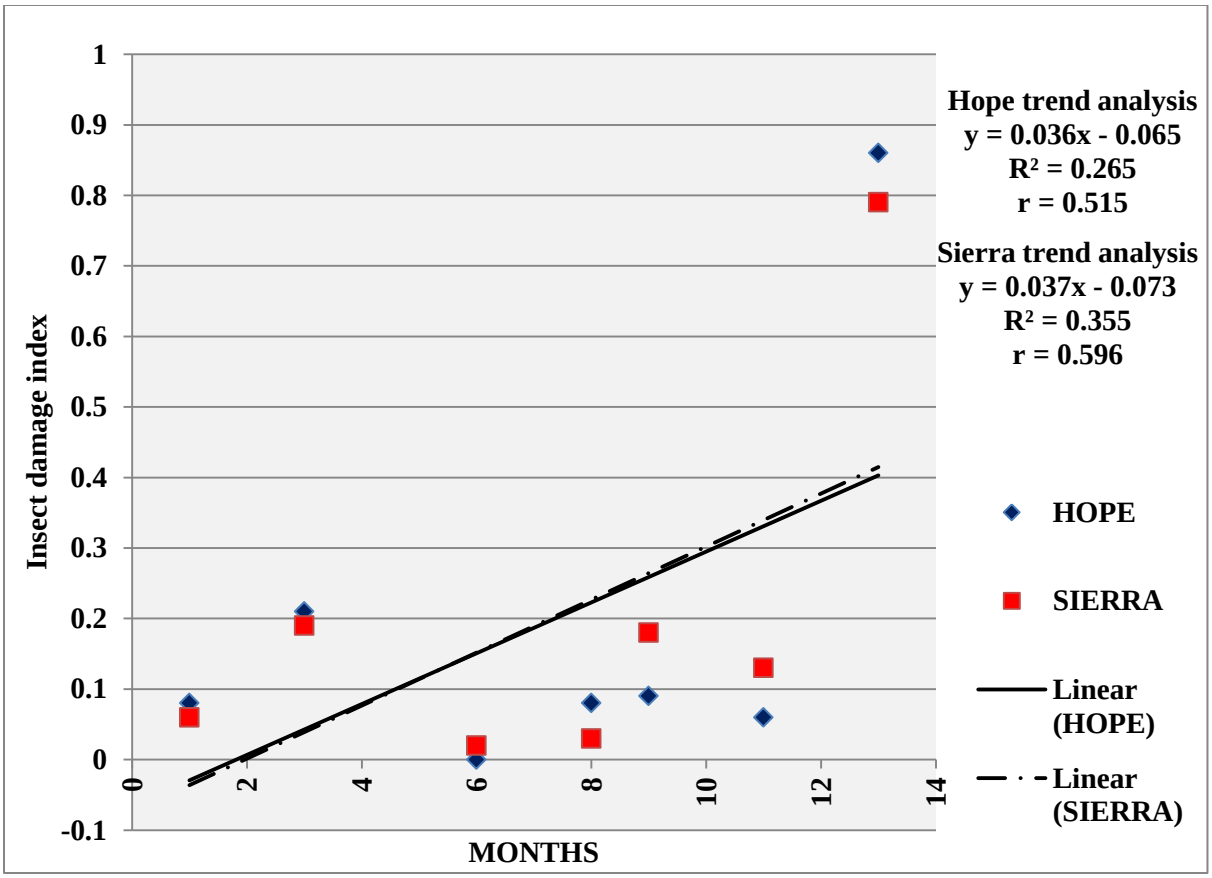


Figure 4.3 Comparison of the insect damage index trends

The insect damage index increased during storage (Fig 4.3), with both varieties having moderate positive uphill correlation. Hope had an r value of 0.515 and Sierra had 0.596. During the first month for the two varieties the insect damage index had an average of 0.07% but by the end of the study after 13 months of storage the average had increased to 0.83%.

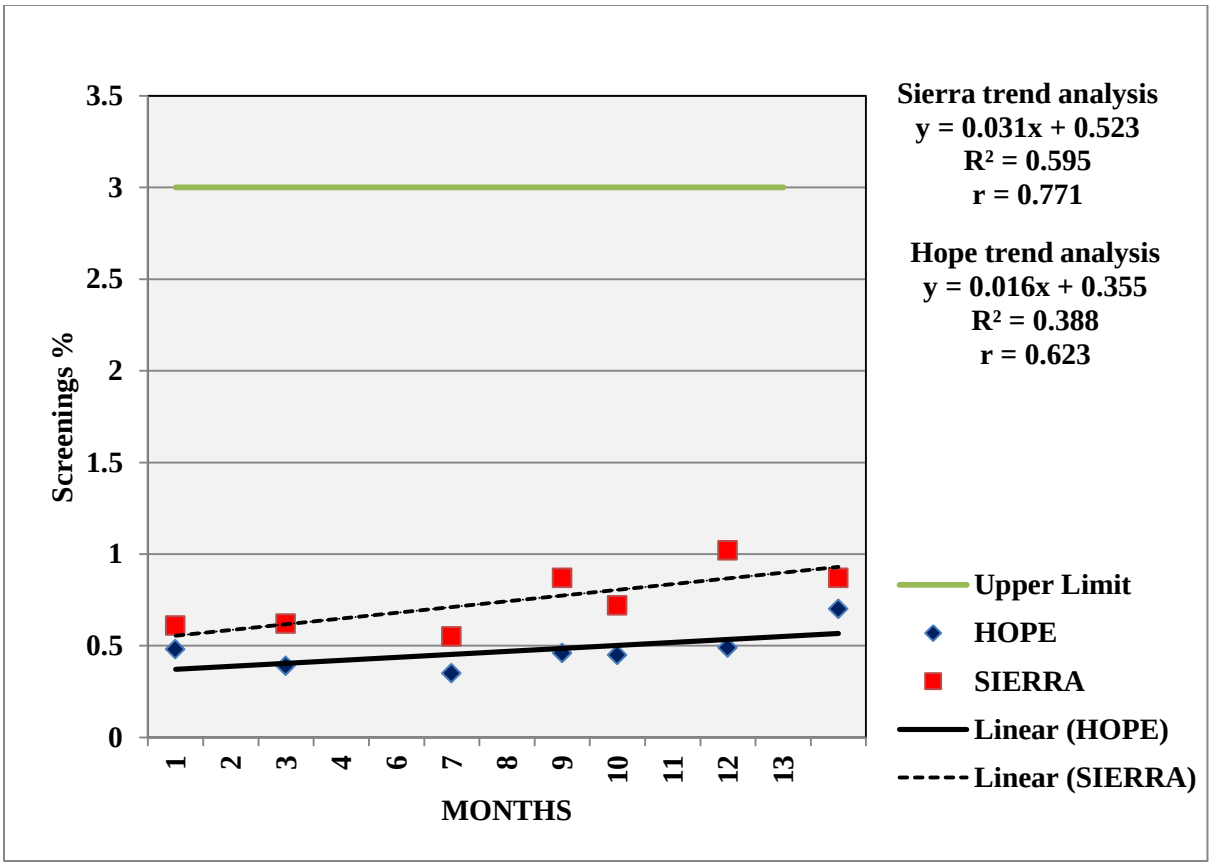


Figure 4.4 Comparison of < 2.2 screenings trends

For the < 2.2mm screenings both varieties changed in the index values but still remained within the threshold limit of not exceeding 3%. Hope with an r value of 0.623 had a moderate positive correlation whilst Sierra had a strong positive uphill correlation (indicated by the r value of 0.771).During month one the average < 2.2mm screenings index value was 0.61 for both varieties but by the end of the research it had increased to 0.87.

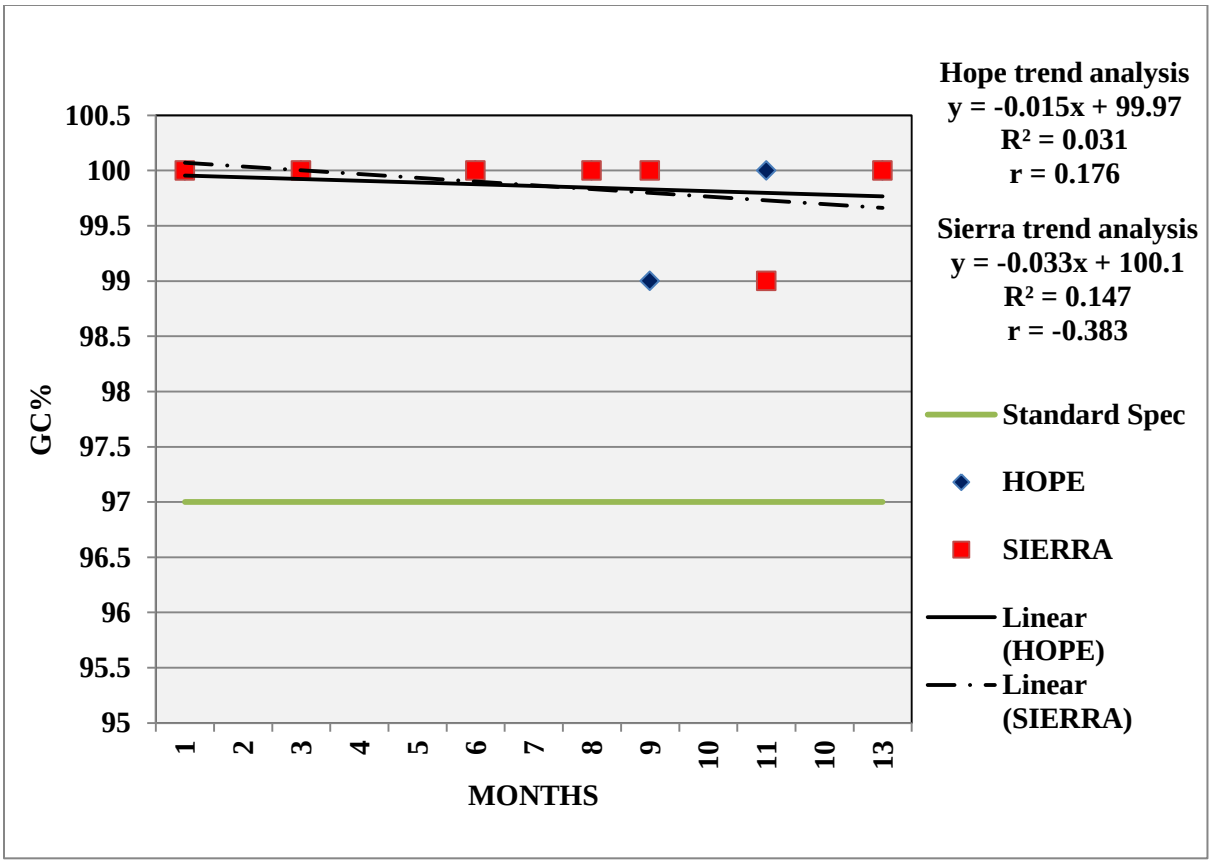


Figure 4.5 Comparison of germination capacity trends

Both Hope and Sierra malting barley varieties maintained desirable germination capacity scores which were above the 97% expected standard throughout the post-harvest storage (Fig 4.5). During the course of the research Hope showed no correlation for the GC as storage time increased (indicated by the r value of 0.716), whilst a very weak negative downhill correlation close to zero was noted in Sierra (indicated by the r value of -0.038).

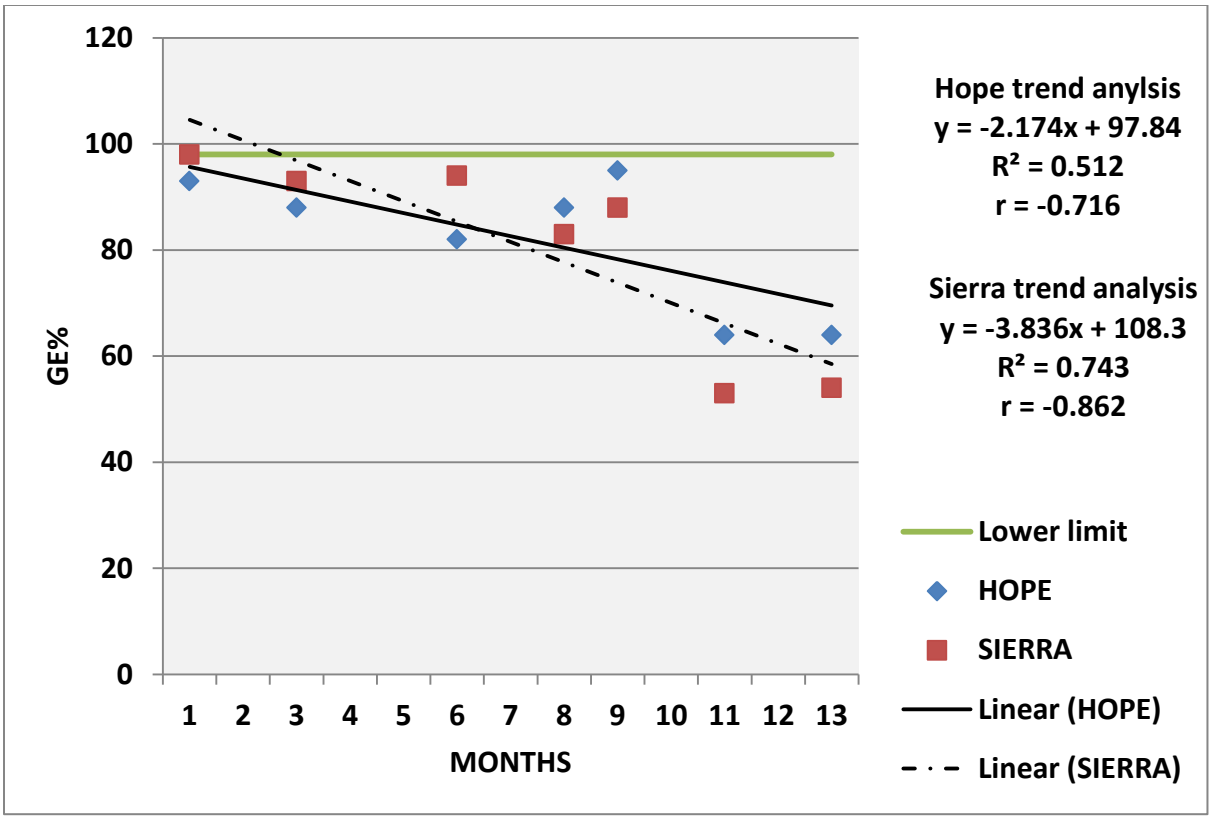


Figure 4.6 Comparison of germination energy trends

For the germination energy trends observed, as the time in storage increased both Sierra and Hope malting barley varieties have strong downhill negative correlations. The decrease in germination energy is significantly pronounced in both varieties with Hope and Sierra having r values of -0.716 and -0.862 respectively. From the first month germination energy for both varieties remained below the expected 98% standard.

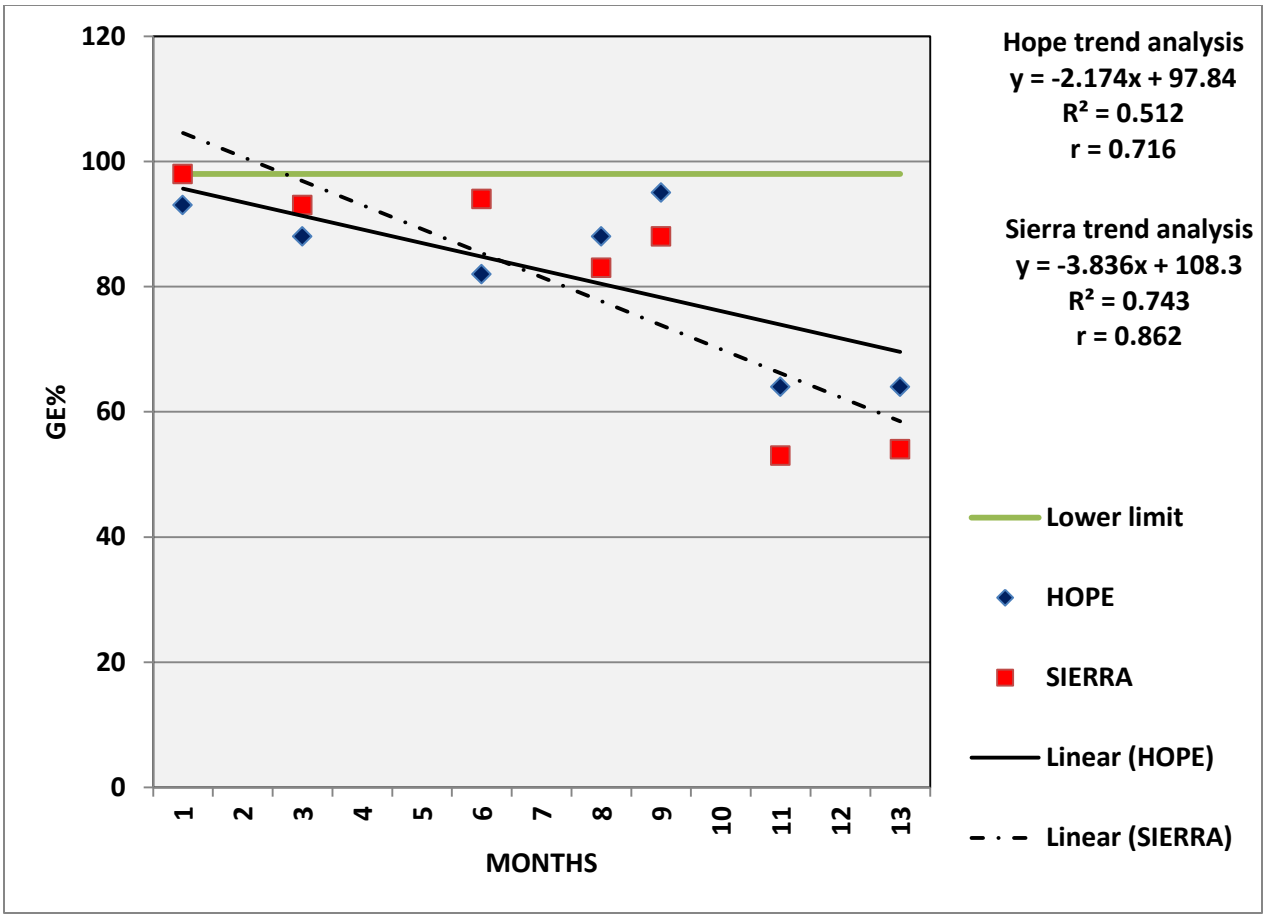


Figure 4.7 Comparison 8ml GE sample

Both Sierra and Hope barley varieties had their 8 ml GE indices decreasing as time in storage increased as shown by the negative downhill correlation trend lines. The r values showed that the strength and direction of the correlation is more pronounced for Sierra (r value = 0.862) than for Hope (r value = 0.716)

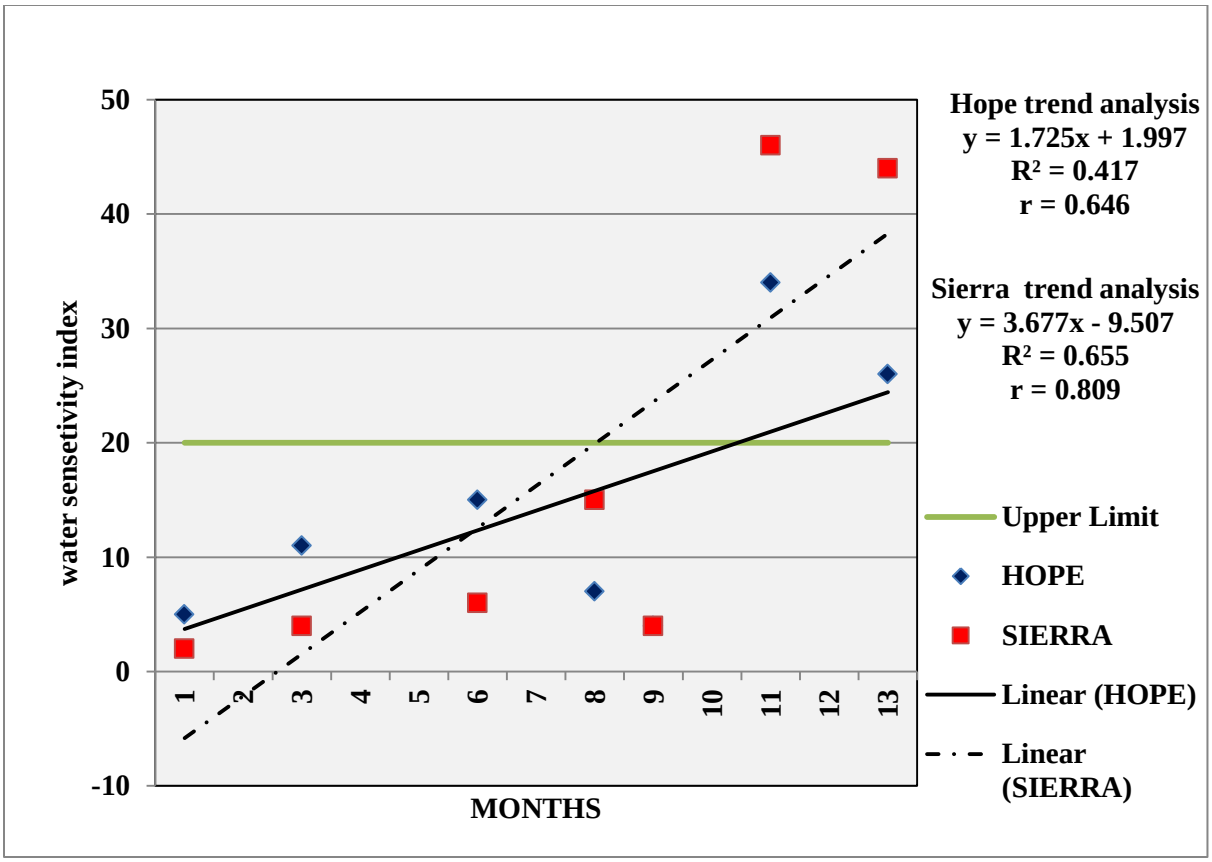


Figure 4.8 Comparison of water sensitivity trends

For the water sensitivity, increase in storage time was characterised with a positive uphill correlation for both malting barley varieties. Hope recorded a moderate positive uphill correlation with the r value of 0.646 and on the other hand the correlation in Sierra was strong as denoted by the r value of 0.809.By the 13th month both varieties had become water sensitive, with the Sierra exceeding the water sensitivity limit early around month 8 and Hope at a later stage around month 11.

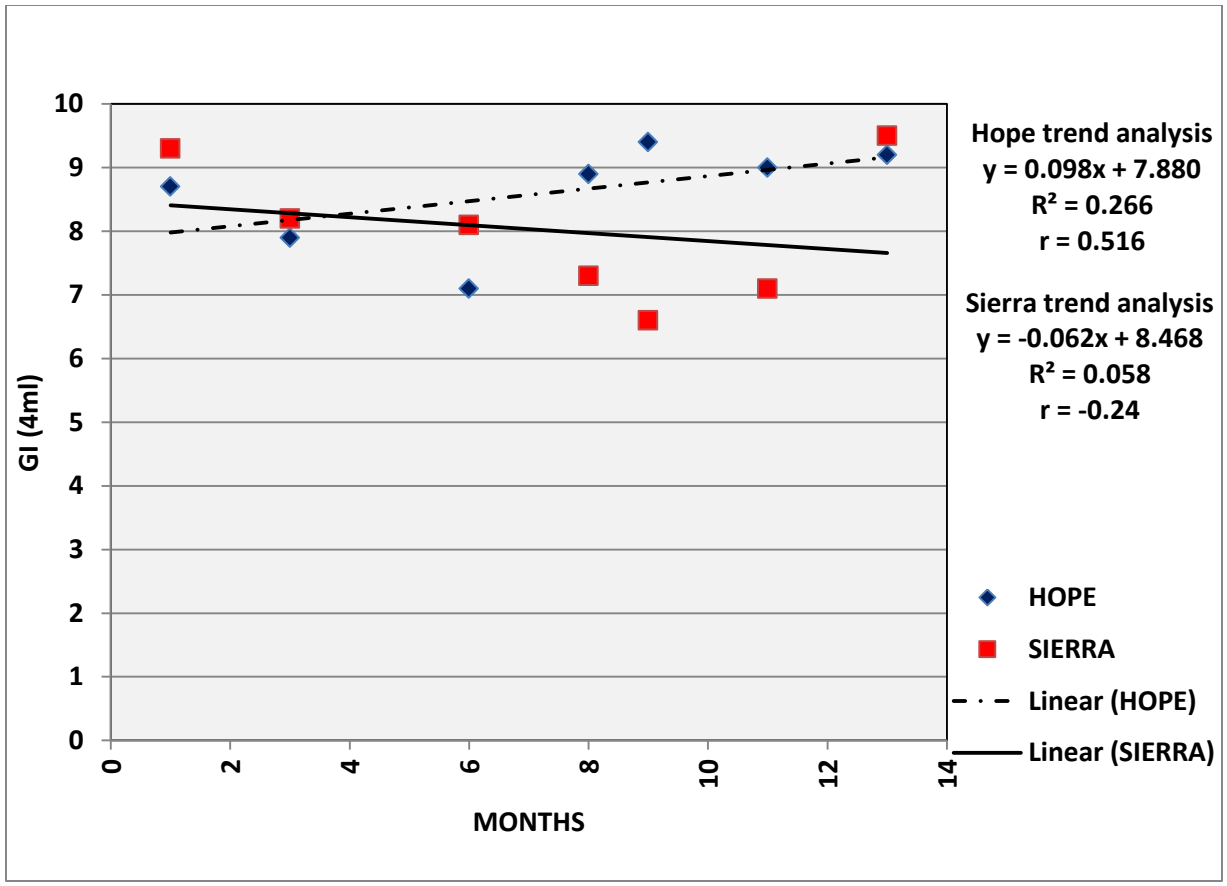


Figure 4.9 Comparison of the germination index trends

As time in storage increased seed germination vigour as indicated by the germination index (GI) did not uniformly change for the two varieties, with both varieties having opposite correlation directions. The trends shows a moderate positive uphill correlation for Hope as denoted by the r value of 0.516 .Sierra recorded as extremely weak negative downhill correlation with an r value of -0.24 which is almost an indication of no correlation.

4.2 Hypothesis testing

H_0: There will be no significant differences in seed germination vigour with prolonged storage time between Hope and Sierra barley varieties.

H_1: There will be significant differences in seed germination vigour with prolonged storage time between Hope and Sierra barley varieties.

Table 3 Tabular two tailed t test results (for hypothesis testing) calculated using the graph pad statistical package.

Parameter	**Value**
Table Analyzed	Data 1
Column A	HOPE (GI)
vs	vs
Column B	SIERRA (GI)
Unpaired t test	
P value	0.2798
P value summary	ns
Are means signif. different? (P < 0.05)	No
One- or two-tailed P value?	Two-tailed
t, df	t=1.132 df=12
How big is the difference?	

Mean ± SEM of column A	8.600 ± 0.3086 N=7
Mean ± SEM of column B	8.014 ± 0.4154 N=7
Difference between means	0.5857 ± 0.5175
95% confidence interval	-0.5420 to 1.713
R squared	0.09645
F test to compare variances	
F,DFn, Dfd	1.812, 6, 6
P value	0.2439
P value summary	ns
Are variances significantly different?	No

Decision: If $t_{calculated} < c_{ritical}$ we fail to reject null hypothesis and If $t_{calculated} > t_{critical}$ we reject null hypothesis

Actual Decision: 1.132 > 0.695 ($t_{calculated} > t_{critical}$); therefore we reject null hypothesis.

Conclusion

H_1: There will be significant differences in seed germination vigour with prolonged storage time between Hope and Sierra barley varieties.

4.3 Discussion

In this research two commercially grown Zimbabwean bred malting barley varieties (Hope and Sierra) were assessed, with the aim of comparing the changes in germination vigour and general storage stability during post-harvest storage. Samples of both varieties were from the 2012 winter growing season and after harvesting, for the research purpose they were stored under room temperature laboratory conditions for the 13 months period. Studies done by Woonton, Jacobsen, Sherkat and Stuart (2005) for the Intentional brewing institute on the storage stability of Australian malting barley varieties showed that storage at room temperature positively influenced the germination characteristics of all samples, with concomitant improvements in hydrolytic enzyme production during malting and in a number of malt quality parameters. This research commenced with both varieties having fairly minimal dormancy as signified by high germination capacity and energy scores.

For germination capacity both varieties retained the desired score of GCs above 97% throughout the course of the study (Fig 4.5).The germination capacity score gives an indication of whether the barley would germinate or not germinate when exposed to the conditions necessary for germination. In this case both varieties demonstrated desirable germination capacity which is the ability to germinate or in other terms grain viability for the 13 months postharvest storage. Briggs (1998) notes that the failure of grains to germinate thus low viability is because they are dormant or dead, with dormant grains being alive but at least not able to germinate under the conditions necessary for the non-dormant grains to germinate. Therefore the high GCs (above 97%) recorded for both varieties throughout the postharvest storage explains that this study commenced after the dormancy had been broken and that the storage conditions maintained the grains alive during the course of the study since barley grains will cease to be alive when

exposed to harmful toxic chemicals, insect or fungal attack and damaging physical conditions during storage.

The 4ml GE test (a measure of the extent of germination) provides the conditions necessary for germination and thus is a test for dormancy and malting ability. GE indices of scores less than 98% (below the acceptable limits set by Kwekwe maltings) were observed for both varieties, with analysis of figure 4.6 clearly showing that both varieties have their extent of germination decreasing with increase in storage time. The loss on the desirable ability to germinate is seen to be more pronounced in Sierra which had an r value of -0.8625 as compared to the r value of -0.716 calculated for Hope .Differences between the germinabilities of the barley varieties are substantial. In addition to physiological differences and storage conditions, Briggs (1998) also notes that differences in inherent varietal attributes (influenced mainly by the genetic makeup) also affect germinability and recovery from dormancy. There are many other possible factors that may be influencing the changes in germination, enzyme production and malt quality with barley storage. Changes in the rate and extent of water uptake, the quantity of endogenous hormones and the aleurone response to hormones may all be associated with the observed changes during storage of barley (Woonton et al, 2005). Thus this serves to explain why differences were observed in the germination trends for both the 4ml and 8ml germination energy tests. The 8ml GE test recorded also a negative downhill correlation for both varieties as the storage time increased. Since the 8 ml GE test employs double the amount of water, this test gives a measure of barley water sensitivity.

Analysis of the r values and the trends presented in figure 4.8 (which gives an overview of the calculated water sensitivity indices) shows that Sierra becomes more water sensitive with time as compared to Hope (Hope r value = 0.646; Sierra r value = 0.809). As the grain ripens the

optimum amount of water for germination apparently declines from a 4 ml to about 3 ml/dish. In the GE (4 ml) test, which provides the optimum amount of water for the germination of water-sensitive grains, the grain attains a moisture content of around 35%, and the surface film of water is absorbed during the test (Briggs 1998). If water-sensitive grain is steeped (i.e. is hydrated by immersion to, say, 45% moisture) and then drained and set to germinate under malting conditions, germination is ragged and slow, or fails, and the moisture film only slowly dissipates because the grain is virtually saturated with moisture(Briggs 1998). According to Kelly and Briggs (1992) the mechanisms responsible for water sensitivity remains unknown, though microorganisms present in grain among other factors are known to contribute. Though it was not included into the methodology of this study and thus not quantified mould taints were observed from around month 10 of the research in the Petri dishes during germination energy tests and this could probably explain how the varieties became water sensitive with time. Other reports have suggested that the pericarp is the main controller of water sensitivity and dormancy, as removal or damage to this tissue has shown to decrease both dormancy and water sensitivity without affecting the microbial load (Harvey and Rossnagel; 1983, Jansson, Kirsop and Pollock; 1959). Henceforth the differences in the water sensitivity behaviour of Hope and Sierra maybe due to the structural differences in the properties of their pericarp.

Analysis of the 4ml GE samples (figure 4.6) showed that both malting barley varieties employed had their malting ability decreasing as storage time increased but however for GI which is the measure of the rate of germination/germination vigour the varieties performed differently. Figure 4.9 clearly shows that Hope had its GI improving as storage time increased meaning that , the YDULHW\¶VJHUPLQDWLRQYLJRXULPSURYHVZLWKWLPH%WKHILUVWPRQWKRIWKHUHVHDU for Hope was 8.7 and gradually it increased reaching 9.2 by the end of the research period.

However on the other hand the seed germination vigour for Sierra gradually diminishes with time as indicated by the weak negative downhill correlation (r value = -0.24). There was a significant difference in the germination vigour of these trends as indicated by the t test results which showed that $t_{calculated}$ was greater than $t_{critical}$ (1.132 > 0.695) leading to the acceptance of the alternative hypothesis. The differences in germination performances are common among different varieties due to inherent differences in genetic compositions, grain physiology and growing conditions Briggs (1998). For instance studies done by Woonton et al. (2005) on Australian malting barley varieties (Tasmanian Franklin and Victorian) showed that for the Victorian samples, the GI and 8ml GE data increased similarly. However, the Tasmanian Franklin sample did not perform in the same way, with consistently low 8 ml GE values and increasing GI values throughout storage. The study by Woonton et al. (2005) concluded that samples stored at room temperature had their GI index values increasing gradually in the 380 days period which they were under laboratory storage and this was consistent with the GI trends for Hope (fig 4.9) , but for unknown reasons this was not true for Sierra.

In addition to germination tests other several quality parameters of malting barley had their trends determined and analysed so as to assess the storage stability of the two varieties. Hoseney (1994) explains the major cause of functional changes during postharvest storage of cereals when KH VWDWHV WKDW DV ORQJ DV JUDLQ UHWDLQV LWV YLDELOLW\JUDLQ UHVSLUHV DQG LV (1994) further elaborates that grains stored under reasonable conditions (avoiding high temperatures and moisture augmentation) will slowly lose weight because of its respiration.

One of the parameters used in comparing the storage stability of the barley varieties was moisture content. From the study both varieties gradually had their moisture content decreasing from the initial average of 12.5% to an average of 8.6 by the end of the 13 months storage period

as the grains naturally continued to dry out. This results in a change in the mass of the grains and obviously shrinkage of the kernels. Consequently it would be expected that Hope whose moisture content loss trend line indicates a stronger negative downhill correlation (r value = -0.966) than that of Sierra (r value = -0.941) would have a screenings index signifying a stronger positive correlation than Sierra. However this was not the case in this study and this can be chiefly due to the fact that Sierra as one of its varietal physiological characteristic is naturally less plump and any slight moisture losses will significantly amount to an increase the percentage of screenings (undersized grains).

For the insect damaged index (see figure 4.3) both varieties recorded moderate positive uphill correlations meaning that insect infestation increased gradually with time almost at the same degree in both varieties. This probably also explains that the varieties had the same initial moisture ranges and were stored under same conditions since the degree of insect infestation is due mainly to moisture content and storage conditions (Hoseney, 1994). Most damaging insects including the granary weevils which were observed in this research have their growth restricted by moisture content below 9% (Hoseney, 1994). The grain was stored at relatively safe storage moisture (less than 13%) to avoid proliferation of microbes such as fungi and moulds; however the moisture was not low enough to hinder growth of damaging insects such a weevils. Finally for the protein content just as outlined in Chapter 2 of this report (see table 2.1) Sierra has naturally higher protein content than Hope and this difference was maintained throughout the post-harvest period storage, with Sierra having a moderate positive uphill correlation and Hope a weak positive correlation for the protein content trend lines (see figure 4.2).

4.4 Chapter Summary

This chapter focused on data presentation, analysis (including hypothesis testing) and discussion of the research findings. The findings were displayed in the form of linear regression graphs with the intention of clearly outlining the differences and similarities on the trends of the various parameters which were used to compare the storage stability of Hope and Sierra malting barley varieties with great emphasis being placed on the changes in germination performance. The next chapter will focus on the summary, conclusions and recommendations.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This unit consists of three main sections, which conclude the entire research report. These are the summary, the research conclusions and the recommendations. Through this final chapter an overview of the research problem, research methodology, limitations of the study and major research findings are summarized.

5.2 Summary

The research aimed to make a comparison of the changes in seed germination vigour between Hope and Sierra malting barley varieties as post-harvest storage time advanced. It was also within the scope of the research objectives to carry out tests on non-germination parameters (nitrogen, moisture content, screenings, water sensitivity and insect damage index) which could be used to analyse the storage stability of the malting barley varieties and possibly use the results in the attempt to fully understand and explain the germination performance trends. This researcher was mainly motivated by the need to close the vital knowledge gap existing in terms of WKHPDOVWHU¶V XQGHUVWDQGLQJ of the germination trends changes and storage stability of the two barley varieties during post-harvest storage.

The scope of the research was restricted only to the two malting barley varieties (Hope and Sierra), malted at Delta Beverages Kwekwe Maltings. Only the malting barley harvested from the 2012 winter growing season was used for the research. The primary samples for both varieties were kept at room temperature under laboratory conditions at Kwekwe Maltings which

is the same laboratory all the experiments were carried out according to the SAB Miller malting analytical procedures.

Generally this research can considered successful as all the stages of the research process from the inception of the research topic , through phases of data collection and analysis of results were completed. The research samples (Hope and Sierra varieties) were successfully kept under uniform laboratory conditions for a 13 months period which is reasonable enough to analyse and compare the trends of relevant parameters for the two varieties.

Chapter one of this write up gives a detailed account of the statement of problem, background of this study, research questions, research objectives, possible limitations, delimitations and the significance of this study. Chapter two covered the relevant theoretical aspects which were mainly revolved insights into malting barley varieties and quality aspects (with emphasis on germination attributes), malting barley storage requirements and an overview of the malting process (highlighting on the necessary biochemistry concepts).in chapter three a concise outline of the methodology employed during data collection indicating all the experimental procedures which were utilised during the course of the studies. Information about the study population, sampling procedures and sample preservation, principles of the analytical techniques, experimental procedures and their material requirements is given in chapter three. Chapter for comprises of the presentation of results, data analysis and discussion of the results.

5.3 Conclusion

From the results presented, analysed and discussed in the previous chapter it was clear that differences exist in the trends of the parameters used to compare the two barley varieties. From this research it is concluded that Hope is more stable in storage for most quality specifications (including germination vigour) than Sierra. The germination index (germination vigour) significantly changed during the 13 months of post-harvest storage under room temperature conditions, with Hope having its GI improving with time whilst on the other hand the GI for Sierra diminished with time. This means Hope retains a more desirable germination vigour performance during storage than Sierra. Analysis of the results for germination energy, screenings, and rate of moisture loss, insect infestation and water sensitivity demonstrated that Hope is more stable during storage than Sierra though the differences in these parameters are less significant as compared with the differences in GI trends.

5.4 Recommendations

Having concluded that Hope is a better malting barley variety than Sierra as far as storage stability is concerned the following recommendations have been made:

- In the contractual farming which Delta beverages engages with barley farmers through its Agric Services department its best advised that they minimize the quantity of the Sierra barley variety to be grown, since its quality has proved to diminish more significantly as compared to Hope during post-harvest storage.
- Since the germination vigour of Sierra declined whilst that of Hope increased during storage , this research recommends that once both varieties are in storage at the maltings

Sierra should be malted first and at a much quicker rate than Hope so as to quickly exhaust its stores whilst the germination vigour is still desirable.

- This research challenges the Delta beverages Agric services responsible for barley development to develop another variety which can perform better than Sierra as far as storage stability is concerned to prevent over dependence on Hope.
- For verification of these results by analogy the researcher proposes that this study be repeated using the same varieties and methodology employed. It will be of an added advantage to include micro malting and malt quality analysis in a bid to assess how the post-harvest changes at different stages of storage would be influencing enzyme yield, extract values and other malt quality parameters.

REFERENCE LIST

Aastrup, S., Riis, P., & Hansen, J.R. *Proceedings of the European Brewery Convention Congress, Zurich* 1989, 171-178.

Bamforth, C.W, & Quain, D.E. (1989*). Enzymes in brewing and distilling*. UK: Aberdeen Univ. Press

Bamforth, C.W., & Barclay A.H.P. (1993). Malting technology and the uses of malt. *Barley: Chemistry and Technology. American Association of Cereal Chemists Inc. St. Paul*, 297± 354.

Belitz, H.G, Grosch, W, & Schiebrle, P. (2009*). Food Chemistry.* Berlin: Springer.

Bhatty, R.S, & Rossnagel, B.G. (1997). Zero amylose lines of hull-less barley. *Cereal Chem,* 74:190±1.

Bingham, M.K. (1990). Field detection and implications of mercury in natural gas. *SPE Prod Engg*, 5:120±4.

Briggs, D.E. (1995). *Aspects of Dormancy*. Pauls Malt, London, 31±35.

Briggs, D. E. (1998). *Malts and Malting*. London: Blckie Academic & Professional. .

Briggs, D.E, Boulton, C.A., Brookes, P.A., & Stevens, .R. (2004). *Brewing Science and practice*. New York: Woodhead publishing limited.

Briggs, D. E., Hugh, S.J .(1985), *Malting and Brewing Science Volume 1(* 2nd edition). London: Chapman and Hall Publishing House.

Czuchajowska, Z., Klamczynski, A., Paszczynska, B., & Baik, B.K., (1998). Structure and functionality of barley starches. *Cereal Chem*, 75:747±54.

Enari, T.M., & Sopanen, T. (1968). Mobilisation of endospermal reserves during the germination of barley. *Centenary review. Journal of the Institute of Brewing*, 92, 25±31.

Faivre, J., & Bonithon-Kopp, C. (1999). Diets, fibers and colon cancer. *Adv Exp Med Biol*, 72:199±206

Fox, G.P., Onley-Watson, K., & Osman, A. (2002). Multiple linear regression calibrations for barley and malt protein based on the spectra of hordein. *J Inst Brew*, 108:155±9.

)UDQp NRYi + /tá NRYi 0 %RMDQVNi 7 0DUHp HN - Germination index as an Indicator of malting potential. *Czech J. Food Sci*ence, 30: 377±384.

Frost, G., Leeds, A.A., Dore, C.J., Maderios, S., Brading, S., & Dornhurst, A. (1999). Glycaemic index as a determinant of serum, cholesterol concentration. *Lancet,* 353:1045±8.

Gallagher, D.D., Hassel, C.A., Lee, K.J., & Gallagher, C.M. (1993). Viscosity and fermentability as attributes of dietary fibre responsible for hypocholestrolemic effects in hamsters. *J Nut,*123:244±52.

Gavin, H. (2008).*Understanding Research Methods and Statistics* .London: SAGE Publications

Gupta, M., Abu-Ghannam, N., & Gallaghar, E. (2010). Barley for Brewing: Characteristic Changes during malting, brewing and applications of its by-products. *Comprehensive Reviews In Food Science And Food Safety*, 9:318-325

Hart, C. (2005). *Doing your Masters Dissertation*. London: SAGE Publications

Harvey, B.L., & Rossnagel, B.G. (1983). Sprouting resistance in barley. *Proceedings of the 3rd International Symposium on Pre- harvest Sprouting in Cereals, Epping Bowker: Winnipeg, Canada*, 239±243.

Henry, R.J. (1988). Changes in -glucan and other carbohydrate components of barley during

malting. *J Sci Food Agric*, 42:333±41

Hoseney, R.C. (1994). *Principles of Cereal Science and Technology* (2nd Edition). USA, American Association of Cereal Chemistry

Izydorczyk, M.S., Storsley, J., Labossiere, D., MacGregor, A.W., & Rossnagel, B.G. (2000). Variation in total and soluble -glucan content in hulless barley: effects of thermal, physical, and enzymic treatments. *J Agric Food Chem*, 48:982±9.

Jansson, C., Kirsop, B.H., & Pollock, J.R.A. (1959). Studies in barley and malt: XIII. Water-sensitivity as an intrinsic property of certain barleys. *Journal Institute of Brewing*, 65, 165±168.

Keenan, J.M., Coulson, M., Shamliyan, T., Knutson, N., Kolberg, L., & Curry, L. (2007). The effects of concentrated barley -glucan on blood lipids in a population of hyper cholesterolaemic men and women. *Br J Nutr*, 97:1162±8.

Kelly, L. & Briggs, D.E. (1993).Relationship between duration of steeping, grain microbes, grain maturity and the response of de-embryonated grains to gibberellic acid. *Journal Institute of Brewing*, 99, 57±62

Kunze, W. (1999) .*Technology: Brewing and Malting*. Berlin: VLB Berlin.

Larsenet, J. (1994). Targets for tailored breeding. *Symposium Malting Technology, Andernach, European Brewing Convention. Monograph. Fachverlag Hans Carl, Nürnberg*, 152±164.

Lauro, M., Suortti, T., Autio, K., Linko, P., & Poutanen, K. (1993). Accessibility of barley starch granules to . -amylase during different phases of gelatinisation. *J Cereal Sci*, 17(2):125± 36.

Lewis, M.J, & Young, T.W. (1995). *Mashing biochemistry*. London,UK: Chapman & Hall.

Li, J., Kaneko, T., Qin, L.Q., Wang, J., & Wang, Y. (2003). Effects of barley intake on glucose tolerance, lipid metabolism, and bowel function in women. *Nutr,* 19:926±9.

/X042¶%ULHQ/6WXDUW,0%DUOHPDOWLQJTXDOLWDQGLHOGLQWHUUHODWLRQVKLSV and the effect on yield distribution of selection for malting barley quality in early generations. *Australian Journal of Agricultural Research*, 51: 247±258.

Madhujith, T., & Shahidi, F. (2007). Antioxidative and antiproliferative properties of selected barley cultivars and their potential for inhibition of low-density lipoprotein (LDL) cholesterol oxidation. *J Agric Food Chem,* 55:5018±24.

Manners, D.J., Marshall, J.J, & Yellowlees, D. (1970). The specificity of cereal limit dextrinase. *Biochem J,* 116:539±41

Manners, D.J. (1985). Some aspects of the metabolism of starch. *Cereal Foods World*, 30:722±7.

Moll, M., (1979). *Water in malting and brewing.* London: Academic Press.

Munck, L., & Moller, B. (2004). A new germinative classification model of barley for prediction of malt quality amplified by a near infrared transmission spectroscopy calibration for YLJRXU UHQLQH ERWK LPSOHPHQWHG E\PXOWLYDULDWH*Journal Institute of* V *Brewing*, 110: 2±17.

Naidu, S. (2008). *International Encyclopedia of Agricultural Science and Technology. Volume 4*. New Delhi: Krishan Mittal

Newman, R.K., McGuire, C.F., & Newman, C.W. (1990). Composition and muffin-baking characteristics of flours from four barley cultivars. *Cereal Foods World*, 35:563±6.

Riss, P., & Bang-Olsen, K. (1991). Germination profile ± A new term in malting barley analysis. *Proceedings 23rd European Brewery Convention. Lisabon*, 100±108.

Peltonen, J., Rita, H., Aikasalo, R., Home, S. (1994). Hordein and malting quality in northern barleys. *Hereditas,* 120:231±9.

Psota, V., Vejrazka, K., Famera, O., & Hrcka, M. (2007). Relationship between grain hardness and malting quality of barley (Hordeum vulgare L.). *J Inst Brew,* 113:80±86.

Quinde, Z., Ullrich, S.E., & Baik, B.K. (2004). Genotypic variation in color and discoloration potential of barley-based food products. *Cereal Chem*, 81:752±8.

Slack, P.T., & Wainwright, T. (1980). Amylolysis of large starch granules from barleys in relation to their gelatinisation temperatures. *J Inst Brew,* 86(2):74±7.

Stewart, D.C., Freeman, G., and Evans (2000). Development and assessment of a small-scale wort filtration test for the prediction of beer filtration efficiency. *J Inst Brew,* 106:361±6.

Swanston, J.S., & Taylor K. (1990): The effects of different steeping regimes on water uptake, germination rate, milling energy and hot water extract. *Journal of the Institute of Brewing,* 96:3±6.

Ullrich, S.E., & Eslick, R.F. (1978). Lysine and protein characterization of spontaneous shrunken endosperm mutants of barley. *Crop Sci,* 18:809±12.

White, N.G.G., Hulasare, R.B. & Jayas, D.S. (1999). Effect of storage conditions on quality loss of hull-less and hulled oats and barley. *Canadian Journal of Plant Science,* 79, 475±482.

William. (2005).Your research project (3rd edition).London: SAGE Publications

Woods, J.L., Favier, J.F., & Briggs, D.E. (1994). Predicting the germinative energy of dormant malting barley during storage. *Journal of the Institute of Brewing,* 100, 257±269.

Woonton, B., Jacobsen, J.V., Sherkat F., & Stuart I.M. (2005). Effect of post-harvest storage period on barley germination and malt quality. *Journal of Institute of brewing and distilling*, 111(1), 33±41.

APPENDICES