# EFFECT OF THREE PLANT EXTRACTS ON SPROUTING, DECAY AND WATER ACTIVITY OF FLOUR OF TWO CULTIVARS OF FRAFRA POTATOES (*Solenostemon rotundifolius*)



**A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY**

**(M.Phil. POSTHARVEST PHYSIOLOGY) DEGREE**

**BY**

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## DECLARATION

I hereby declare that this research work is the result of my own work and that it has not been submitted either in part or whole for any other degree elsewhere. Works by other authors have been duly acknowledged.

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## ABSTRACT

This study was carried out from 2nd November, 2012 to 22nd March 2013 at the Department of Horticulture, KNUST. The research work sought to evaluate the effect of three plant extracts on sprouting, decay and water activity of two cultivars of frafra potatoes (*Solenostemon rotundifolius*). The brown cultivar and black cultivar of frafra potatoes were used whiles the extracts used were neem bark extract, ginger rhizome extract and pawpaw leaf extract. A 2 x 4 factorial in a completely randomized design was used with two cultivars and four treatments which were replicated three times. Data resulting from individual parameters were subjected to analysis of variance using Statistix, Student version 9.0 and means were separated using lsd at 5 percent (p=0.05). The pathogens associated with rot of frafra potatoes during the storage period were identified as *Curvularia lunata, Colletotrichum gloeosporioides, Aspergillus niger, Aspergillus flavus, Penicillium sp* and *Trichoderma sp*. Although there were no significant differences on percentage decay among the treated tubers, the extracts were effective in reducing rot as the percentage rot in the control of both cultivars recorded greater rot than the extract treated tubers. There was significant cultivar effect on the water activity of flour of treated tubers. However, the extracts applied on tubers had no significant effect on the water activity of *Solenostemon rotundifolius* flour after the storage period. Also, there was significant cultivar effect on sprouting from week 11 to 19 but not week 21. There was significant extract effect on sprouting from week 11 to 17 but not week 19 and 21. The neem bark extract treated tubers however recorded the least sprouting in both cultivars at the end of storage (week 21). The study also found out that the effect of the cultivar on weight loss was significant. However, there was no significant extract effect on sprouting even though water (control) treated tubers experienced greater weight loss than extract treated tubers. Mechanical injury during harvesting, transportation and storage should be prevented to reduce the possibility of infection by the rot pathogens identified to be

associated with rot. For longer storage life, *Solenostemon rotundifolius* tubers should be processed into flour before storage since flour of frafra potatoes have lower moisture and water activity values. Also, the effect of higher concentrations of neem bark extract on sprouting of *Solenostemon rotundifolius* should be further investigated since neem bark treated tubers experienced lower sprouting in both cultivars at the end of storage (week 21). Finally, tubers of *Solenostemon rotundifolius* should be collected from all the farming communities to fully appreciate the pathogens that cause decay in storage.



## DEDICATION

This work is dedicated to Almighty God Jehovah, the owner and sustainer of the universe.

His love and mercy towards me is immeasurable.

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# CHAPTER ONE

# INTRODUCTION

## 1.0 BACKGROUND

Achieving food security in its totality continues to be a challenge not only for the developing nations, but also for the developed world. The difference lies in the magnitude of the problem in terms of its severity and proportion of the population affected (Mwanki, 2005). Food security is defined as a situation in which all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active healthy life (IFPRI, 2002). From this definition, the following dimensions of food security can be identified: physical availability of food, access to food and food adequacy. Food availability has to do with the supply of food. This should be sufficient in quantity and quality and also provide variety. Food access addresses the demand for the food. It is influenced by economic factors, physical infrastructure and consumer preferences (Mwanki, 2005).

For households to be food secure, food that they have access to must be adequate not only in quantity but also in quality.

In Ghana, about one million and two hundred thousand people, representing five percent of the population, are food insecure (WFP, 2009). WFP (2009) further indicates that about two million more people throughout the country are vulnerable to become food insecure. The higher percentage of food insecure people and those vulnerable to become food insecure live in the three northern regions of Ghana. According to WFP (2009), thirty four percent (34%) of the food insecure population are in Upper West region, followed by Upper East with 15%

and Northern region with 10% whiles about 40% of people are vulnerable of becoming food insecure in the rural areas of Upper West, Upper East and Northern regions.

## 1.1 MONTHS OF INADEQUATE HOUSEHOLD FOOD

Months of inadequate household food provisioning has been defined as the time between stock depletion and the next harvest, that is the period when a family's food stocks run out before new harvest, (Coates *et al.*, 2007). It is usually used as a measure of food insecurity in a highly subsistence-oriented area where production is primarily for home consumption and households do not make significant sales or purchases in the market. Quaye (2008) reported that most farmer households experience significant degree of food insecurity with food insecure periods spanning between three and seven months (Table 1.1).Upper East Region is the worst affected as it experiences the longest food shortage period of 6 months. The Northern and Upper West regions experience five months of food inadequacy.

Table 1.1: Months of household food insecurity in Upper West, Upper East and Northern Regions of Ghana.

| Crop | Upper west region | | | Upper east region | | | Northern region | | |
|---|---|---|---|---|---|---|---|---|---|
| | Months of harvest | Months of stock depletion | Month of food insecurity | Months of harvest | Months of stock depletion | Month of food insecurity | Months of harvest | Months of stock depletion | Month of food insecurity |
| Sorghum | October | June | 4 | August | Feb | 6 | Nov | June | 5 |
| Maize | October | June | 5 | October | April | 6 | Sep | June | 3 |
| millet | September | April | 4 | July/Nov | Jan | 6 | Nov | June | 5 |
| rice | October | June | 5 | Nov | April | 7 | Oct | May | 5 |
| yam | October | May | 6 | NA | NA | NA | Sep | June | 4 |
| groundnut | * | * | 4 | October | April | 6 | Sep | April | 5 |
| cowpea | October | June | 5 | October | Mar | 7 | Oct | May | 5 |
| soybean | September | April | * | NA | NA | NA | Nov | April | 7 |

Source: Quaye, 2008

## 1.2 CAUSES OF FOOD INSECURITY

Several reasons have been given for the causes of food insecurity. However, according to Mwanki (2005), the major challenge to food security in Africa include low fertile soils, minimal use of external farm inputs, environmental degradation, significant food crop loss (both pre- and post- harvest), minimal value addition and product differentiation, and inadequate food storage and preservation that result in significant commodity price fluctuation. This therefore implies that, to mitigate the effects of food insecurity these major challenges, among others, have to be seriously looked at.



## 1.3 ROLE OF ROOT AND TUBER CROPS IN THE FIGHT AGAINST FOOD INSECURITY

Tropical root and tuber crops are considered as the third important crops after cereals and grain legumes; they contribute six percent of the average daily calorific intake of human beings Lenka *et al.* (2012). Hahn (1992) indicates that to prevent any food deficit in the future and its resultant effect of food insecurity, production of food crops especially root crops has to be increased to at least three percent per annum. According to Lenka *et al.* (2012), root and tuber crops constitute a cheap source of food and energy particularly suitable for the poor section of human populations and capable to withstand biotic and abiotic stresses. Lenka *et al.* (2012) further indicates that tuber crops have a higher biological efficiency as food producers and show the highest rate of dry matter production per day per unit area among all crops and are also recognized as the most efficient converters of solar energy. Frafra potato is particularly used as a famine food and is usually harvested and stored for use during the long dry season (Burkill, 1995).

## 1.4 PROBLEM STATEMENT AND JUSTIFICATION

Food security on the African continent has worsened since 1970 and the proportion of the malnourished population has remained within 33 to 35 percent range in Sub-Saharan Africa (Mwaniki, 2005). To eradicate or mitigate this situation, an increase in the productivity of food crops especially root and tuber crops is necessary. This is because root and tuber crops are adaptable to marginal environments and are also flexible in mixed farming systems (Scott *et al.*, 2000 and Lebot, 2009). According to Lebot (2009), enhanced productivity and nutritional characteristics of root and tubers can have a major impact on family food and nutritional security, especially for children and pregnant/lactating women.



The importance of frafra potato in the fight against food insecurity cannot therefore be downplayed. According to National Research Council, of the United States National Academies, (2006), frafra potatoes are clonal crops that are easy to handle and propagate. They are found in the areas of low agricultural potential across the neediest regions of the continent. They occur where a shortage of suitable vegetable crops now results in endemic malnutrition. They produce large amounts of nutritious food from a small land area. National Research Council (2006) further indicates that taken all round, frafra potatoes could prove good tools for reducing malnutrition and hunger while improving farm profitability and providing African families with greater food security.

Due to its relatively low starch content, when compared with other tropical tuber crops such as cassava and sweet potato, frafra potato is a crop with export potential to places such as Europe and the Middle East where non-fattening foods are in high demand (Prematilake, 2005).

In spite of the importance of frafra potatoes in the fight against food insecurity and its potential as an export crop, its cultivation appears to be declining in areas of its production in Ghana (Tetteh *et al.*, 1997). The decline in production is as a result of problems encountered by farmers in the production of the crop. According to Tetteh *et al.* (1997), the following problems contribute significantly to the current state of production of the crop in Ghana: erratic rainfall, spoilage in storage, pest and diseases, lack of planting material and ineffective tools.

No research work has however been cited on the effect of plant extracts on sprouting, rot causing organisms and water activity of tubers of frafra potatoes during storage in Ghana. Also, no research work has been cited on organisms that cause rot during storage of frafra potatoes in Ghana.



## 1.5 MAIN OBJECTIVE

To determine the effect of three organic treatments on sprouting, rot causing organisms and water activity of flour of two cultivars of frafra potatoes (*Solenostemon rotundifolius*).

## 1.6 SPECIFIC OBJECTIVES

1. To identify the organisms associated with rot of two frafra potato cultivars.
2. To determine the effect of three plant extracts on rot causing organisms of two frafra potato cultivars.
3. To determine the effect of three plant extracts on sprouting of two frafra potato cultivars during storage.
4. To determine the effect of the extracts on water activity of the flour of two cultivars of frafra potato.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.0 ORIGIN AND DISTRIBUTION OF *Solenostemon rotundifolius* Poir

*Solenostemon rotundifolius* (Frafra potato) is a herbaceous perennial which is normally cultivated as an annual (National Research Council, NRC, 2006). Frafra potatoes belong to the family Labiatae (lamiaceae) (Tindall, 1983). The plant is known by the following scientific names: *Coleus parviflorus* (Benth) (IAEA, 1990), *Coleus rotundifolius* (coursey and Booth, 1997), *Coleus esculentus*, *Coleus dazo* (Purseglove, 1968) and *Coleus dysentericus* (Baker) (Wills, 1962). According to Peter (2007), it is also known by the following vernacular names: Hausa potato, frafra potato, Sudan potato, pomme de terre du Soudan, frafra-salaga, saluga, tumuku, fabirama, china potato.

*Solenostemon rotundifolius* originates from tropical Africa, where it is still found in the wild in East Africa (Nkansah, 2004). According to Nkansah (2004), it was widely cultivated in the savannah region from Senegal to Western Sudan and South Africa but nowadays there are only relics of former cultivation in Mali, Ghana, Nigeria and South Africa. As a crop it is now more important in tropical Asia (Nkansah, 2004). Its southern counterpart (*Plectranthus esculentus*) is known as the Livingstone potato or Madagascar potato and produces long fingerlike tubers. Across their diverse growing environments, both species can produce large amounts of food from a very small land area (NRC, 2006).

Despite their name, frafra potatoes are neither potatoes (*Solanum tuberosum*) nor are they related to potato (*Solanum tuberosum*) or its relatives. They are not also related to yam, sweet potatoes, or cassava. Frafra potatoes are actually members of the mint family (NRC, 2006).

Members of the mint family include lavender, mint, spearmint, rosemary, sage, thyme, oregano, basil, and majoram. Africa's native potatoes are the only mints producing human food below ground (NRC, 2006).

In Ghana, frafra potato is mainly grown in the Guinea and Sudan Savannah agro-ecological zones (Opoku-Agyeman *et al.*, 2004), specifically in the Builsa, Kassena-Nankani, Bolgatanga, Lawra-Nandom, Jirapa-Lambussie, Nandawli and Wa districts of the Upper East and West Regions (Tetteh *et al.*, 1997). It has however been observed that the crop also does well in the moist semi deciduous forest ecology of Ghana (Opoku-Agyeman *et al.*, 2004).



## 2.1 VARIETIES

Frafra potatoes have an extremely low genetic variability. In Sri Lanka, only two main varieties have been identified as Dik innala and Bola innala. The main difference being their tuber shapes, elongated (Dik) and round (bola) respectively (Prematilake, 2005). According to Tindall (1983), *Solenostemon rotundifolius* has three varieties based on skin colour. *Var. Nigra* (which is black in colour), *Var. Rubra* (which is red-grey or red-yellow in colour) and *Var. Alba* (which is white in colour). However, a germplasm collection of frafra potatoes held at the Plant Genetic Resources Research Institute (PGRRI) of Ghana recognizes four main varieties based on skin colouration- white, black, brown and red FAO (2010).

Plate 2.1: White cultivar of frafra potatoes

Plate 2.2: Brown cultivar of frafra potatoes

Plate 2.3: Black cultivar of frafra potatoes

## 2.2.ECOLOGY

According to Nkansah (2004), *Solenostemon rotundifolius* occurs wild in the grasslands of East Africa up to 2200 m altitude in Kenya. It does well even when cultivated in marginal areas in the dry savanna with poor soils. However, tubers may not be formed when rain is insufficient. Nkansah (2004) further indicates that too much rain makes the tubers to branch, which is disliked by consumers because they are then difficult to peel. Frafra potato requires full sunlight because shade from other crops reduces yield. Tubers are relatively formed with ease in sandy soils, but will not develop well in compacted heavy soils. Soils for frafra potato cultivation should be well drained as water logging is not tolerated.

## 2.3 BOTANY

### 2.3.1 Stem

The stem of frafra potato (*Solenostemon rotundifolius)* is square in cross-section (Dupriez, 1989). These prostrate, lateral trailing branches, which are covered in white hair, root at the nodes (NRC, 2006). The predominant stem colours are varied green, light green, yellowish-green and purple (Opoku-Agyeman *et al.*, 2004).

### 2.3.2 Leaves

The Leaves of frafra potatoes are opposite and simple with stipules absent. The petiole is about 2cm to 3cm long. The blade with an area of 2.5cm to 8cm × 2cm to 5cm has the following characteristics: it is ovate, cuneate at the base, obtuse to acute at apex, margin crenate-dentate, puberulous and gland-dotted below and distinctly veined (Nkansah, 2004).The leaves are hairy, oval, and aromatic. They can be up to 6cm long and have toothed margins. Some plants have a central purple marking on the lamina (NRC, 2006).

According to Opoku-Agyeman *et al.* (2004), the leaves of frafra potatoes are predominantly (over 90%) green with the following variations; green, light-green and olive-green. The leaf colours are also independent of the incidence and position of the anthocyanin pigmentation on them.

### 2.3.3 Tubers

The tubers occur in clusters of three to seven, either at the base of the stem or at the nodes below the soil surface.

Frafra potato tubers are generally small (about 28g). However, they can be as heavy as 480g (Opoku-Agyeman et. al., 2004).

Most tubers found in Africa are 2.5cm to 4cm × 1cm to 1.5cm. Larger tubers are common in India and Sri Lanka, where yields are also higher than those in Africa's semi-arid zones

(Nkansah, 2004). The tubers of frafra potatoes have varied shapes. According to Opoku-Agyeman *et al.* (2004), shapes of tubers are mostly undetermined, elliptical, irregular, oblong, obovate or spherical.

Tuber skin colour can be red, white or black Dittoh *et al.* (1998). According to Tindall (1983), *Solenostemon rotundifolius* has three varieties based on skin colour: *Var. Nigra* (which is black in colour), *Var. Rubra* (which is red-grey or red-yellow in colour) and *Var. Alba* (which is white in colour). Even though tubers can be of different colours, the tuber flesh in all three varieties is white (Opoku-Agyeman *et. al.*, 2004). However, reddish yellow, dark brown and light grey flesh colours have also been reported (Burkill, 1995).

## 2.4 PROPAGATION AND PLANTING

Frafra potato is normally propagated vegetatively by tubers, suckers or soft-woody stem cuttings (Nkansah, 2004). However, tissue culture plantlets can also be used (Acheampong and Asante, 1998). If vines are to be used for propagation, then nursery beds should be established about one month before planting. An area of 500 $m^2$ to 600 $m^2$ is sufficient to produce cuttings required for a one hector field (Peter, 2007). According to Peter (2007), about 170 kg to 200 kg of tubers is required to raise the nursery. Planting is done at the beginning of the rainy season either in mounds or ridges or in well-drained loose soils on flat ground. In Ghana only sprouted tubers are planted with the growing end placed above the soil surface and not covered by soil. Burying tubers will delay sprouting. Ridges are spaced at 90cm and plants are spaced at 15cm to 20cm in the ridges, resulting in a plant density of about 50,000 plants/ha. In South Africa tubers are planted at a depth of 5cm to 10cm with a spacing of 25cm on ridges spaced at 75cm (Nkansah, 2004).

According to Nkansah (2004), cuttings are planted in pairs facing opposite directions. They are placed at a depth of 5cm, but with the growing point clearly above the soil surface. Vine

cutting collected from the nursery should be spaced at 30cm x 15cm (Peter, 2007). Farmers in Ghana apply wood ash and diluted cattle urine prior to planting to promote growth and development of the crop (Nkansah, 2004).

When the crop is well established, earthing up the soil is necessary for good tuber development (Peter, 2007).


Plate 2.4: A frafra potato farm in Bongo-soe, Upper East Region, Ghana.

## 2.5 NUTRIENT MANAGEMENT OF CULTIVATED FRAFRA POTATOES

Frafra potato is grown either as a sole crop or intercropped with Bambara groundnut, yam, okra, millet, maize or sorghum. Because of the comparatively low yields, people hardly apply manure or fertilizer (Nkansah, 2004). Reports however indicate that in Ghana better yields are obtained when a liberal application of organic material is incorporated into the ridges or mounds before planting and followed by a top dressing of NPK fertilizer (Nkansah, 2004). According to Kerala Agriculture University (2002), broadcasting ten tonnes of farmyard manure and NPK at 30:60:50 kg per hectare at the time of land preparation is good for frafra

potatoes. Kerala Agriculture University (2002) further indicates that farm yard manure (10 t/ha) has been identified as the best source of manure for frafra potatoes.

## 2.6 SOIL

Like most root crops, frafra potatoes does best in deep, well-drained soils that are well prepared before planting so that the underground portion can develop to its full size with minimal restriction. Well-drained sandy loams are preferable to clays since the crop is sensitive to water logging NRC (2006).



## 2.7 WEED MANAGEMENT

According to NRC (2006), weeding is required only in the first stage of growth, that is, before the stems begin to spread. Spreading foliage shades out competing species. Also covering a portion of the vine with soil, promotes tuber formation Peter (2007).

## 2.8 DAY LENGTH SENSITIVITY OF CULTIVATED FRAFRA POTATOES

Recent work shows that, the South African counterpart (*Plectranthus esculentus*) is day length sensitive with a critical photoperiod of 12.5-13 hours (NRC, 2006). No literature has however been cited on the day length sensitivity of frafra potatoes.

## 2.9 DISEASES AND PEST OF FRAFRA POTATOES

According to Nkansah (2004), the incidence of pests and diseases in frafra potato is generally low. However, the following has been observed; Tuber rot, virus mottling, scab as well as damage by termites, centipedes and potato weevils. Millipedes bore holes in the tubers. Grasshoppers and stem borers may attack the leaves. Nkansah (2004) further notes that in South Africa, it is believed the crop suppresses nematode populations but the Crop Research Institute in Kumasi (Ghana), has however found that infestation by nematodes may rather

lead to large yield losses. Pigs are a serious pest of frafra potatoes when they are allowed to roam freely. NRC (2006) indicates that *Pycnarmon cribata*, *Phostria piasusalis, Hymenia curvalis*, have been reported from India as being important. These have however been controlled by spraying with pesticides such as dimethoate.

## 2.10 HARVESTING OF CULTIVATED FRAFRA POTATOES

Depending on the place and the plant, the tubers are ready for harvesting after 120-200 days. In Ghana, frafra potato mature in about three months (FAO, 2010).When the leaves and stems begin to whither, it is a sign that tubers have reached maturity (NRC, 2006). Harvesting is done with the tubers still attached by gently excavating them. The tubers are then removed and packed in baskets or sacks. Matured tubers left in the soil decays at a faster rate (Nkansah, 2004).

## 2.11 YIELD OF CULTIVATED FRAFRA POTATOES

Tuber yield depends strongly on the amount and regularity of rain. In Ghana, yields range between 5 and 15 t/ha when conditions are good but are considerably lower when soil fertility or rainfall is poor. An experimental work carried out at Roodeplaat in South Africa has indicated that the potential yield could be up to 45 t/ha when adequate irrigation and plant nutrients are provided together with good agronomic practices (Nkansah, 2004).

## 2.12 CHEMICAL AND NUTRITIONAL COMPOSITION

The nutritional importance of frafra potatoes cannot be overemphasized. For instance, a standard serving provides a large percentage of the daily requirement of calcium and vitamin A (in the form of β-carotene) as well as more than the daily complement of iron (NRC, 2006). NRC (2006) further indicates that the tubers contain 5-13 percent protein (calculated

on a dry weight basis). In addition, the protein of *P. esculentus* is well endowed with essential amino acids (threonine, tyrosine, methionine, valine, leucine, lysine, etc.). A serving thus contributes a fair portion of the daily protein requirement. According to NRC (2006), the food energy content of frafra potatoes is also good, almost 400 calories per 100g dry matter of *S. rotundifolius* tubers. Even in their current horticulturally fairly primitive form, they can yield a lot of food from a small area. According to a study conducted by GGAP (1977), frafra potato ranks the highest in protein content amongst the tuber crops grown in Ghana. The study revealed that frafra potato has a protein content of 1.9 g / 100 g as compared with that of sweet potato (0.8g / 100g), yam (1.8g / 100g), and cassava (0.7g / 100g). According to Stone *et al.* (2011), frafra potatoes also provides twice the protein offered by common potatoes (*Solanum tuberosum*).The principal amino acids in the protein are arginine, aspartic and glutamic acids (NRC, 2006). Compared to common potatoes and most cereal grains, frafra potatoes are one of the most nutritionally complete staple crops available. In areas where a shortage of vitamin-rich vegetables leads to endemic malnutrition, frafra potatoes could be a helpful solution, Stone *et al.* (2011).

## 2.13 UTILISATION OF FRAFRA POTATOES

The tubers of frafra potatoes are mostly boiled before consumption. However, they can also be roasted, baked, or fried. Indeed, they can probably replace potato (*Solanum tuberosum*) in each and every recipe, even potato salad (National Research Council, 2006).

Frafra potatoes also have some medicinal importance. Abapol (1997) revealed that frafra potato is used in the treatment of dysentery, blood in urine and eye disorders in Africa. He further indicated the crop also has a lot of socio-cultural importance such as presentation as gifts to in-laws, served as food to mourners at funerals, and snacks at child naming ceremonies. According to Tetteh *et al.* (1997), a local alcoholic drink has also been brewed

from frafra potato. It is also believed that one can stay for a long time without food after a meal of frafra potatoes. For this reason, it is the favourite dish served to hunters or persons engaged in strenuous activities which demand that they stay off food for long periods of time.

Plate 2.5: Cooking *P. rotundifolius* tubers as upperi, in north Karela (a similar frafra potato dish in Bongo-soe).

Source: Wikipedia (03/06/2013)

## 2.14 POST HARVEST HANDLING OF FRAFRA POTATOES

Traditionally, the tubers of frafra potatoes are stored in the ground under a tree, where it is cooler than in the open. When stored in this manner under hot conditions the special taste of frafra potato mostly lasts for two months only after which the tubers become bland and are no longer considered a delicacy (Nkansah, 2004). Nkansah (2004) further notes that frafra potatoes can also be packed in bags or baskets stuffed with straw but if these are kept under warm conditions the tubers will shrivel at a faster rate and will no longer be edible. To keep the tubers a bit longer, people put them in pots sealed with cow dung. In cooler conditions however, storage is easier.

According to Tindall (1983), tubers of frafra potatoes can be successfully stored by packing them in dry sand under cool shaded conditions. Processing for storage in dehydrated form may be considered for tubers meant for consumption.

A research work conducted, in some farming communities in upper east region, by Alagumpola (2007), indicates that storage of frafra potatoes can be classified into two major ways:

Storage of tubers for use as planting materials; under this method, tubers are stored with straw and or chaff in pots. This protects the planting materials from storage pest and also creates a conducive environment for the tubers to sprout.

Storage of tubers for consumption; under this method, tubers may be stored in pits, baskets, pots or on the floor of cool rooms. Storage of tubers for consumption can also be done after they have been parboiled.

### 2.14.1 Storage problems of frafra potatoes

Frafra potato is difficult to store. No matter the method of storage practiced there are high losses, especially under bulk storage (Tetteh *et al.,* 1997). Tindall (1983) reported that one of the major problems of *Solenostemon rotundifolius* tubers is loss during storage. According to FAO (2010), frafra potato tubers can only be stored for two months after which they begin to sprout. Sprouted tubers are not palatable.

The following problems have been observed during storage of frafra potatoes:

Sprouting; preliminary observation of tubers acquired for this research work showed some tubers sprout as early as one month after harvesting. Tetteh *et al.* (1997), indicates that storage in sand or pits promotes early sprouting of tubers. Early sprouting of tubers defeats the usability of frafra potatoes as a hunger crop.

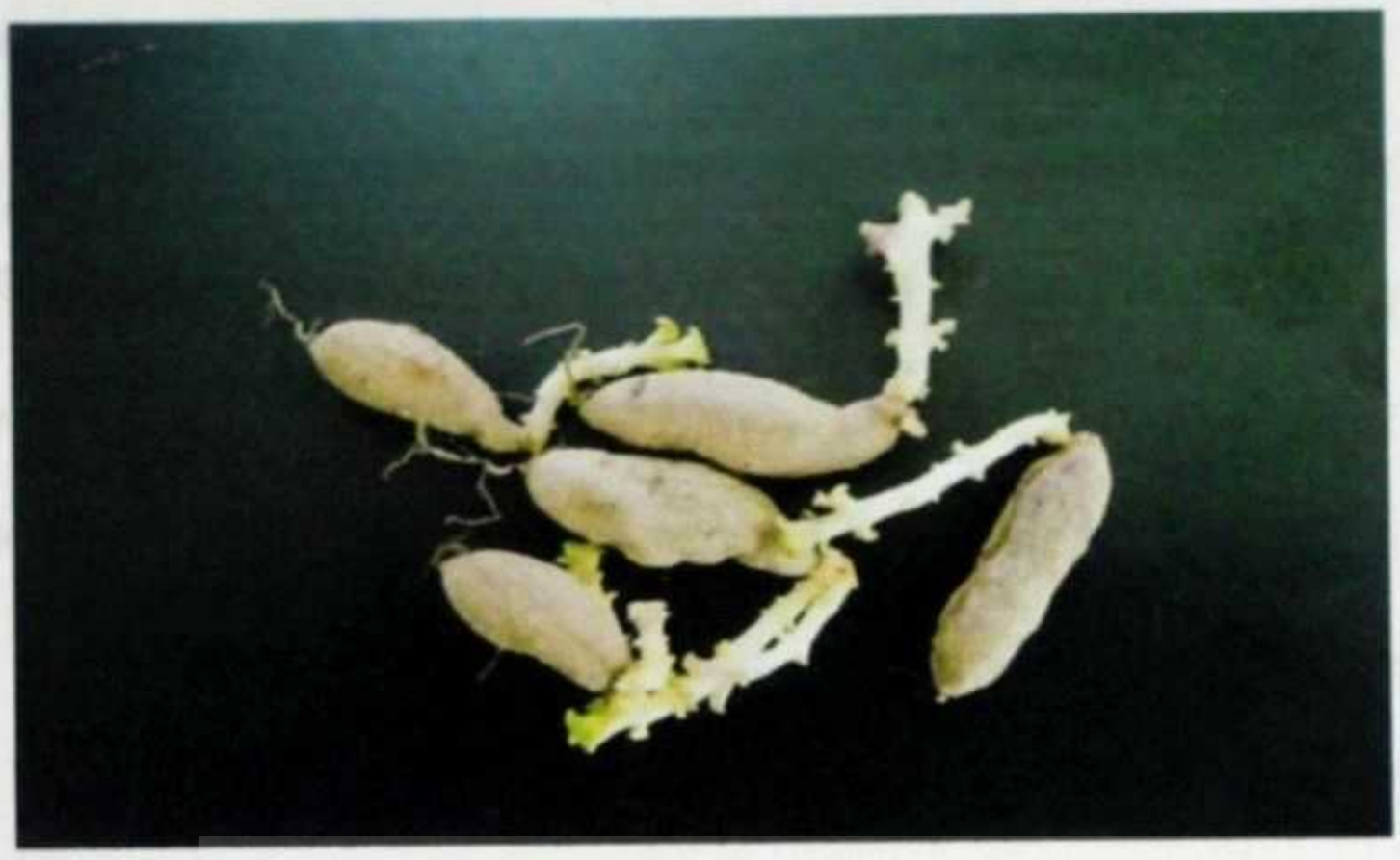

Plate 2.6: Sprouted frafra potato tubers



Rotting of tubers; Alagumpola (2007) revealed that rotting of tubers is another problem facing tubers in storage. However, the cause and prevention of this problem in Ghana has not been cited in any literature. A preliminary observation of tubers acquired for this research backs Alagumpola's claims. Tubers that rot during storage normally exude a black liquid substance.

Plate 2.7: Frafra potato tubers showing signs of decay

### 2.14.2 Effects of rot on the postharvest life of roots and tubers

Postharvest rot has been a major contributor to postharvest losses of roots and tubers. Rots from microbial infestation of healthy tubers normally reduce their table quality and renders them unappealing to consumers (Amusa, 1999).

According to Bonire (1985), postharvest losses in yam due to postharvest rots are about 40%. Rees *et al.* (2003) also indicates that, of the range of factors that precipitate losses of marketable tubers, rots are the most immediately apparent causing both primary and secondary damage.

Postharvest losses as a result of rot pathogens have also been reported in cassava. According to Okigbo *et al.* (2009), Postharvest deterioration is the most important cause of loss in cassava production and is mainly as a result of microbial invasion of the tubers. In sweet potato cultivation, Postharvest rots have been noted to be a major factor limiting its usage. According to Mutuura *et al.* (1992), rotting of sweet potato root tubers is rated as the seventh (out of seventeen) most important production constraint of sweet potato production in Kenya.

#### 2.14.2.1 Causal agents of postharvest rot in roots and tubers

Roots and tubers have been subjected to different diseases by different post-harvest rot organisms including viruses, fungi, bacteria, nematodes etc. In yam, the pathogens that commonly cause storage rots include: *Colletotrichum gloeosporioides*, *Botryoidplodia theobromea*, *Aspergillus spp*, *Penicillium spp*, *Sclerotium rolfsii*, *curvularia verruculosa*, *Rhizoctonia solani* and *Fusarium moniliforme* (Nwankiti and Okpala, 1981; Green, 1994).

The following rot pathogens have also been identified in Ghana by Lawrence *et al.* (2000); *Phioma spp, Rhizopus spp, Phomopsis spp, Altenaria spp, Acremonium strictum, Nigrospora oryzae, Sclerobinia bacaticola, Cladosporium herbarum, Pestalotia spp, Ascochyba spp.*

Also in Sweet potatoes, pathogens commonly associated with storage rots are *Ceratocystis fimbriata* (a fungus that causes Black rot), *Fusarium* (a fungus that causes Fusarium surface rot and Fusarium root rot), *Rhizopus stolonifer* (a fungus that causes Rhizopus soft), *Diplodia gossypina* (a fungus that causes Java black rot), *Erwinia chrysanthemi* (a bacteria that causes Bacterial soft rot, also known as bacterial stem and root rot), *Monilochaetes infuscans* (a fungus that causes scurf, also known as soil-stain), *Macrophomina phaseoli* (a fungus that causes Charcoal rot) (Sikora *et al.*,1995).

For frafra potatoes, until recently, no work has been cited on the pathogens associated with rot in storage. A research work in Nigeria indicates that the following pathogens are associated with rot during storage; *Aspergillus niger*, *Fusarium oxysporum*, *Penicillium expansum* and *Rhizopus stolonifer* (Mohammed *et al.*, 2013). However, in Ghana, no research work has been cited on the pathogens causing rot in storage.

### 2.14.2.2 Control of storage rots of roots and tubers

Several measures have been recommended for the control of rot in roots and tubers. According to Knoth (1993), rot, especially in yam and cassava, is mostly caused by fungus and bacteria pathogens and that these pathogens can only penetrate the skin of the tuber through damaged spots, like injuries, lesions and holes made by nematodes. An important precaution, therefore, is to minimise the risk of injury to the tuber during harvest, transport and storage by handling it carefully. Tubers already showing signs of rot at the time of being stored should also be put to some other use. Knoth (1993) further indicates that tubers should be checked on a regular basis so that infested tubers can be removed from the store at the right time. Curing of tubers has also been reported to reduce both water loss and the incidence of decay by wound pathogens (Rivera *et al.*, 1974; Passam *et al.*, 1976; Been *et al.*, 1977). Curing heals/closes wounds so that agents causing rot can no longer enter the tuber.

According to Okigbo (2004), low temperature storage also slows down the metabolism of pathogens and frequently arrests rotting. However, the pathogens are rarely killed and thus making it possible for rotting to restart rapidly when the produce are returned to ambient temperatures.

The use of synthetic chemicals has also been found to be effective in the control of storage rots. For instance, Sodium orthiophenylphenate, borax, captan, thiobendazole, benomyl and sodium hypochlorite have been found to significantly reduce storage rot in yam (Booth, 1974; Noon, 1978,). The fungicides thiabendazol and benomyl has also been used to control rot (Demeaux and Vivier, 1984). The use of synthetic chemicals is however expensive and can also leave harmful residues in the environment (Okigbo and Ikediugwu, 2000). No research work has been cited on the use of synthetic chemicals to control storage rot of frafra potatoes.



### 2.14.2.3 The use of plant extracts to control storage rot of roots and tubers

Studies on the use of plant extracts have opened a new avenue for the control of plant diseases. These plant extracts have been reported to be safe and non-phytotoxic to man, but effective against plant pathogens (Shivpuri *et al.,* 1997).

Extracts from leaves of *Carica papaya*, *Cassia alata*, *Cassia fistula* and stems of *Citrus limon* have been found to inhibit the growth of *Collectotrichum gloeosporiodes* (Banos *et al.*, 2002). Extracts of leaves of both Neem and Lantana plants have also been found to significantly reduce the growth of *Fusarium oxysporium* (Srivastava *et al.*, 2011). Equally, extracts from leaves of *Zingiber officinale*, *Vernonia amygdalina*, *Senna alata*, *Cymbopogon citrates* and *Ricinus communis* are known to have antifungal effects against yam rot (Amusa, 2001; Nahunaro, 2008). Osunde (2008) also indicates that neem bark water extract

applied to yam delayed rotting by three months. No research work has however been cited on the use of plant extracts to control storage rot of frafra potatoes in Ghana.

### 2.14.3 Effect of sprouting on the postharvest life of roots and tubers

Tuber sprouting during storage is caused by the cessation of natural dormancy of the tuber (Eshela *et al.*, 2011). Sprouting is normally associated with quality loss in roots and tubers. For instance: it increases reducing sugar content, respiration, water loss and glycoalkaloid content (Burton 1989; Suttle, 2004). In the United States, Sprouting is considered to be one of the most important physiological factors of post-harvest loss (Suttle, 2004).



#### 2.14.3.1 Control of sprouts in roots and tubers

The following methods have been used to control/reduce sprouting rates in some roots and tubers:

##### 2.14.3.1.1 Gamma Irradiation

Gamma irradiation can induce lesions on nucleic acids and cellular proteins thus preventing them from multiplying. Gamma irradiation applied at doses of about 7.5 head has been reported to inhibit sprouting of yams, potatoes and sweet potatoes (Diop, 1998). Diop (1998) further indicates that this technique has not yet been applied on a commercial scale in the tropics and is unlikely to be of practical value to farmers because of the cost of the high technology involved. Furthermore it is a treatment that is not widely acceptable to consumers or a permitted treatment for food commodities in some developed countries (Diop, 1998). No research work has been cited on the use of this method to control sprouts in frafra potatoes.

##### 2.14.3.1.2 Manipulation of storage temperatures

Lower storage temperatures are widely practiced as a technique for reducing the metabolic activity of roots and tubers and prolonging their dormancy. Temperatures of 16° C to 17°C

have been used to prolong the storage period for *D. alata* tubers for up to four months, provided the tubers were properly cured prior to storage (Diop, 1998).

For potatoes (*Solanum tuberosum*), sprout growth is practically negligible at 4°C and below and increases with increasing temperature. However, reducing temperatures to control sprouting leads to sweetening of the tuber, which lowers the value of the stored crop (Diop, 1998). No research work has however been cited on the use of this method to control sprouting in frafra potatoes in Ghana.



**2.14.3.1.3 The use of chemical sprout inhibitors**

Several synthetic chemicals have been found to be effective in the control of sprouting in roots and tubers. The following chemicals have good sprout suppressing ability in some roots and tubers: Maleic hydroxide, α–naphthalene acetic acid, methylester, isopropyl N-(3chlorophenyl) carbonate and 1, 2, 4, 5 tetra chloro-3nitro benzene (Gómez *et al.*, 2010). Treatment with such chemicals however produces many undesirable side effects (McQeen, 1985). According to David (2009), the unavailability of the right type of chemicals, their toxic nature and the widespread adulteration of the available chemicals makes the use of Chemical sprout inhibitors a serious problem. No research work has been cited on the use of this method to control sprouting in frafra potatoes.

**2.14.3.1.4 The use of plant extracts as sprout inhibitors**

Some extracts of plant origin have also been found to possess inhibitory effects on sprouting of roots and tubers. For instance essential oils from *Eucalyptus* and *Coriandrum Sativum* have been found to be effective anti-sprouting agents on potato tubers (Gómez *et. al.*, 2010). According to Spencer and Vaughan (1991), cinnamaldehyde which can be extracted from

cassia flowers or the bark of the cinnamon tree completely inhibited sprouting on stored tubers. Also, the effect of neem bark water extract, neem bark slurry and neem leaf slurry treatments on the quality of stored yam showed that sprouting was delayed by one month in all neem treated tubers (Osunde, 2008). No research work has however been cited on the use of plant extracts to control sprouting of frafra potatoes in Ghana.

## 2.15 WATER ACTIVITY OF FRAFRA POTATO FLOUR

The water activity of food describes the degree to which water is bound in the food, its availability to participate in chemical/ biochemical reactions and its ability to make possible the growth of microorganisms (IFT/FDA, 2001). Water activity was developed to account for the strength with which water associates with various non-aqueous constituents and solids (Clinquart, 2011). There is a critical water activity level below which no microorganisms can grow. Pathogenic bacteria cannot grow bellow a water activity of 0.85, whereas yeast and molds are more tolerant to reduced water activity, but usually no growth occurs below a water activity of about 0.60 (Rahman, 2009). Most fresh foods have a water activity values that are close to the optimum growth level of most microorganisms, 0.97 to 0.99 (Novasina, 2006). Novasina (2006), further indicates that the water activity of flours range from 0.80 to 0.87. However, the water activity value of frafra potato flour has not been cited.

Water activity values are obtained with either capacitance or dew point hygrometers and according to Fontana (2008), these values are important in predicting food stability and safety with respect to microbial growth, rates of deteriorative reactions and physical properties. For instance, water activity values play significant roles such as determining the water migration levels in multi-component foods, the textural properties of foods, the shelf life of food products, and the enzyme, protein, carbohydrate and vitamin stability of foods.

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 GEOGRAPHICAL LOCATION OF EXPERIMENT

The experiment was carried out in the laboratory of the Department of Horticulture, Faculty of Agriculture-KNUST. Proximate determinations of tubers were done at the laboratory of the Institute of Renewable Natural Resources, KNUST, and the Biochemistry laboratory of the Department of Biochemistry, KNUST. Water activity analysis of tubers was done at the Food Research Institute (FRI) of the Council for Scientific and Industrial Research (CSIR), Accra. The rot identification of tubers was also done at the pathology laboratory of the Faculty of Agriculture, KNUST. The research work began on 2nd November 20012 and ended on 22nd March 2013.

## 3.2 SOURCE OF CULTIVARS

Black and Brown cultivars of frafra potato tubers were used for the experiment. These tubers were all obtained from a single farm in Bongo-soe, in the Bongo district of the Upper East Region of Ghana. The farm was monitored from planting to harvest. The tubers were obtained on the day of harvest and transported on that same day to the location of experiment (Department of Horticulture, KNUST).

## 3.3 SOURCE OF BOTANICALS

The botanicals from which the extracts were prepared from were pawpaw (*Carica papaya*) leaves, neem (*Azadirachta indica*) barks, and rhizomes of Ginger (*Zingiber officinale).*



Plate 3.1: Botanicals (Neem bark, ginger and pawpaw leaves) used in the experiment

## 3.4 EXTRACT PREPARATION AND APPLICATION

Fresh leaves of pawpaw and neem barks were obtained from trees on KNUST campus. However, the rhizomes of *Zingiber officinale* were bought from the Ayigya market in Kumasi. The botanicals were washed and air dried. A killogramme each of the botanicals was measured with an electronic scale and then pound separately into paste with a mortar and pestle. The pounded pastes were then kept in three separate buckets and four litres of water poured into each. Each was mixed thoroughly and then allowed to settle for eighteen hours. Extract application was done by soaking tubers in the prepared extracts for thirty minutes.

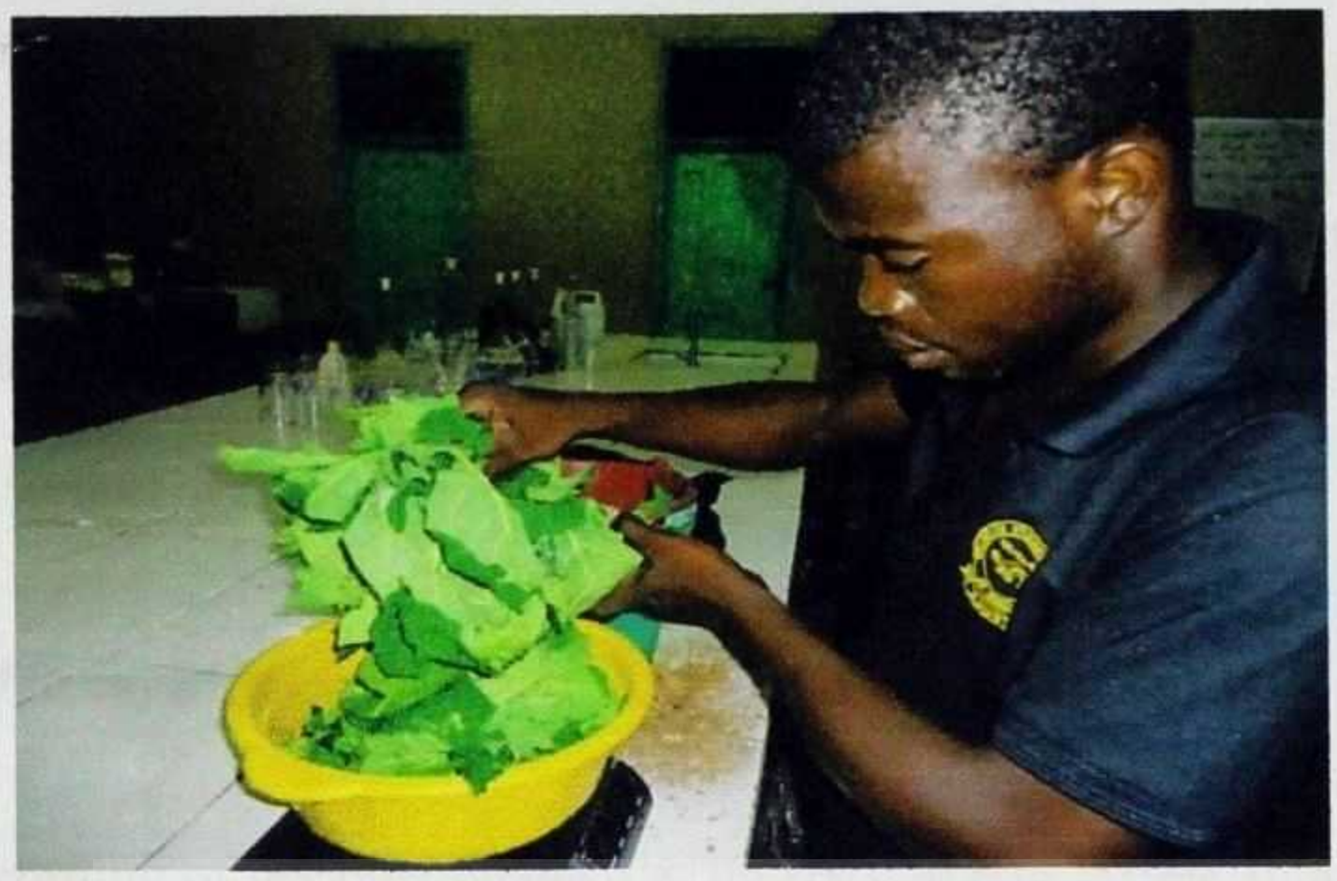

Plate 3.2: Weighing of botanicals (pawpaw leaves) used in the experiment

Plate 3.3: Extract application

## 3.5 DATA RECORDED

Data was collected on the following parameters during the experiment:

### 3.5.1 Temperature and relative humidity of storage room

Daily temperature and humidity readings were taken at 9.00 am, 12.00 midday, 6.00 pm and 12.00 midnight during storage. The "Acurite" indoor digital humidity and temperature Monitor (00325) was used to take the readings.

### 3.5.2 Weight of tubers

Weight of tubers was recorded every two weeks. The measurement was done in grammes with Kern electronic Precision Scale PCB 350-3. Weight loss of tubers was calculated by subtracting final weight of tuber from initial weight of tuber.

### 3.5.3 Number of decayed tubers

Counting and recording of decayed tubers, i.e. tubers showing visible signs of rot, was done every two weeks. Percentage rot was calculated as shown below:



$$\text{Percentage rot (\%)} = \frac{\text{Number of decayed tubers at the end of the storage period}}{\text{Total number of tubers stored}} \times 100$$

### 3.5.4 Identification of rot pathogens

Tubers with visible signs of rot were taken to the Pathology laboratory of the Faculty of Agriculture for identification of the possible pathogens responsible for the rot. This was done fortnightly.

The procedure involved taking pieces of diseased tissues (2-5 mm square) from the margin of the necrotic lesion using a sterile scapel blade. The next step involved surface sterilizing the necrotic tissue segments and this was done by immersing the tissue segments in 10 % commercial bleach solution in a beaker. Duration of sterilization was one minute. Tissue segments were taken out of the sterilant solution in intervals of 10 seconds and blotted dry with a clean paper towel. This ensured that at least some of the segments were exposed to the sterilant for the appropriate period of time. The surface sterilized tissue segments were then plated on a medium, PDA, using a pair of forceps which was flamed sterilized periodically.

The plates were sealed with a sellotape to prevent desiccation and contamination and then incubated in an incubator at room temperature until growth occurred. The plates were then observed daily for fungal growth from the tissues. The characteristics of the spore and mycelium were studied using a compound microscope. The characteristics observed were used in identifying the rot organisms according to standards described by Mathur and Kongsdal (2003) and Barnett and Hunter (1972).

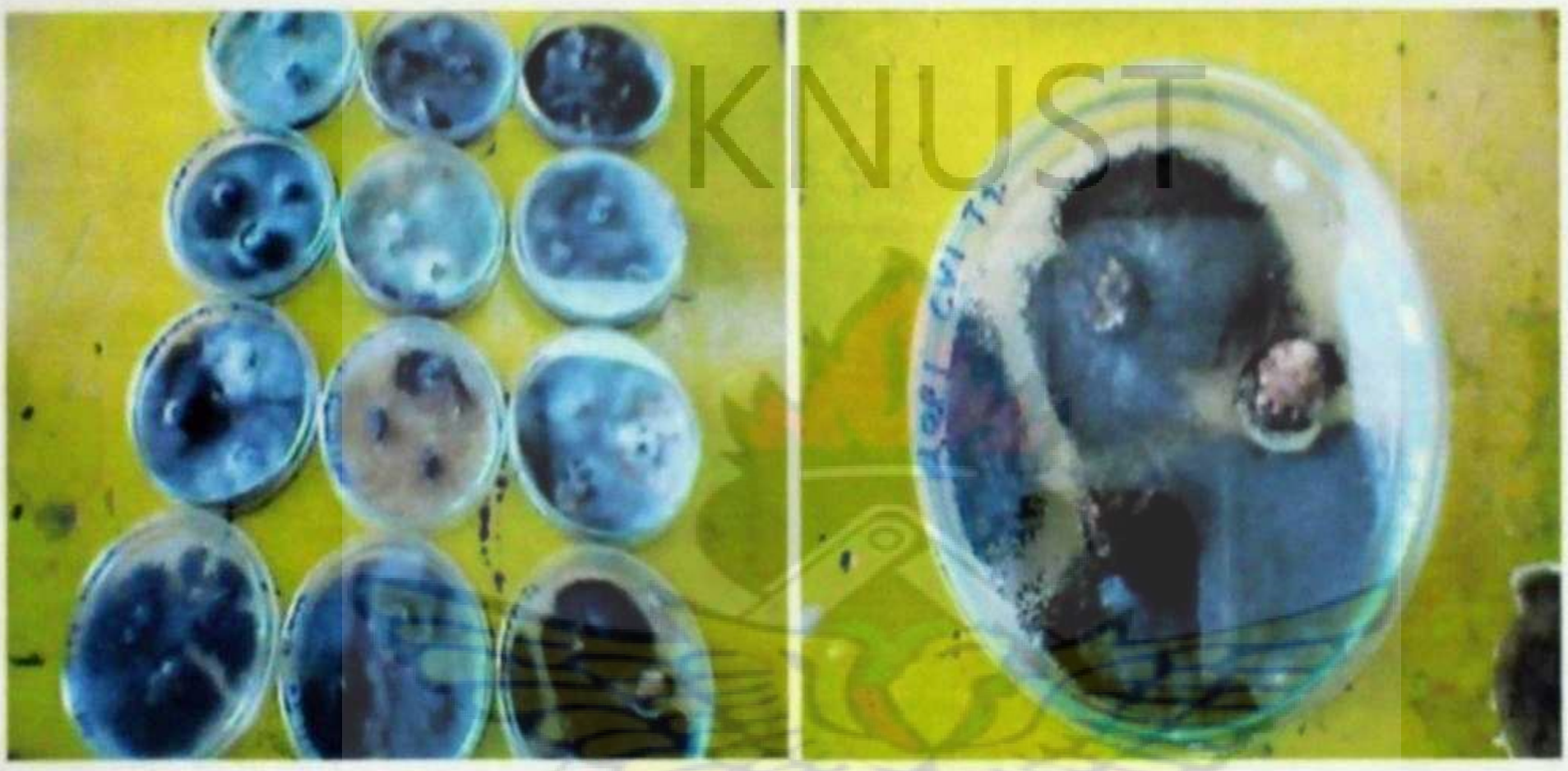

Plate 3.4: Plates showing fungal growth

### 3.5.5 Water activity of frafra potato flour

The water activity measurements were done at the beginning and at the end of the experiment. The Rotronic HygroLab 2 water activity meter (#29348002) was used to determine the water activity of samples. The determination was done by inserting the sample (frafra potato flour i.e. ground frafra potato tubers) into the measuring chamber of the water activity meter. The measurement probe was then inserted firmly onto the sample in the chamber. The start button was pressed to start the measurement. The trend arrows appear sixty (60) seconds after the start button of the equipment has been pressed. Some few seconds was then allowed for the probe to be in equilibrium with the sample indicating the steady

humidity and temperature readings. The "ON" button was pressed to freeze the display (i.e. readings). The reading displayed was recorded and the end button on the instrument pressed to end the measurement. The sample was removed and the next sample inserted.

### 3.5.6 Number of sprouted tubers

Counting and recording of decayed tubers was done every two weeks. This was done by visually observing and recording tubers showing signs of sprouting. Percentage sprout of tubers was calculated as shown below:



$$\text{Percentage tuber sprout (\%)} = \frac{\text{Number of sprouted tubers}}{\text{Total number of tubers stored}} \times 100$$

### 3.5.7 PROXIMATE ANALYSIS

Proximate analysis was also done at the beginning of the experiment and end of the experiment (i.e. at Week 1 and Week 21 respectively). Proximate analysis provides information on the basic chemical composition of food samples. The components measured were moisture, ash, protein, fat, fibre, and nitrogen free extract. Proximate determination was done following guidelines from the 'Integrated laboratory methods practical manual' prepared by the Department of Biochemistry and Biotechnology, KNUST.

#### 3.5.7.1 Determination of moisture content

A 5.00 g sample of ground frafra potato tubers was transferred to a previously dried and weighed dish. The dish was then placed in an oven, thermostatically controlled at 105 °C, for five hours. The dish was removed and placed in a desiccator to cool to room temperature and weighed. The sample was dried again for 30 minutes, cooled down and weighed. The process was repeated until a constant weight was reached. Percentage moisture was calculated by:

$$\text{Percentage moisture (\%)} = \frac{\text{(weight of wet sample - weight of dry sample)}}{\text{weight of wet sample}} \times 100$$

### 3.5.7.2 Determination of crude fat (ether extract)

A previously dried 250 ml round bottom flask was weighed and 2.00 g of dried sample (ground frafra potato tubers) was transferred into a 22 × 80 mm paper thimble. The next step involves placing a small ball of cotton wool into the thimble to prevent loss of the sample. 150 ml of petroleum spirit (B.P 60-80 $^{\circ}$C) was added to the round bottom flask and the apparatus assembled. The quickfit condenser to the soxhlet extractor was then connected and refluxed for 4 hours on high heat (16 hours on normal heat) on the heating mantle. After extraction, the thimble was removed and the solvent recovered by distillation. The flask with the fat was heated next for 30 minutes in an oven at a temperature of 103 $^{\circ}$C. The flask and its contents were then cooled to room temperature in a desiccator. The final step involved accurately weighing the flask and determining the weight of the fat collected. The fat content, expressed as a percentage by weight, was calculated as:

$$\text{Percentage fat (\%)} = \frac{\text{Mass (g) of the extracted matter}}{\text{Mass of the tested sample}} \times 100$$

### 3.5.7.3 Determination of crude fibre

The sample from the crude fat determination was transferred into a 750 ml Erlenmeyer flask and approximately ½ g of asbestos added. The next step involved adding 200 ml of boiling 1.25% $H_2SO_4$ and immediately setting the flask on a hot plate and connecting the condenser. The contents started boiling within one minute. Care was taken to keep material

from remaining on the sides of the flask. At the end of 30 minutes, the flask was removed and immediately filtered through a linen cloth in a funnel and washed with a large volume of boiling water until the residue washing was no longer acidic. The filtrate containing the sample from the acidic hydrolysis and asbestos was washed back into the flask with 200 ml boiling 1.25% NaOH solution. The flask condenser was connected and boiled for exactly 30 minutes. The contents in the flask were filtered again through a linen cloth and washed thoroughly with boiling water until residue washing was no longer basic. The next step involved washing the filtered residue with approximately 15ml alcohol and transferred to a porcelain crucible quantitatively with water. The crucible and its contents were next dried for one hour at 105 $^{o}$ C. The sample was then cooled in the desiccator and reweighed. The crucible was ignited again in a furnace for 30 minutes, cooled and reweighed. Loss of weight observed was reported as the crude fibre content. Percentage fibre was calculated by:

$$\text{Percentage crude fibre (\%)} = \frac{\text{Weight of crude fibre}}{\text{Weight of sample}} \times 100$$

### 3.5.7.4 Determination of ash content

A 2.00 g sample (ground frafra potato tubers) was transferred into a crucible, which was previously ignited in a muffle furnace (pre-heated to 600 $^{o}$ C) for two hours. The crucible was removed, permitted to cool in a desiccator and weighed. Percentage ash was calculated as:

$$\text{Percentage ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

### 3.5.7.5 Determination of protein content

The Kjeldahl method was used in determining the protein content. In this method, a sample was heated in the presence of a catalyst (0.7 g mercury oxide and 15 g potassium sulphate) and digested till the carbon and hydrogen were oxidized, as the protein nitrogen was reduced and transformed into ammonium sulphate. The concentrated sodium hydroxide was added, and the digest heated to drive off the liberated ammonium sulphate into a volume of standard acid solution. The unreacted acid was determined and by calculation, the percentage nitrogen in the sample determined. In the calculation, the assumption was that, N is derived from protein containing 16% N, and multiplying the N value by 100/16 or 6.25, an approximate protein value was obtained.



### 3.5.7.6 Determinations of nitrogen free extract

The determination of nitrogen free extract (NFE) was made after completing the analysis for ash, crude fibre, ether extract and crude protein. The calculation was made by adding the percentage values on dry matter basis of these analysed contents and subtracting them from 100%. That is,

Percentage NFE= 100 % - (% crude protein + % ether extract + % crude fibre + % ash)

## 3.6 TREATMENT DETAILS

CV1= Black cultivar

CV2 = Brown cultivar

T1= Pawpaw leaf extract

T2 = Ginger rhizome extract

T3 = Neem bark Extract

T4 = water (control)

## 3.7 EXPERIMENTAL DESIGN AND ANALYSIS

A 2 x 4 factorial in a completely randomized design was used with two cultivars and four treatments which were replicated three times. Data resulting from individual parameters were subjected to analysis of variance using Statistix Student version 9.0 and means separated at 5 percent (p=0.05) least significant differences.

# CHAPTER FOUR

# RESULTS

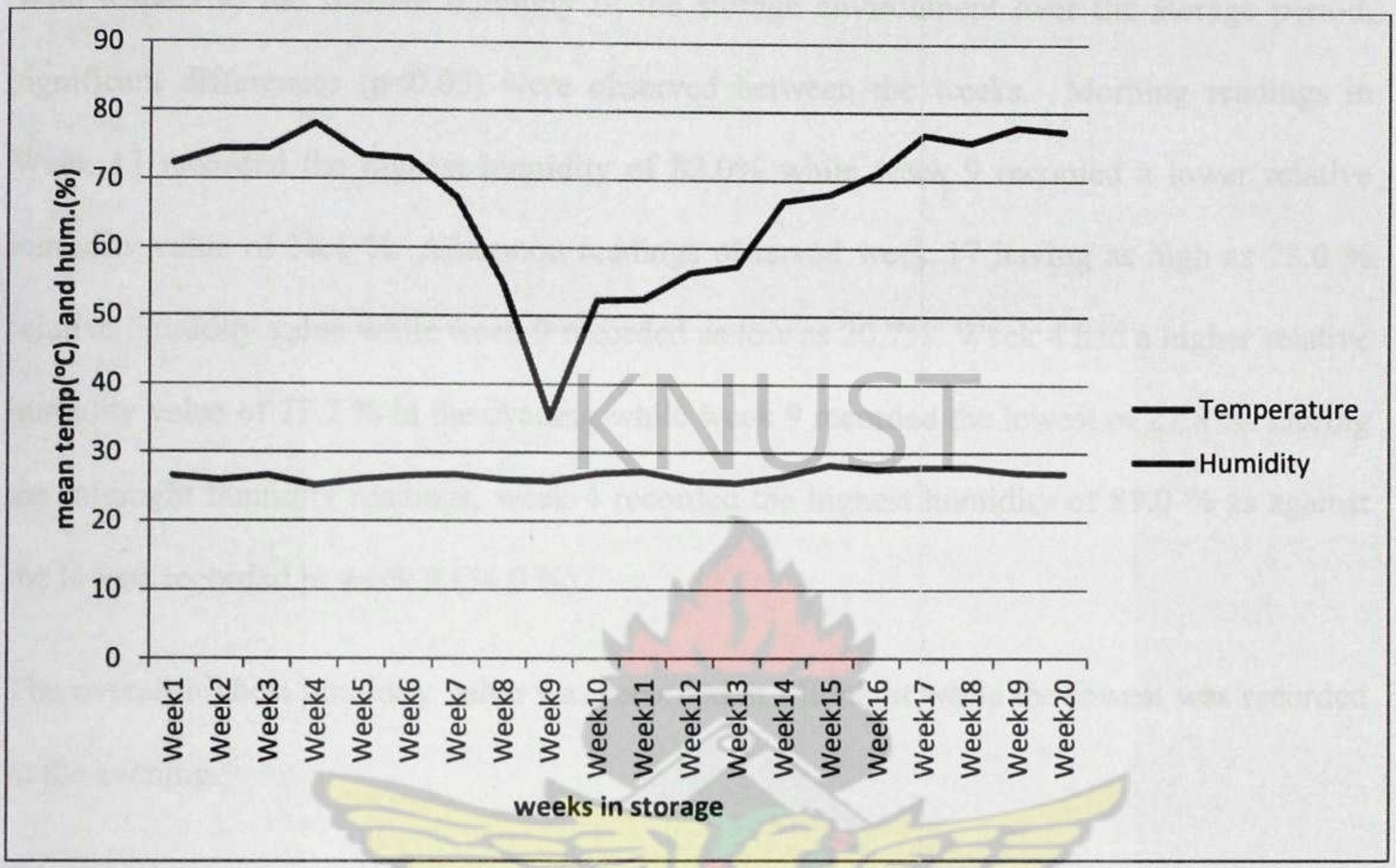


Figure 4.1: Average temperature and Relative Humidity values over the Storage Period

## 4.1 TEMPERATURE AND HUMIDITY OF THE STORAGE ROOM

Temperature readings over the storage period showed significant variations ($p<0.05$) only in the evening and at mid night. Week 15 recorded the highest average temperature of $30.5^0$ C in the evening while the lowest was recorded at week 4 ($24.8^0$ C). Midnight temperatures readings showed week 17 recording the highest of $26.6^0$ C and week 12 having as low as $20.3^0$ C. Both morning and afternoon temperatures did not vary significantly ($p>0.05$) with temperature readings ranging from $24.0^0$ C to $27.3^0$ C in the morning and $28.0^0$ C to $30.1^0$ C in the afternoon.

The highest temperature over the whole period was record in the evening while the lowest was recorded at mid night.

With respect to the relative humidity of the storage environment over the storage period, significant differences ($p<0.05$) were observed between the weeks. Morning readings in Week 17 recorded the highest humidity of 82.0% while week 9 recorded a lower relative humidity value of 38.1 %. Afternoon readings observed week 17 having as high as 73.0 % relative humidity value while week 9 recorded as low as 20.7%. Week 4 had a higher relative humidity value of 77.7 % in the evening while week 9 recorded the lowest of 27.8 %. During the midnight humidity readings, week 4 recorded the highest humidity of 89.0 % as against the lowest recorded in week 9 (54.0 %).

The overall highest humidity value was recorded at Midnight while the lowest was recorded in the evening.

The average temperature reading over the storage period ranged from 24.0° C and 29.0 °C. The highest average temperature recorded over the storage period was 29.0° C. This was recorded during midday and in the evening at 6:00 pm. The lowest was recorded at (12:00 am).

Average relative humidity reading during the storage period ranged from 58.0 % at 12:00 noon and 6:00 pm and 78.0 % at 12:00 midnight. This reading was inversely proportional to that of the temperature reading thus relative humidity increased with decreasing temperature.

## 4.2 ORGANISMS IDENTIFIED TO BE RESPONSIBLE FOR ROT

Table 4.1: Isolated organisms identified to be responsible for rot in two cultivars of frafra potatoes treated with plant extracts.

| Extract | Organisms in Black cultivar | Organisms in Brown cultivar |
|---|---|---|
| Pawpaw leaf extract | *Curvularia lunata, Colletotrichum gloeosporiodes, Aspergillus niger* | *Collectotrichum gloeosporiodes and Penicillium sp* |
| Ginger rhizome extract | *Curvularia lunata, Colletotrichum gloeosporiodes, Aspergillus niger, Aspergillus flavus* | *Trichoderma sp, Curvularia lunata and Collectotrichum gloeosporiodes* |
| Neem Bark Extract | *Colletotrichum, Penicillium, Aspergillus niger* | *A. Niger, Trichoderma, Curvularia lunata, Colletotrichum gloeosporiodes* |
| Water (control) | *A. niger, Curvularia lunata, Colletotrichum gloeosporiodes* and *Aspergillus flavus* | *Collectotrichum gloeosporiodes, Aspergillus niger and A. flavus* |

From the results, five genera of organisms were identified to be associated with rot on the stored tubers. These were: *Curvularia sp., Colletotrichum sp., Aspergillus sp., Penicillium sp.* and *Trichoderma sp. Colletotrichum sp.* was observed to be the most dominant of all the genera and was found to cause rot in all the treatments. *Penicillium sp.* and *Trichoderma sp.* were observed to be the least dominant, appearing in only two of the treatments. *Aspergillus sp.* was the only genera that recorded two different rot causing species, *niger* and *flavus*. In total, six different organisms were identified.

## 4.3 EFFECT OF CULTIVAR ON PERCENTAGE SPROUTING

Table 4.2: Effect of cultivar differences on percentage sprouting (%)

| Cultivars | wk11 | wk13 | wk15 | wk17 | wk19 | wk21 |
|---|---|---|---|---|---|---|
| **Black** | 1.72 | 1.74 | 2.39 | 3.67 | 6.06 | 6.93 |
| **Brown** | 1.40 | 2.26 | 4.05 | 5.64 | 6.60 | 6.97 |
| **Lsd** | 0.23 | 0.23 | 0.24 | 0.38 | 0.22 | 0.11 |
| **Cv %** | 17.13 | 12.92 | 8.59 | 9.36 | 3.93 | 1.80 |



The results in Table 4.2 show the effect of the cultivars on the sprouting of the frafra potato tubers over the storage period. From the table, there were significant differences (P>0.05) between the two cultivars from the week 11 through to the 19th week. However, there was no significant difference between the cultivars on the 21st week. The Black cultivar recorded significantly higher percentage sprout of 1.72 % on the 11th week. However, from the 13th to 19th week, the brown cultivar recorded significant higher percentage sprouting of 2.26 % on the 13th week, 4.05 % on the 15th week, 5.64 % on the 17th week and 6.60 % on the 19th week. The Brown cultivar also recorded the highest percentage sprouting on the 21st week. However, the difference between the cultivars was not statistically significant. Thus, there was no significant difference between the two cultivars with respect to the total percentage sprout after the storage period.

## 4.4: EFFECT OF THE ORGANIC EXTRACTS ON PERCENTAGE SPROUTING.

Table 4.3: Extract effect on percentage sprouting

| Extracts | wk11 | wk13 | wk15 | wk17 | wk19 | wk21 |
|---|---|---|---|---|---|---|
| **Pawpaw leaf** | 1.54 | 1.93 | 3.16 | 4.71 | 6.32 | 7.00. |
| **Ginger rhizome** | 1.40 | 1.72 | 2.83 | 4.83 | 6.47 | 6.99 |
| **Neem bark** | 1.55 | 1.95 | 3.21 | 4.62 | 6.27 | 6.88 |
| **Water (control)** | 1.74 | 2.39 | 3.68 | 4.47 | 6.28 | 6.93 |
| **Lsd** | 0.33 | 0.32 | 0.34 | 0.54 | 0.31 | 0.16 |
| **CV (%)** | 17.13 | 12.92 | 8.59 | 9.36 | 3.93 | 1.80 |



The results in Table 4.3 show the effect of the extracts on sprouting of frafra potato. From the results, the control recorded significantly higher sprouting as compared to the extracts. At week 11, the control recorded significantly higher percentage sprout of 1.74 % as against 1.55 % by neem bark extracts, 1.40 % by Ginger rhizome extract and 1.54 % by pawpaw leaf extract. Week 13 also showed the control recording a higher sprouting of 2.39 % which was significantly higher than that recorded by the ginger rhizome extract (1.72 %), Pawpaw leaf extract (1.93%) and neem bark extracts (1.95 %). The control still recorded significantly higher percentage sprout of 3.68% at week 15 which was statistically different from that recorded by the neem bark extract (3.21 %), ginger rhizome extract (2.83%) and pawpaw leaf extract (3.16 %). Week 17 however saw the control recording a lower percentage sprout of 4.47 % which was not statistically different from that of the Pawpaw leaf extract (4.71 %), ginger rhizome extracts (4.83 %) and neem bark extract (4.62 %). Also, there was no significant difference between the extracts at week 19 and 21. Thus, the total percentage sprout after the storage period did not show significant differences.

## 4.5 INTERACTIVE EFFECT OF EXTRACTS AND CULTIVARS ON SPROUTING

Table 4.4: The interactive effect of the extracts on sprouting of two cultivars of frafra potato

| Source of Variation | wk11 | wk13 | wk15 | wk17 | wk19 | wk21 |
|---|---|---|---|---|---|---|
| **CV1/T1** | 1.00 | 1.49 | 2.32 | 3.69 | 6.13 | 7.05 |
| **CV1/T2** | 1.52 | 1.73 | 1.99 | 3.94 | 6.13 | 6.95 |
| **CV1/T3** | 1.58 | 1.82 | 2.35 | 3.72 | 5.92 | 6.83 |
| **CV1/T4** | 1.49 | 1.91 | 2.88 | 3.35 | 6.07 | 6.88 |
| **CV2/T1** | 2.08 | 2.37 | 3.99 | 5.73 | 6.50 | 6.95 |
| **CV2/T2** | 1.26 | 1.72 | 3.67 | 5.71 | 6.81 | 7.02 |
| **CV2/T3** | 1.52 | 2.08 | 4.08 | 5.73 | 6.63 | 6.93 |
| **CV2/T4** | 2.00 | 2.87 | 4.47 | 5.59 | 6.48 | 6.98 |
| **Lsd (5%)** | 0.47 | 0.45 | 0.48 | 0.76 | 0.44 | 0.22 |
| **CV (%)** | 17.13 | 12.92 | 8.59 | 9.36 | 3.93 | 1.80 |

**Note: CV1 = Black cultivar CV2= Brown cultivar T 1= Pawpaw, T 2= Ginger rhizome T3 = Neem Extract T 4= Control (water)**

Table 4.4 shows percentage of tubers that sprouted over the 21 weeks of storage. From the results in the table, sprouting was observed to have started from the 11week onwards with percentage of sprouted tubers increasing with duration of storage.

There were significant differences ($p<0.05$) between the interactive effect of the cultivars and the organic extracts over the weeks. By the $11^{th}$ week, there was significant difference between all the interactions and the control. However, there was no significant difference between the interactions between the brown cultivar treated with water and brown cultivar

treated with pawpaw leaf extracts. The brown cultivar treated with pawpaw leaf extracts recorded the highest percentage sprouting (2.08 %) followed by the brown cultivar treated with water (2.00 %). The black cultivar treated with pawpaw leaf extract recorded the least sprouting (1.00 %) as at the 11$^{th}$ week. The brown cultivar treated with water (control) record the highest percentage of sprouts with 2.87 % sprout in week 13 while the black cultivar treated with pawpaw leaf extracts recorded the lowest sprout of 1.49 % followed by black cultivar treated with ginger rhizome extracts (1.73 %). By the end of the 15$^{th}$ week, the brown cultivar treated with water (control) still recorded a higher sprouting percentage of 4.47 % while the black cultivar treated with ginger extract also recording the lowest sprouting of 1.99 %. Week 17 saw the brown cultivar treated with neem bark extract and brown cultivar treated with pawpaw leaf extract both recording 5.37 % sprout while the black cultivar treated with water recording the lowest sprout of 3.34 %. Black cultivar treated with neem bark extract recorded the lowest percentage sprout of 5.92 % as at week 19 with the brown cultivar treated with ginger rhizome extract recording the highest sprouting of 6.81 %. At week 21, the black cultivar treated with pawpaw leaf extract recorded the highest sprouting of 7.05 % while the black cultivar treated with neem bark extract recorded the lowest sprouting of 6.83 %. Also, the brown cultivar treated with ginger rhizome extract recorded the highest sprouting of 7.02 % while the brown cultivar treated with neem bark extract recorded the lowest sprouting of 6.93 %.

At the end of the storage period, the total percentage of sprouted tubers did not show significant differences ($p>0.05$) among the treatments however both cultivars treated with neem bark extracts recorded the lowest sprouting.

## 4.6: CULTIVER EFFECT ON SOME QUALITY PARAMETERS OF FRAFRA POTATO

Table 4.5: Cultivar effect on some quality parameters of frafra potato

| Cultivar | Water activity (aW) | Weight loss (g) | Protein | Ash content | NFE | Moisture | Fat content | Fibre | Rot (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Black** | 0.69 | 25.65 | 4.72 | 3.76 | 0.76 | 7.25 | 0.30 | 0.77 | 1.73 |
| **Brown** | 0.71 | 17.68 | 4.75 | 3.25 | 0.76 | 6.86 | 0.54 | 0.59 | 1.45 |
| **Lsd** | 8.31E-03 | 6.37 | 0.23 | 0.08 | 0.04 | 0.09 | 0.08 | 0.05 | 0.33 |
| **CV (%)** | 1.36 | 33.60 | 5.58 | 2.45 | 5.52 | 1.48 | 15.25 | 8.89 | 23.48 |

### 4.6.1: EFFECT OF CULTIVAR ON THE WATER ACTIVITY OF FRAFRA POTATO FLOUR

On cultivar types, the two cultivars varied significantly ($P<0.05$) from each other with respect to the water activity of the flours. The brown cultivar recorded a higher water activity value of 0.71 (from Table 4.5) while the black cultivar recorded a significantly lower water activity value of 0.69.

### 4.6.2: EFFECT OF CULTIVAR ON WEIGHT LOSS OF FRAFRA POTATO TUBERS

The differences between the individual effects of the two cultivars with respect to weight loss were significant ($P<0.05$). From table 4.5, the black cultivar recorded the highest weight loss of 25.65 grammes while the brown cultivar recorded the lowest weight loss of 17.68 grammes.

### 4.6.3: EFFECT OF CULTIVAR ON THE PROTEIN CONTENT OF FRAFRA POTATO FLOUR

There was no statistical difference between the cultivars with respect to the protein content of the flour. The black cultivar and the brown cultivar both recorded 4.72 % and 4.75 % protein content respectively.

### 4.6.4: EFFECT OF CULTIVAR ON THE ASH CONTENT OF FRAFRA POTATO FLOUR

Considering Ash content of the flour produced from the tubers, there were significant differences recorded between the two cultivars ($P<0.05$). The black cultivar recorded 3.76 % ash content which was significantly higher than that recorded by the Brown cultivar which was 3.25 %.

### 4.6.5: EFFECT OF CULTIVAR ON THE NITROGEN FREE EXTRACT (NFE) CONTENT OF FRAFRA POTATO FLOUR

There were no significant differences ($p>0.05$) with respect to the individual effect of the cultivar. The two cultivars recorded the same value of 0.76 % (Table 4.5).

### 4.6.6: EFFECT OF CULTIVAR ON THE MOISTURE CONTENT OF FRAFRA POTATO FLOUR

From Table 4.5, there were significant differences recorded between the two cultivars with respect to moisture content of the flour ($P<0.05$). The black cultivar recorded 7.25 % moisture content which was significantly higher than 6.86 % recorded by the Brown cultivar.

### 4.6.7: EFFECT OF CULTIVAR ON THE FAT CONTENT OF FRAFRA POTATO FLOUR

The two cultivars showed significant differences among themselves ($P<0.05$) with regards to the fat content of flour. The brown cultivar recorded significantly higher fat content of 0.54 % while the black cultivar recorded as low as 0.30 % fat content.

### 4.6.8: EFFECT OF CULTIVAR ON FIBRE CONTENT

There were significant differences recorded between the two cultivars ($P<0.05$).The black cultivar recorded 0.77 % fibre content which was significantly higher than the 0.59 % recorded by the brown cultivar.

### 4.6.9: EFFECT OF CULTIVAR ON PERCENTAGE ROT

There were no statistical differences between the two cultivars though the black cultivar recorded 1.73 % rot which was higher than that recorded by the brown cultivar. The brown cultivar recorded 1.45 % rot.

## 4.7: EFFECT OF ORGANIC EXTRACTS ON SOME QUALITY PARAMETERS OF FRAFRA POTATO

Table 4.6: Effect of Different organic Extracts on some Quality parameters of frafra potato

| Extracts | Water activity (aW) | Weight loss (g) | Protein | Ash content | NFE | Moisture | Fat content | Fibre | Rot (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Pawpaw leaf** | 0.70 | 23.62 | 4.73 | 3.48 | 0.76 | 7.02 | 0.41 | 0.68 | 1.45 |
| **Ginger rhizome** | 0.70 | 17.75 | 4.64 | 3.53 | 0.74 | 7.06 | 0.41 | 0.69 | 1.50 |
| **Neem bark** | 0.70 | 21.02 | 4.94 | 3.51 | 0.79 | 7.03 | 0.43 | 0.68 | 1.56 |
| **Water (control)** | 0.69 | 24.26 | 4.63 | 3.48 | 0.74 | 7.11 | 0.43 | 0.68 | 1.85 |
| **Lsd** | 0.01 | 9.01 | 0.33 | 0.11 | 0.05 | 0.13 | 0.08 | 0.08 | 0.46 |
| **CV (%)** | 1.36 | 33.60 | 5.58 | 2.45 | 5.52 | 1.48 | 15.25 | 8.89 | 23.48 |

### 4.7.1: EFFECT OF ORGANIC EXTRACTS ON THE WATER ACTIVITY OF FRAFRA POTATO FLOUR

There were no significant differences between the different plant extracts. The water activity values ranged from 0.69 for water (control) and 0.70 for pawpaw leaf extract.

### 4.7.2: EFFECT OF EXTRACTS ON WEIGHT LOSS OF FRAFRA POTATO TUBERS

The extracts on their own did not show any significant differences ($P>0.05$) with respect to weight loss of the tubers. The weight loss by the tubers however ranged from 17.75 grammes for ginger extract and 24.26 grammes for water (control).

### 4.7.3: EFFECT OF EXTRACTS ON PROTEIN CONTENT OF FRAFRA POTATO FLOUR

The different plant extracts did not vary significantly from each other though neem bark extract recorded slightly higher protein content than the remaining extracts. The protein content ranged from 4.63 % to 4.94 % (Table 4.6).

### 4.7.4: EFFECT OF EXTRACTS ON ASH CONTENT OF FRAFRA POTATO FLOUR

The individual effect of the extracts did not show any significant differences ($P>0.05$) in terms of the ash content. Values obtained ranged from 3.48 % to 3.51 %.

### 4.7.5: EFFECT OF EXTRACTS ON NITROGEN FREE EXTRACT (NFE) CONTENT OF FRAFRA POTATO FLOUR

There were no significant differences ($p.>0.05$) with respect to the individual effect of the extracts. The NFE values recorded as a result of the extract effect ranged from 0.74 % for both pawpaw leaf and water (control) and 0.93 % for Neem bark extract (from Table 4.6).

### 4.7.6: EFFECT OF EXTRACTS ON MOISTURE CONTENT OF FRAFRA POTATO FLOUR

The individual effect of the extracts did not show any significant differences (P>0.05) in moisture content. Values obtained ranging from 7.02 % for pawpaw leaf extract and 7.11 % for water, which served as the control.

### 4.7.7: EFFECT OF EXTRACTS ON FAT CONTENT OF FRAFRA POTATO FLOUR

The organic extracts on their own did not show any significant differences (p>0.05) between each other. The fat content however ranged from 0.41% and 0.43%.



### 4.7.8: EFFECT OF THE ORGANIC EXTRACTS ON FIBRE CONTENT

The individual effect of the extracts did not show any significant differences (P>0.05) with fibre content values ranging from 0.68 % and 0.69 %.

### 4.7.9: EFFECT OF THE ORGANIC EXTRACTS ON PERCENTAGE ROT

From the results, there were no significant differences recorded between the different extracts used with respect to the percentage rot. However, the highest percentage rot was recorded by the control (1.85 %) whiles the least was recorded by pawpaw leaf extract (1.45 %).

## 4.8: INTERACTIVE EFFECT OF EXTRACTS AND CULTIVARS ON SOME QUALITY PARAMETERS OF FRAFRA POTATO

Table 4.7: Interactive effect of extracts and cultivars on some quality parameters of frafra potato

| Interaction | Water activity (aW) | Weight loss (g) | Protein | Ash | NFE | Moisture | Fat | Fiber | Rot (%) |
|---|---|---|---|---|---|---|---|---|---|
| CV1/T1 | 0.69 | 21.49 | 4.86 | 3.73 | 0.77 | 7.18 | 0.27 | 0.74 | 1.38 |
| CV1/T2 | 0.68 | 22.00 | 4.54 | 3.79 | 0.73 | 7.23 | 0.28 | 0.78 | 1.72 |
| CV1/T3 | 0.69 | 28.38 | 4.92 | 3.78 | 0.79 | 7.28 | 0.30 | 0.77 | 1.75 |
| CV1/T4 | 0.69 | 30.74 | 4.58 | 3.72 | 0.73 | 7.31 | 0.34 | 0.79 | 2.07 |
| CV2/T1 | 0.70 | 25.75 | 4.60 | 3.24 | 0.74 | 6.86 | 0.55 | 0.62 | 1.52 |
| CV2/T2 | 0.71 | 13.51 | 4.74 | 3.27 | 0.76 | 6.89 | 0.54 | 0.60 | 1.28 |
| CV2/T3 | 0.71 | 13.67 | 4.97 | 3.23 | 0.80 | 6.79 | 0.57 | 0.58 | 1.38 |
| CV2/T4 | 0.71 | 17.78 | 4.68 | 3.25 | 0.75 | 6.92 | 0.52 | 0.57 | 1.63 |
| **Lsd** | 0.02 | 12.75 | 0.46 | 0.15 | 0.07 | 0.18 | 0.11 | 0.11 | 0.65 |
| **CV (%)** | 1.36 | 33.60 | 5.58 | 2.45 | 5.52 | 1.48 | 15.25 | 8.89 | 23.48 |

**Note: CV1 = Black cultivar CV2= Brown cultivar T 1= Pawpaw leaf extract, T 2= Ginger rhizome extract T3 = Neem bark extract T 4= Control (water)**

### 4.8.1: INTERACTIVE EFFECT OF EXTRACTS AND CULTIVARS ON THE WATER ACTIVITY OF FRAFRA POTATO FLOUR

From the results in Table 4.7, the interactive effect of the cultivar and extract had a significant effect ($p<0.05$) on the water activity of flour produced from the frafra potatoes. The brown cultivar treated with neem bark extracts showed significantly higher water activity value (0.71) than the black cultivar treated with pawpaw leaf, neem bark, water (control) and ginger extract. It was however not significantly different ($p>0.05$) from the water activity values obtained in the brown cultivar treatments. The black cultivar treated with ginger rhizome extract obtained the lowest water activity value of 0.68.



### 4.8.2: INTERACTIVE EFFECT OF EXTRACTS AND CULTIVARS ON WEIGHT LOSS OF FRAFRA POTATO TUBERS

Weight loss of the tubers treated with the different extracts showed significant variation ($P< 0.05$). The black cultivar treated with water (control) recorded the highest weight loss of 30.74 grammes significantly different from those recorded by the brown cultivar treated with water (17.78 grammes), neem bark extract (13.67 grammes) and ginger extract (13.51 grammes). However, it was not statistically different ($P>0.05$) from those recorded by brown cultivar treated with pawpaw leaf extract (25.75 grammes) and black cultivar treated with pawpaw leaf extract, ginger extract, and neem bark extract. The brown cultivar treated with ginger rhizome extract recorded the lowest weight loss.

### 4.8.3: INTERACTIVE EFFECT OF EXTRACTS AND CULTIVARS ON PROTEIN CONTENT OF FRAFRA POTATO FLOUR

From Table 4.7, there were no significant differences ($p> 0.05$) between the interactions of the cultivars and the extracts with respect to protein content of the tubers. The protein content

ranged between 4.97 % for the brown cultivar treated with the neem bark extract and 4.54 % for the black cultivar treated with ginger extract.

### 4.8.4: INTERACTIVE EFFECT OF EXTRACTS AND CULTIVARS ON ASH CONTENT OF FRAFRA POTATO FLOUR

Table 4.7 shows the ash content of flour produced from tubers treated with the different organic extracts. From the results, the combined effect of the cultivar and the extract showed some level of significance. The black cultivar treated with ginger extracts recorded the highest Ash content of 3.79 % which was significantly different ($p<0.05$ ) from those recorded by the brown cultivar treated with pawpaw leaf extracts (3.24 %), ginger extracts (3.27%), neem bark extracts (3.23 %) and water (control) (3.25 %), it was however not statistically different ($p>0.05$) from those recorded by the black cultivar treated with pawpaw leaf extracts (3.73 %), neem bark extracts (3.78%) and water (control) (3.72 %).



### 4.8.5: INTERACTIVE EFFECT OF EXTRACTS AND CULTIVARS ON THE NITROGEN FREE EXTRACT (NFE) CONTENT OF FRAFRA POTATO FLOUR

Table 4.7 shows the Nitrogen Free Extract content of the potato flours produce from the frafra potatoes after the treatment with the organic extracts. From the results, the synergy effect of the cultivars and extracts showed some significant differences ($p<0.05$). The brown cultivar treated with neem bark extract recorded the highest nitrogen free extract content of 0.80 significantly different from that recorded by the brown cultivar treated with ginger extract, it was however not different from the remaining treatments.

### 4.8.6: INTERACTIVE EFFECT OF EXTRACTS AND CULTIVARS ON THE MOISTURE CONTENT OF FRAFRA POTATO FLOUR

From the results shown in table 4.7, the interactive effect of the cultivar and the extract showed some level of significance with regards to the moisture content of the flour. The

black cultivar treated with water recorded the highest moisture content of 7.31 % which was significantly different from those recorded by the brown cultivar treated with pawpaw leaf extracts (6.86 %), ginger extracts (6.89 %), neem bark extracts (6.79 %) and water (control) (6.92 %). It was however not statistically different from those recorded by the black cultivar treated with pawpaw leaf extracts (7.18 %), ginger extracts (6.89 %) and neem bark extracts (7.28 %).

### 4.8.7: INTERACTIVE EFFECT OF EXTRACTS AND CULTIVARS ON FAT CONTENT OF FRAFRA POTATO FLOUR



Results from table 4.7 shows the fat content of the two Frafra potatoes treated with the organic extracts. From the results, the interactive effect of the extract and the cultivars showed significant differences ($p<0.05$). The brown cultivar treated with neem bark extract recorded the highest fat content (0.57 %) though not significantly different from the other extracts applied on the same cultivar. However, it did vary significantly from that of the black cultivar treated with pawpaw, ginger, neem bark and the control (water). The black cultivar treated with pawpaw extracts recorded the lowest fat content of 0.27 %.

### 4.8.8 INTERACTIVE EFFECT OF EXTRACTS AND CULTIVARS ON FIBRE CONTENT

From the results shown in Table 4.7, the interactive effect of the cultivar and the extract showed some level of significance. The black cultivar treated with water (control) recorded the highest fibre content of 0.79 % which was significantly different ($p<0.05$) from those recorded by the brown cultivar treated with pawpaw leaf extracts, ginger extracts, neem bark extracts and water, it was however not statistically different ($p>0.05$) from those recorded by the black cultivar treated with pawpaw leaf extracts, ginger extracts and neem bark extracts

### 4.8.9 INTERACTIVE EFFECT OF EXTRACTS AND CULTIVARS ON PERCENTAGE ROT

From the results in Table 4.7, there were no significant differences ($p > 0.05$) between the interactions of the cultivars and the extracts. The percentage of rot ranged between 1.28 % for the brown cultivar treated with the ginger extracts and 2.07 % for the black cultivar treated with water (control). The interaction between cultivar and water (control) recorded the highest percentage rot in both the black and brown cultivars.

# CHAPTER FIVE

# DISCUSSION

## 5.1: TEMPERATURE AND HUMIDITY OF THE STORAGE ROOM

Temperature readings were generally low with high humidity between week 1 and week 10 of the storage period as compared to the readings from week 11 onwards. High temperatures are generally associated with increased sprouting which subsequently leads to weight loss of tubers (Song *et al.*, 2004 and Suhag *et al.*, 2006). The general increase in temperatures from week 11 could therefore be a contributory factor to the observed increase in sprouting from the 11th week onwards.

## 5.2 ORGANISMS IDENTIFIED TO BE ASSOCIATED WITH ROT

The pathogens identified to be responsible for causing decay in *Solenostemon rotundifolius* were six in number. *Colletotrichum gloeosporioides* was identified to be responsible for 30.76 % of rots observed, followed by *Aspergillus niger*, 23.07 %, *Curvularia lunata*, 19.23 %, *Aspergillus flavus*, 11.54 %, *Trichoderma sp* and *Penicillium sp* both recorded 7.70 % of rots observed.

The identification of *Aspergillus niger and Penicillium sp.* Confirmed the observations made by Mohammed *et al*. (2013). *Curvularia lunata, Colletotrichum gloeosporioides, Aspergillus niger, Aspergillus flavus, Penicillium sp* and *Trichoderma sp.* has also been found to be associated with rots in other roots and tubers (Nwankiti and Okpala, 1981; Green, 1994, Rees *et al.*, 2003, Messiga *et al*. 2004). These pathogens are wound pathogens that infect mechanically injured tubers and have been found to infect tubers in the field and later

manifest in storage (Rees *et al*., 2003, Okigbo *et al*., 2010). These microorganisms can also infect tubers through diseased foliage, mother tubers or roots (Nmeka *et al*., 2005).

The skin of *Solenostemon rotundifolius* tubers is easily damaged (Mohammed *et al.,* 2013) and farmers make matters worse with poor practices that encourage mechanical damage during harvesting, transportation and even storage. This may therefore explain the presence of these pathogens on frafra potatoes.

## 5.3 EFFECT OF THE EXTRACTS ON SPROUTING OF TUBERS

The initiation of sprouting generally marks the end of the dormancy period in root and tubers (Ellis *et al*., 2007). Initiation of sprouting leads to increased respiration and dry matter loss (Diop, 1998). Length of dormancy period of *Solenostemon rotundifolius* is from eight weeks onwards (FAO, 2010). Significant sprouting was observed in the 11$^{th}$ week, with the sprouting of the black cultivar treated with pawpaw leaf extracts recording the least sprouting. This was not however the case for the brown cultivar treated with pawpaw leaf extracts. This probably meant that the two cultivars responded differently to the treatments. The fluctuation in rate of sprouting between the two cultivars buttresses this observation. According to Babajide *et al.,* 2008, characteristics between species vary considerably.

A significantly high percentage of sprouted tubers were observed from week 15 to week 19. This observation could have been triggered by the high temperatures recorded from week 11 onwards. According to Song *et al.,* 2004 and Suhag *et al.,* 2006, increased temperatures during storage is associated with increased sprouting which subsequently leads to weight loss of tubers.

Generally, the treatments were able to suppress sprouting. However, the three extracts could not suppress the tubers from sprouting beyond eleven (11) weeks.

At the end of the experiment, neem bark extract treated tubers recorded the least percentage sprouts in both cultivars. This confirmed the observations made by Osunde in 2008. According to Osunde (2008), neem bark treatments on yam tubers affects sprouting rates and can even delay sprouting by up to one month. The fact that neem bark extract treated frafra potato tubers recorded the least sprouting may be an indication that it is more anti-sprouting than the other extracts.

## 5.4 EFFECT OF THE EXTRACTS ON WATER ACTIVITY OF FRAFRA POTATO FLOUR



No research work has been cited on the water activity values of frafra potato flour or the effect of plant extracts on these values. However, flours generally have a water activity value in the range of 0.80 to 0.87 (Novasina, 2006). The water activity values of the *Solenostemon rotundifolius* flour in this research work however ranged from 0.68 to 0.71 and this contradict the findings of Novasina (2006).

Pathogenic bacteria cannot grow below a water activity of 0.85 (Rahman, 2009). Rahman (2009) further indicates that yeast and molds are more tolerant to reduced water activity levels. Water activity levels ranging between 0.68 to 0.71 for *Solenostemon rotundifolius* flour therefore implies that the flour will be less susceptible to pathogenic bacteria in storage and more susceptible to yeast and molds in storage.

The two cultivars varying significantly in terms of water activity values could be due to cultivar differences that enabled varying degree of osmotic interaction. Babajide *et al.*, 2008, indicates that characteristics between species vary considerably. According to Andrew (1992), some products increase in water activity with increase in temperature whereas some other products decrease in water activity with increase in temperature caused by varying degree of osmotic interaction.

The extracts not showing any significant effect on water activity values of flour from the treated tubers could be that external extract treatments on tubers have no impact on water activity values of flour from processed tubers. Thus additives in the flour of frafra potatoes may rather have a significant effect on water activity values in storage. Suhendro *et al.* (1995) observed that the addition of glycerol reduced water activity of tortillas from 0.93 to 0.90.

The generally low water activity levels of the flour of the black cultivar (0.69) compared to that of the brown cultivar (0.71) indicates that the flour of the black cultivar would have a more stable enzymatic activity than the brown cultivar in storage. Novasina (2006) indicates that lower water activity levels lead to lower enzymatic activities. Enzymatic activities lead to changes in nutritional values, colour and flavour of produce (Novasina, 2006).



## 5.5 EFFECT OF THE EXTRACTS ON WEIGHT LOSS

Arif *et al.* (2010) attributed moisture loss, respiration and other metabolic activities to be the main cause of weight loss during storage. Sprouting is known to lead to increased respiration and dry matter loss (Diop, 1998). Weight loss leads to economic loss and also makes produce less attractive to potential buyers when sent to the market (FAO, 1990).

The black cultivar generally experienced greater weight loss as compared to the brown cultivar. This observation could be as a result of cultivar differences that enabled the black cultivar to experience greater moisture loss, respiration and other metabolic processes that promoted greater weight loss in storage. However, research work on the particular aspect of cultivar (tuber) physiology or biochemical activity of frafra potatoes responsible for this observation has not been cited.

The brown tubers treated with ginger extract recorded the least weight loss whiles pawpaw leaf extract also recorded the least weight loss for the black cultivar. This observation could also be as a result of cultivar differences.

## 5.6 EFFECT OF THE EXTRACTS ON PROTEIN CONTENT

The protein content averagely was 4.54 % for the black cultivar and 4.97 % for the brown cultivar. According to Allemann and Coertze (1997), protein content of *Solenostemon rotundifolius* ranges between 4.7 to 5.2 %. However, a higher range of 5-13 % has been reported by National Research Council (2006). Several factors might have influenced the protein content recorded in this experiment. A similar variation in protein content of yam has been attributed to factors including cultural practices, climate and edaphic factors under cultivation, maturity at harvest, and storage period (Osunde, 2008). The results clearly indicate that the extracts did not influence nor had any significant effect on the protein content of *Solenostemon rotundifolius*.

## 5.7 EFFECT OF THE EXTRACTS ON ASH CONTENT

The ash content of food materials reflect the mineral content in such foods ant this is influenced by factors such as soil mineral content, climatic conditions and harvest maturity (Ellis *et al.*, 2007).

The ash content of frafra potatoes in this experiment ranged from 3.23 to 3.79 % and this vastly contradicted the ash content of frafra potato, 1%, reported by Blench (1997) and FAO (1987). The black cultivar had significantly higher ash content than the brown cultivar and this could be attributed to cultivar differences. The experiment revealed that the ash composition is dependent on the cultivar and not the treatments and thus the treatments had

no significant impact on the ash content of *Solenostemon rotundifolius*. However, there was significant cultivar effect on the ash content after the storage period.

## 5.8 EFFECT OF THE EXTRACTS ON THE NITROGEN FREE EXTRACT (NFE) CONTENT

The nitrogen free extract (NFE) content was in the range of 0.73 % to 0.80 % and this contradicted the 21.4% reported by FAO (1987).

Neem bark treated brown cultivar had the highest, 0.80 %, NFE content while the black cultivar treated with ginger extract had the least percentage of 0.73 %. This probably means that the cultivars reacted differently to the extracts.

There was a significant interaction effect on NFE content. However, the treatments and the cultivars clearly did not show any significant effect.

## 5.9 EFFECT OF THE EXTRACTS ON MOISTURE CONTENT

Higher moisture content in flour has been reported to hasten spoilage by creating favourable conditions for microbial growth and enhancing enzymatic deterioration (Oduro *et al.*, 2009).

The moisture content ranged between 6.79 % and 7.31 %. The flour of *Solenostemon rotundifolius* is therefore expected to have a longer shelf life because of its low moisture content.

The results indicate that the black cultivar has significantly higher moisture (7.25 %) than the brown cultivar (6.86 %). This may be due to cultivar differences. Research work on the particular aspect of cultivar (tuber) physiology or biochemical activity of frafra potato tubers responsible for this observation has however not been cited.

The results also indicate that individually, the treatments had no significant effect on the moisture content of the cultivars. However, there was significant cultivar effect on the moisture content after the storage period.

## 5.10 EFFECT OF THE EXTRACTS ON FAT CONTENT

The fat content ranged from 0.27 to 0.57 %. Blench (1997) reported the fat content of *Solenostemon rotundifolius* to be 0.5 % whiles Allemann and Coertze (1997) also reported 3.5 %. The results obtained in the experiment could therefore be attributed to cultivar differences or the environment within which the tubers were cultivated (Osunde, 2008). This could also be the reason for the generally higher fat content in the brown cultivar than the black cultivar. The result also shows that the extracts did not have significant effect on the fat content. However, there was significant cultivar effect on the fat content after the storage period.

## 5.11 EFFECT OF THE EXTRACTS ON THE FIBRE CONTENT

Fibre content has beneficial effect in preventing cancer (Shankar and lanzar, 1991). The fibre content in this experiment ranged between 0.57 % and 0.79 %. This is greater than the fibre content reported by Blench (1997), 0.50 %, and less than that reported by Allemann and Coertze (1997), 3.5 %. The black cultivar is richer in fibre content (0.74 % to 0.79 %) than the brown cultivar (0.57 % to 0.62 %). Cultivar difference could be attributed to this observation. The extracts clearly had no significant effect on the fibre content of *Solenostemon rotundifolius*. However, there was significant cultivar effect on the fibre content after the storage period.

## 5.12 EFFECT OF THE EXTRACTS ON PERCENTAGE ROTTEN TUBERS

Generally, few tubers experienced decay during the experiment. This could be as a result of the antifungal properties of the extracts applied or lack of entry wounds on the tubers thus making it difficult for secondary infections. According to Knoth (1993), pathogens can only penetrate the skin of tubers through damaged spots, like injuries, lesions and holes. Injury on tuber skins can occur in the field, during harvesting, transportation or in storage.

Even though there were no significant differences on percentage rot among the treated tubers, and its interaction, the brown cultivar generally responded well to the extracts as they recorded a considerably lower percentage rot than the black cultivar. This observation could however be as a result of cultivar difference. It could also mean that the brown cultivars generally had fewer mechanically injured tubers. Injury on tubers paves way for rot pathogen infection (Knoth 1993).

In the brown cultivar, ginger recorded the least percentage rot of 1.28 % whiles the control recorded 1.63 %. This may be that ginger extracts were more fungitoxic on the rots of the brown cultivar than the extracts. A similar explanation could also be given to the observations in the black cultivar which experienced the pawpaw leaf extract treated tubers recording the least percentage rot of 1.38 % as compared to the other extracts.

The fungicidal properties of the extracts in reducing rot generally tend to be good since the control of both cultivars recorded greater rot than the extract treated tubers and this agrees with observations made by several authors; Banos *et al.*, 2002, Amusa 2001, Nahunaro 2008, Osunde 2008, Nmeka *et al.*, 2005. However, the extracts could not completely prevent rot from occurring as the efficacy may have reduced over time or as a result of tubers being infected already before the application of the extracts. According to Stuart *et al.* (2004), the

effect of a fungicide depends on the extent of latent infection, the amount of soil on the tuber and the interval between harvest and application.

# CHAPTER SIX

# CONCLUSION AND RECOMMENDATIONS

## 6.1 CONCLUSION

The study revealed that the pathogens associated with rot of frafra potatoes during storage were; *Curvularia lunata, Colletotrichum gloeosporioides, Aspergillus niger, Aspergillus flavus, Penicillium sp.* and *Trichoderma sp*. These are pathogens that can infect tubers after mechanical injury during harvesting, transportation or storage. *Colletotrichum gloeosporioides*, *Curvularia lunata*, *Aspergillus flavus* and *Aspergillus niger* were the most occurring rot pathogens (84.6 % of identified pathogens) whiles *Penicillium sp* and *Trichoderma sp.* were the least occurring (15.4 % of the identified pathogens).

Although there were no significant differences on percentage rot among the treated tubers, the extracts were effective in reducing rot as the percentage rot recorded was very low in all extract treated tubers than the control. The brown cultivar recorded the least rot when compared to the black cultivar. In the brown cultivar, ginger treated tubers recorded the least percentage rot whiles pawpaw extract treated tubers also recorded the least percentage rot in the treated black cultivars.

The study also found out that the extracts could not suppress tubers from sprouting over the entire storage period. However, the extracts were able to suppress sprouting for up to 11 weeks. The neem bark extract treated tubers recorded the least sprouting in both cultivars at the end of the storage period (week 21).

The differences between the individual effects of the two cultivars with respect to weight loss were significant. However, the extracts had no effect on weight loss after the storage period.

The black cultivar generally experienced greater weight loss. Brown tubers treated with ginger extract recorded the least weight loss whiles pawpaw extract treated tubers also recorded the least weight loss for the black cultivar.

Finally, the extracts applied on tubers before storage did not have any effect on the proximate composition of *Solenostemon rotundifolius* after the five months storage period. Even though there were significant cultivar and interaction effect on some proximate compositions, these could be attributed to cultivar differences or factors such as cultural practices, climate and edaphic factors under cultivation, maturity at harvest or the length of storage period.



## 6.2 RECOMMENDATIONS

1. Mechanical injury during harvesting, transportation and storage should be prevented or reduced since it may pave the way for infection by the rot pathogens identified to be associated with rot of frafra potatoes.

2. For better storage life, frafra potato tubers can be processed into flour. This is because the observed low water activity and moisture values of flour in this research work indicate that it will have a low enzymatic activity in storage and thus prolonging storage.

3. The tubers for this experiment were sourced from a single farm. More tubers should be collected from all the farming communities to fully identify the pathogens associated with rot in frafra potatoes.

4. Higher concentrations of neem bark extract should be investigated since its sprout suppressing ability was prominent on both cultivars at the end of the storage period.

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# APPENDIX

Average temperature and Relative Humidity values over the Storage Period

| | 9:00am | | 12:00noon | | 6:00pm | | 12:00am | |
|---|---|---|---|---|---|---|---|---|
| **Weeks** | **Temp$^0$c** | **Hum (%)** | **Temp$^0$c** | **Hum (%)** | **Temp$^0$c** | **Hum (%)** | **Temp$^0$c** | **Hum (%)** |
| **Week1** | 25.533 A | 77.333 A | 28.767 A | 62.100 ABCD | 28.033 AB | 64.100 ABCD | 23.900 ABC | 85.367 A |
| **Week2** | 25.100 A | 78.033 A | 28.467 A | 64.567 ABC | 27.033 AB | 68.767 ABC | 23.200 ABC | 86.000 A |
| **Week3** | 25.433 A | 80.533 A | 29.433 A | 67.200 ABC | 28.233 AB | 68.333 ABC | 23.433 ABC | 81.433 ABC |
| **Week4** | 24.700 A | 81.200 A | 29.033 A | 64.367 ABC | 24.800 B | 77.700 A | 22.333 ABC | 89.000 A |
| **Week5** | 25.100 A | 79.700 A | 28.533 A | 65.567 ABC | 27.333 AB | 67.200 ABC | 23.433 ABC | 81.533 ABC |
| **Week6** | 25.333 A | 79.800 A | 28.900 A | 66.367 ABC | 28.233 AB | 67.800 ABC | 24.033 ABC | 78.000 ABCD |
| **Week7** | 24.433 A | 75.767 A | 28.967 A | 56.800 ABCD | 28.967 A | 58.367 BCDEF | 24.867 ABC | 78.467 ABCD |
| **Week8** | 24.200 A | 64.333 AB | 28.000 A | 42.433 BCDE | 29.100 A | 43.533 EFGH | 22.800 ABC | 68.467 BCDE |
| **Week9** | 24.000 A | 38.100 B | 29.233 A | 20.667 E | 28.567 AB | 27.800 H | 21.567 BC | 53.967 E |
| **Week10** | 24.433 A | 69.300 AB | 29.433 A | 39.900 CDE | 30.000 A | 37.767 GH | 24.033 ABC | 62.233 DE |
| **Week11** | 25.533 A | 71.033 AB | 30.100 A | 38.800 CDE | 29.767 A | 34.300 GH | 23.667 ABC | 65.667 CDE |
| **Week12** | 25.767 A | 68.567 AB | 29.567 A | 32.867 DE | 27.900 AB | 46.667 DEFG | 20.367 C | 77.567 ABCD |
| **Week13** | 25.200 A | 61.433 AB | 28.233 A | 46.367 ABCDE | 28.233 AB | 41.900 FGH | 20.900 C | 79.633 ABC |
| **Week14** | 25.100 A | 77.133 A | 28.700 A | 57.300 ABCD | 28.900 A | 51.900 CDEFG | 23.533 ABC | 81.767 ABC |
| **Week15** | 27.033 A | 76.700 A | 29.233 A | 62.967 ABC | 30.533 A | 52.133 CDEFG | 26.100 AB | 80.300 ABC |
| **Week16** | 27.300 A | 76.333 A | 29.233 A | 67.133 ABC | 29.367 A | 61.667 ABCDE | 24.767 ABC | 79.333 ABC |
| **Week17** | 26.333 A | 82.033 A | 28.767 A | 72.967 A | 30.000 A | 69.200 ABC | 26.567 A | 82.533 AB |
| **Week18** | 26.467 A | 79.233 A | 28.967 A | 72.233 A | 30.333 A | 68.567 ABC | 26.000 AB | 82.433 AB |
| **Week19** | 26.667 A | 80.567 A | 29.967 A | 70.133 AB | 27.700 AB | 75.200 AB | 24.300 ABC | 85.567 A |
| **Week20** | 26.767 A | 77.867 A | 28.867 A | 72.000 AB | 28.200 AB | 73.300 AB | 24.200 ABC | 85.767 A |

# ANALYSIS OF PARAMETERS

## ROT

Student Edition of Statistix 9.0 Total Rot_Apuri, 09/06/2013, 17:56:44

**Analysis of Variance Table for total_rot**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Rep | 2 | 0.04078 | 0.02039 | | |
| variety | 1 | 0.45907 | 0.45907 | 3.30 | 0.0909 |
| Treatment | 3 | 0.56967 | 0.18989 | 1.36 | 0.2945 |
| variety*Treatment | 3 | 0.34991 | 0.11664 | 0.84 | 0.4955 |
| Error | 14 | 1.94983 | 0.13927 | | |
| Total | 23 | 3.36926 | | | |

Grand Mean 1.5894 CV 23.48



## WATER ACTIVITY

Student Edition of Statistix 9.0 Water Activity_Apuri, 03/06/2013, 18:44:08

**Analysis of Variance Table for aw1**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.00556 | 0.00278 | | |
| Cultivar | 1 | 0.00317 | 0.00317 | 16.53 | 0.0012 |
| Treatment | 3 | 0.00071 | 0.00024 | 1.23 | 0.3359 |
| Cultivar*Treatment | 3 | 0.00030 | 0.00010 | 0.53 | 0.6701 |
| Error | 14 | 0.00269 | 0.00019 | | |
| Total | 23 | 0.01243 | | | |

Grand Mean 0.6953 CV 1.99

**Analysis of Variance Table for aw2**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.00371 | 0.00185 | | |
| Cultivar | 1 | 0.00219 | 0.00219 | 24.24 | 0.0002 |
| Treatment | 3 | 0.00011 | 0.00004 | 0.41 | 0.7486 |
| Cultivar*Treatment | 3 | 0.00012 | 0.00004 | 0.45 | 0.7194 |
| Error | 14 | 0.00126 | 0.00009 | | |
| Total | 23 | 0.00739 | | | |

Grand Mean 0.6980 CV 1.36

## WEIGHT LOSS

Student Edition of Statistix 9.0 Weight Loss_Apuri, 09/06/2013, 17:00:37

**Analysis of Variance Table for wk3**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 15.979 | 7.98945 | | |
| Cultivar | 1 | 8.736 | 8.73627 | 1.11 | 0.3089 |
| Treatment | 3 | 17.316 | 5.77203 | 0.74 | 0.5474 |
| Cultivar*Treatment | 3 | 6.214 | 2.07137 | 0.26 | 0.8499 |
| Error | 14 | 109.703 | 7.83592 | | |
| Total | 23 | 157.948 | | | |

Grand Mean 3.6825 CV 76.02

**Analysis of Variance Table for wk5**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 10.583 | 5.2917 | | |
| Cultivar | 1 | 0.694 | 0.6936 | 0.04 | 0.8462 |
| Treatment | 3 | 74.047 | 24.6823 | 1.39 | 0.2871 |
| Cultivar*Treatment | 3 | 48.179 | 16.0595 | 0.90 | 0.4639 |
| Error | 14 | 248.683 | 17.7631 | | |
| Total | 23 | 382.186 | | | |

Grand Mean 3.5933 CV 117.29

**Analysis of Variance Table for wk7**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 14.698 | 7.3492 | | |
| Cultivar | 1 | 27.886 | 27.8857 | 5.56 | 0.0334 |
| Treatment | 3 | 0.698 | 0.2325 | 0.05 | 0.9862 |
| Cultivar*Treatment | 3 | 0.696 | 0.2321 | 0.05 | 0.9862 |
| Error | 14 | 70.166 | 5.0118 | | |
| Total | 23 | 114.144 | | | |

Grand Mean 1.7671 CV 126.69

**Analysis of Variance Table for wk9**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 7.6881 | 3.84403 | | |
| Cultivar | 1 | 0.0007 | 0.00070 | 0.00 | 0.9894 |
| Treatment | 3 | 4.7371 | 1.57905 | 0.41 | 0.7488 |
| Cultivar*Treatment | 3 | 12.5503 | 4.18345 | 1.08 | 0.3878 |
| Error | 14 | 54.0047 | 3.85748 | | |
| Total | 23 | 78.9810 | | | |

Grand Mean 1.5854 CV 123.88

**Analysis of Variance Table for wk11**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.3121 | 0.1560 | | |
| Cultivar | 1 | 18.5856 | 18.5856 | 4.73 | 0.0473 |
| Treatment | 3 | 6.7145 | 2.2382 | 0.57 | 0.6443 |
| Cultivar*Treatment | 3 | 6.1414 | 2.0471 | 0.52 | 0.6749 |
| Error | 14 | 55.0339 | 3.9310 | | |
| Total | 23 | 86.7875 | | | |

Grand Mean 1.7025 CV 116.46

**Analysis of Variance Table for wk13**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 2.9009 | 1.45043 | | |
| Cultivar | 1 | 0.6080 | 0.60802 | 0.17 | 0.6831 |
| Treatment | 3 | 7.3567 | 2.45223 | 0.70 | 0.5671 |
| Cultivar*Treatment | 3 | 10.8867 | 3.62889 | 1.04 | 0.4065 |
| Error | 14 | 48.9959 | 3.49971 | | |
| Total | 23 | 70.7481 | | | |

Grand Mean 1.3483 CV 138.75

**Analysis of Variance Table for wk15**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.8879 | 0.44393 | | |
| Cultivar | 1 | 3.5728 | 3.57282 | 9.38 | 0.0084 |
| Treatment | 3 | 0.8655 | 0.28849 | 0.76 | 0.5363 |
| Cultivar*Treatment | 3 | 1.4056 | 0.46854 | 1.23 | 0.3357 |
| Error | 14 | 5.3314 | 0.38081 | | |
| Total | 23 | 12.0632 | | | |

Grand Mean 1.2042 CV 51.25

**Analysis of Variance Table for wk17**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 13.3262 | 6.66312 | | |
| Cultivar | 1 | 6.6360 | 6.63602 | 3.65 | 0.0767 |
| Treatment | 3 | 1.5705 | 0.52349 | 0.29 | 0.8333 |
| Cultivar*Treatment | 3 | 4.9347 | 1.64489 | 0.91 | 0.4634 |
| Error | 14 | 25.4438 | 1.81741 | | |
| Total | 23 | 51.9112 | | | |

Grand Mean 1.4342 CV 94.00

**Analysis of Variance Table for wk19**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 1.000E-04 | 0.0001 | | |
| Cultivar | 1 | 6.97682 | 6.9768 | 0.63 | 0.4410 |
| Treatment | 3 | 34.9904 | 11.6635 | 1.05 | 0.4008 |
| Cultivar*Treatment | 3 | 35.8768 | 11.9589 | 1.08 | 0.3904 |
| Error | 14 | 155.346 | 11.0961 | | |
| Total | 23 | 233.190 | | | |

Grand Mean 2.7850 CV 119.61

**Analysis of Variance Table for wk21**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.6502 | 0.32512 | | |
| Cultivar | 1 | 0.0088 | 0.00882 | 0.01 | 0.9405 |
| Treatment | 3 | 2.3284 | 0.77612 | 0.51 | 0.6825 |
| Cultivar*Treatment | 3 | 3.7363 | 1.24543 | 0.82 | 0.5059 |
| Error | 14 | 21.3506 | 1.52505 | | |
| Total | 23 | 28.0743 | | | |

Grand Mean 2.5617 CV 48.21

**Analysis of Variance Table for Total weight Loss**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 86.38 | 43.191 | | |
| Cultivar | 1 | 381.60 | 381.604 | 7.20 | 0.0178 |
| Treatment | 3 | 157.72 | 52.573 | 0.99 | 0.4250 |
| Cultivar*Treatment | 3 | 330.24 | 110.080 | 2.08 | 0.1493 |
| Error | 14 | 741.87 | 52.990 | | |
| Total | 23 | 1697.81 | | | |

Grand Mean 21.664 CV 33.60

## SPROUTED TUBERS

Student Edition of Statistix 9.0 Sprouted Tubers_Apuri, 09/06/2013, 17:44:10

**Analysis of Variance Table for wk11**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.5833 | 0.29167 | | |
| Cultivar | 1 | 5.0417 | 5.04167 | 11.60 | 0.0043 |
| Treatment | 3 | 7.1250 | 2.37500 | 5.47 | 0.0107 |
| Cultivar*Treatment | 3 | 10.1250 | 3.37500 | 7.77 | 0.0027 |
| Error | 14 | 6.0833 | 0.43452 | | |
| Total | 23 | 28.9583 | | | |

Grand Mean 1.2917 CV 51.03

**Analysis of Variance Table for wk13**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 3.0000 | 1.50000 | | |
| Cultivar | 1 | 9.3750 | 9.37500 | 7.43 | 0.0164 |
| Treatment | 3 | 12.1250 | 4.04167 | 3.20 | 0.0561 |
| Cultivar*Treatment | 3 | 7.4583 | 2.48611 | 1.97 | 0.1649 |
| Error | 14 | 17.6667 | 1.26190 | | |
| Total | 23 | 49.6250 | | | |

Grand Mean 1.6250 CV 69.13

**Analysis of Variance Table for wk15**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 125.083 | 62.542 | | |
| Cultivar | 1 | 416.667 | 416.667 | 173.70 | 0.0000 |
| Treatment | 3 | 17.833 | 5.944 | 2.48 | 0.1040 |
| Cultivar*Treatment | 3 | 10.667 | 3.556 | 1.48 | 0.2623 |
| Error | 14 | 33.583 | 2.399 | | |
| Total | 23 | 603.833 | | | |

Grand Mean 7.0833 CV 21.87

**Analysis of Variance Table for wk17**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 79.000 | 39.500 | | |
| Cultivar | 1 | 352.667 | 352.667 | 26.78 | 0.0001 |
| Treatment | 3 | 208.333 | 69.444 | 5.27 | 0.0121 |
| Cultivar*Treatment | 3 | 7.667 | 2.556 | 0.19 | 0.8987 |
| Error | 14 | 184.333 | 13.167 | | |
| Total | 23 | 832.000 | | | |

Grand Mean 11.500 CV 31.55

**Analysis of Variance Table for wk19**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 11.08 | 5.542 | | |
| Cultivar | 1 | 782.04 | 782.042 | 35.06 | 0.0000 |
| Treatment | 3 | 8.12 | 2.708 | 0.12 | 0.9459 |
| Cultivar*Treatment | 3 | 70.46 | 23.486 | 1.05 | 0.4001 |
| Error | 14 | 312.25 | 22.304 | | |
| Total | 23 | 1183.96 | | | |

Grand Mean 17.458 CV 27.05

**Analysis of Variance Table for wk21**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 28.583 | 14.292 | | |
| Cultivar | 1 | 222.042 | 222.042 | 15.75 | 0.0014 |
| Treatment | 3 | 21.125 | 7.042 | 0.50 | 0.6887 |
| Cultivar*Treatment | 3 | 13.792 | 4.597 | 0.33 | 0.8066 |
| Error | 14 | 197.417 | 14.101 | | |
| Total | 23 | 482.958 | | | |

Grand Mean 7.9583 CV 47.19

**Analysis of Variance Table for Tsprout**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 6.3333 | 3.16667 | | |
| Cultivar | 1 | 3.3750 | 3.37500 | 0.90 | 0.3581 |
| Treatment | 3 | 9.1250 | 3.04167 | 0.81 | 0.5073 |
| Cultivar*Treatment | 3 | 8.7917 | 2.93056 | 0.78 | 0.5225 |
| Error | 14 | 52.3333 | 3.73810 | | |
| Total | 23 | 79.9583 | | | |

Grand Mean 47.208 CV 4.10

Student Edition of Statistix 9.0 Sprouted Tubers_Apuri, 09/06/2013, 17:44:57

## PROXIMATE ANALYSIS

Student Edition of Statistix 9.0 Proximate analysis_A..., 09/06/2013, 16:52:27

**Analysis of Variance Table for Ash**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.05867 | 0.02934 | | |
| Cultivar | 1 | 1.55550 | 1.55550 | 211.17 | 0.0000 |
| Treatment | 3 | 0.00961 | 0.00320 | 0.43 | 0.7314 |
| Cultivar*Treatment | 3 | 0.00555 | 0.00185 | 0.25 | 0.8593 |
| Error | 14 | 0.10312 | 0.00737 | | |
| Total | 23 | 1.73246 | | | |

Grand Mean 3.5012 CV 2.45

**Analysis of Variance Table for Fat**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.00086 | 0.00043 | | |
| Cultivar | 1 | 0.35770 | 0.35770 | 87.33 | 0.0000 |
| Treatment | 3 | 0.00305 | 0.00102 | 0.25 | 0.8615 |
| Cultivar*Treatment | 3 | 0.01255 | 0.00418 | 1.02 | 0.4130 |
| Error | 14 | 0.05734 | 0.00410 | | |
| Total | 23 | 0.43150 | | | |

Grand Mean 0.4196 CV 15.25

**Analysis of Variance Table for Fibre**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.03851 | 0.01925 | | |
| Cultivar | 1 | 0.19082 | 0.19082 | 52.08 | 0.0000 |
| Treatment | 3 | 0.00125 | 0.00042 | 0.11 | 0.9506 |
| Cultivar*Treatment | 3 | 0.00872 | 0.00291 | 0.79 | 0.5178 |
| Error | 14 | 0.05129 | 0.00366 | | |
| Total | 23 | 0.29058 | | | |

Grand Mean 0.6808 CV 8.89

**Analysis of Variance Table for Moisture**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.28090 | 0.14045 | | |
| Cultivar | 1 | 0.89320 | 0.89320 | 82.40 | 0.0000 |
| Treatment | 3 | 0.02728 | 0.00909 | 0.84 | 0.4949 |
| Cultivar*Treatment | 3 | 0.02701 | 0.00900 | 0.83 | 0.4989 |
| Error | 14 | 0.15177 | 0.01084 | | |
| Total | 23 | 1.38016 | | | |

Grand Mean 7.0563 CV 1.48

**Analysis of Variance Table for Protein**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.14836 | 0.07418 | | |
| Cultivar | 1 | 0.00375 | 0.00375 | 0.05 | 0.8201 |
| Treatment | 3 | 0.37667 | 0.12556 | 1.80 | 0.1940 |
| Cultivar*Treatment | 3 | 0.17178 | 0.05726 | 0.82 | 0.5044 |
| Error | 14 | 0.97818 | 0.06987 | | |
| Total | 23 | 1.67873 | | | |

Grand Mean 4.7367 CV 5.58

Student Edition of Statistix 9.0 Nitrogen Free Extrac..., 14/06/2013, 11:14:54

**Analysis of Variance Table for NFE**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Reps | 2 | 0.00373 | 0.00187 | | |
| Cultivar | 1 | 0.00020 | 0.00020 | 0.12 | 0.7376 |
| Treatment | 3 | 0.01075 | 0.00358 | 2.05 | 0.1532 |
| Cultivar*Treatment | 3 | 0.00385 | 0.00128 | 0.73 | 0.5491 |
| Error | 14 | 0.02447 | 0.00175 | | |
| Total | 23 | 0.04300 | | | |

Grand Mean 0.7579 CV 5.52

# EFFECT OF THREE PLANT EXTRACTS ON SPROUTING, DECAY AND WATER ACTIVITY OF FLOUR OF TWO CULTIVARS OF

# FRAFRA POTATOES (*Solenostemon rotundifolius*)




**BY**

**APURI SAMUEL**

**JUNE, 2013**

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,**

**KUMASI, GHANA**

**COLLEGE OF AGRICULTURAL AND NATURAL RESOURCES**

**DEPARTMENT OF HORTICULTURE**



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