ASSESSMENT OF THE PHYSICAL, CHEMICAL AND ORGANOLEPTIC CHARACTERISTICS OF WATERMELON (*Citrullus lanatus* [THUNB]) WAXED WITH DIFFERENT PLANT OILS

BY

SAMUEL LAMPTEY

This thesis is submitted to the University of Ghana, Legon in partial fulfilment of the requirements for the award of MPhil Crop Science degree.

DEPARTMENT OF CROP SCIENCE
COLLEGE OF AGRICULTURE AND CONSUMER SCIENCES
UNIVERSITY OF GHANA, LEGON.

JUNE, 2013

DECLARATION

I, SAMUEL LAMPTEY, do hereby declare that except for references cited which have been duly acknowledged; this thesis "**Assessment of the physical, chemical and organoleptic characteristics of watermelon (C*itrullus lanatus* [thunb]) waxed with different plant oils**" is the result of my own research. It has never been presented either in part or in whole for the award of any degree.

....

Samuel Lamptey (student) Date

This thesis has been submitted with the approval of the supervisors

....

Dr. Gloria Essilfie (Main supervisor) Date

....

Dr. Firibu Kwesi Saalia (Co-supervisor) Date

DEDICATION

I dedicate this thesis to my Dad, Rev. Edison Nii-Lamptey and my Mum, Mrs. Joana Edith Lamptey.

ACKNOWLEDGEMENT

Thanks be to the almighty God for his mercies, grace and wisdom; who gave me this breadth of life and guided my footpath throughout this period of study.

My sincerest gratitude goes to Dr. (Mrs.) Gloria Essilfie and Dr. Firibu Kwesi Saalia; my supervisors, whose guidance, suggestions, positive criticisms and involvement saw to the completion of this work.

My deepest appreciation goes to my father, Rev. Edison Nii-Lamptey whose financial support and personal advice contributed immensely to the success of this work and my mother, Mrs. Joana Edith Lamptey, who also financed this project, encouraged and motivated me throughout this period of study.

My heartfelt appreciation also goes out to Dr. (Mrs.) C. A. Amoatey for her encouragement and advice and also, to Prof. Afreh Nuamah who provided me with a thermohydrometer and a Carbon-dioxide/Oxygen analyzer. Many thanks also go out to Mr. Richard Otoo and Mr. Elvis Appiah both of the Crop Science pathology laboratory who assisted me with the identification of pathogens and also, to Mr. Joseph Ampah who assisted me with my titrations.

I am also thankful to the University of Guelph for the online access to their library system and training in laboratory safety, WHMIS and SAS©

Finally, to all the teacher trainees from Ada College of Education (ADACOE) who assisted me in administering the questionnaire and especially to the Principal who made it possible to use the assembly hall for interviewing some of the respondents, I say a big thank you.

List of Abbreviations

1-MCP	1-Methylcyclopropene
AEA	Agric Extension Agent
CTS	Chitosan Wax
FAO	Food & Agricultural Organization
NCW	Neem Coconut-oil Wax/Waxing
NPW	Neem Palm-oil Wax/Waxing
NSBW	Neem Shea-butter Wax/Waxing
NTE	Non Traditional agricultural Exports
TRT	Treatment
TSS	Total Soluble Solids
TTA	Total Titrable Acids
ISSER	Institute of Statistical & Socio-Economic Research
JSS	Junior Secondary School
SSS	Senior Secondary School

ABSTRACT

The study was conducted in two phases. Phase 1 was to assess the handling and management of watermelon along the value chain in the Ada-East district of Ghana. One hundred open and close ended questionnaires were administered to farmers and dealers of watermelon. From the study, it was observed that the value chain of watermelon starts from land preparation and ends at the point it gets to the final consumer. The key players along the chain were identified to be farmers, dealers (transporters and sellers i.e. both whole sellers and retailers) and consumers. The losses incurred started on the farm especially during husbandry operations and harvesting. Losses also occurred during loading/off-loading activities (0.45%) and vehicular transportation (0.93%). Additionally, inappropriate storage conditions also resulted in some losses. The main causes of the losses in the value chain were seen to be attack by disease causing organisms, insect pest attack, dropping and cracking of fruits, thieves and materials used to cover fruits during transportation. The total losses before harvest were estimated to be GH₵ 31,649.00 per season whiles total losses during and after harvest was projected to stand at GH₵ 69,825.00 per season. It was therefore recommended that farmers pay a particular attention to the onset of diseases and take quick measures such as immediate use of fungicides as well as the physical removal of affected fruits. Extra care should be taken when handling fruits especially during loading and off-loading operations. Vehicles used in transporting watermelon fruits should be types that are designed for carrying agricultural goods. These may include trucks with cooling systems and cushioning materials that mitigates the forces of impact; responsible for causing internal injury and cracks. Phase 2 was to assess the effect of different plant oils used as waxing material on the physical, chemical and organoleptic characteristics of watermelon following length of storage. Watermelons were waxed with different plant oils and stored for 21 days. The experiment was a full factorial experiment laid out in completely randomized design (CRD) with 5 replicates. The study revealed that the waxing mixtures containing Neem oil with Shea-butter (NSBW) and Neem oil with Palm oil (NPW) were not able to prolong the storage life of watermelon. However,

the mixture containing 4% Neem oil and 96% Coconut oil [NCW (4:96)] was able to prolong the storage life and reduce percent total weight loss (%TWL) of watermelon by decreasing rate of respiration. Neem oil with Coconut oil treatments (NCW treatments) also retained the vitamin C content of fruits better than non-waxed fruits especially when waxed with NCW (1:99), NCW (2:98) and NCW (3:97). Additionally, NCW did not affect some organoleptic and chemical properties such as attractiveness, flavour (smell/aroma), glossiness, mouth feel, taste, overall acceptability and Total Titrable Acids (TTA). NCW (3:97) also retains % brix better than any of the NCW treatments. It was also put forward that, long term storage of watermelon without NCW waxing reduced some organoleptic properties and created undesirable chemical and physical properties. It was therefore recommended that NCW be considered as a possible watermelon waxing material in prolonging the storage life of watermelon as well as maintaining its physical, chemical and organoleptic properties. Additionally, it was advised that the use of Shea-butter and palm oil should not be considered in the future for waxing watermelon.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Watermelon, (*Citrullus lanatus* [Thunb] Matsum. & Nakai), is a popular fruit crop grown in Ghana (Agbetiameh, 2006) and produced widely in many other countries (FAOSTAT, 2011). Records available suggest that watermelon production accounts for nearly a 6.8% of the world area reserved for the purposes of growing vegetables (Guner & Wehner, 2004; Goreta *et al.*, 2005). In Ghana, the area under cultivation is typically around the southern belt however, other areas around the Upper Volta basin are also under cultivation (Agbetiameh, 2006; Lamptey, 2010).

Agriculture forms the backbone of most developing countries including Ghana. Until recently, agriculture accounted for 38% of its GDP, trade and industry accounted for 28.6% and services accounted for 33.6% (ISSER, 2008). Over the years, non-traditional agricultural exports (NTE) have been a major foreign exchange earner with commodities such as orange, banana, papaya, mango and pineapple topping the list as major NTE earners. Even though there is a potential for the development of watermelon into a major foreign exchange earner, significantly missing among the list of non-traditional export is watermelon (ISSER, 2011). Watermelon will serve as a better option than most non-traditional export due to its high market value and potential in ensuring food security; evidently due to its high nutritional content (Kwofie, Pers. Com.).

According to Gichimu *et al.*, (2008), watermelon is one of the widely produced vegetable fruit crop and the global consumption of watermelon is speculated to be greater than any other crop of the cucurbitacea family. In the meantime, the over 6 billion people in the world may have to depend on certain countries for their watermelon needs. In confronting this challenge, countries within the tropics such as Ghana are at a comparatively advantageous position because both climatic and soil condition favour year round production. Ghana can therefore place itself strategically for a take-off as one of the leading producers of watermelon in the world. However, this can only be achieved if an effective production and postharvest system is put in place. Additionally, the whole pre and postharvest value chain must be assessed in order to enhance the knowledge base.

1.2 Justification

Kader (2005) noted that, almost a third of all fruits and vegetables produced in the world are not consumed as a result of postharvest losses of which watermelon is no exception. Lamptey,(2010) found huge losses during storage of watermelon; 17% were caused by rot and more than 50% was due to physiological problems such as bruising and sun scorching. Okine, (2011) also found similar problems. During traditional storage of watermelon, the fruit undergoes a lot of physiological changes and pathological/microbial attack. These actions render the fruits undesirable especially to the consumer and the importing country. Watermelon kept at ambient tropical conditions has a market life of 14 days (Postharvest Handling Technical Bulletin, 2003). However, watermelon must be kept at an optimum temperature of 10°C to maintain a market value of 21days (Postharvest Handling Technical Bulletin, 2003). This procedure therefore requires cool storage systems and facilities but the implementation of this method can be quiet difficult due to technical and economic problems that local farmers are faced with. This therefore calls for an alternative method of preservation such as waxing.

Waxing as a method for extending the shelf life of fruits in general has been well investigated and documented by several authors (Parades-Lopez *et al.*, 1975; Drake & Nelson, 1990; Krochta *et al.*, 1994; Hagenmaier & Baker, 1994; Baldwin *et al.*, 1995; Saftner *et al.*, 1998). However, the use of waxing as a method of extending the shelf life of watermelon has not been investigated in Ghana and in many other developing countries. To take advantage of the huge watermelon market that exists in the world, it is important to investigate the use of indigenous/locally available waxing materials and the possibility of extending the shelf life of watermelon whilst maintaining its key sensory and quality attributes. Already, the use of shea butter as a food waxing material has been well studied (Sugri *et al*, 2010) however; the synergistic use of shea-butter and neem in food waxing formulations has not been studied. The same situation holds true for the use of neem and palm oil; and neem and coconut oil. Neem has over the years been studied for its activity and efficacy in the control of insect pests (Tanzubil *et al.*, 1985; Cobbina & Appiah-Kwarteng, 1989; Owusu-Akyaw, 1991; Allotey and Dankwah, 1994; Obeng-Ofori and Akuamoah, 2000) and most especially in the control of fungi (Schmutterer, 1985).

The overall objective of this research is to exploit locally available plant oils in extending the shelf life of watermelon under ambient tropical conditions (28 ±5 °C and 75±5 RH) and to assess the watermelon value chain in order to enhance the knowledge base. The specific objectives of this research are the following;

- Assess the watermelon Value Chain with emphasis on losses of watermelon in the Ada-East district.
- Evaluate the effects of plant oils and length of storage on the physico-chemical properties of watermelon
- Conduct a sensory evaluation of watermelon for their organoleptic properties following waxing and storage duration.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin

Watermelon (*Citrulllus lanatus* [Thunb]) belongs to the family *cucurbitaceae* and is believed to have originated from South-Africa where a wild variety is still found growing. As postulated by Candolle (1882), there is evidence sufficient to prove that watermelon may be native to tropical Africa. Though *Citrullus colocynthis* has been often been considered to be an undomesticated ancestor of watermelon, and is now found native to North and West Africa, Dane and Liu (2007) suggest on the basis of chloroplast DNA investigations that the cultivated and undomesticated watermelon appear to have diverged independently from a common ancestor, most likely *Citrullus ecirrhosus* from Namibia. It can therefore be suggested that watermelon may have originated from the southern regions of Africa however, for the avoidance of doubt, watermelon can be said to have originated from Africa.

2.2 Classification

Watermelon, *Citrullus lanatus* (Thunb.) Matsummura and Nakai, is an annual plant of the Cucurbitaceae family. The edible fruit is produced on trailing vines that may reach 4.6 m or more in length. Fruit vary in shape from globular to oblong. The rind colour varies in shades of green from pale yellow to almost black and may be solid, striped, or marbled. Fruits have a thin, firm outer rind, a layer of white-fleshed inner rind that may be up to about one inch thick, and an interior edible pulp containing seeds unless the variety is triploid. Pulp colour of most commercial varieties is some shade of red or yellow (Sackett, 1974).

2.3 Varieties of watermelon

All over the world, more than 1,200 varieties of watermelons are produced, with between 200 and 300 varieties grown in the United States alone (National Watermelon Promotion Board 2003a). There are four basic groups of watermelon varieties: Picnic, Ice-Box, Seedless, and Yellow-Flesh.

The Picnic type is oblong in shape, have dark green skin/rind (with or without stripes), weigh 9-11 kg, and have red flesh (National Watermelon Promotion Board 2003b). This group includes varieties named Sangria, Fiesta, and Regency. In the Ice-Box group are varieties such as Sugar Baby, Petite Sweet, and Yellow Doll (National Watermelon Promotion Board 1999). These melons are round, weigh 2.5-7 kg, can have either red or yellow pulp, and can have dark or light green rind (National Watermelon Promotion Board 2003b). Varieties such as Crimson Trio, Farmers Wonderful, and Honey Heart are seedless type of watermelons (National Watermelon Promotion Board 1999b). Seedless watermelons weigh 4.5-11 kg, are oval to round in shape, have a light green rind with dark green stripes, and can have either red or yellow flesh. The melons in the "yellow-flesh" variety have yellow to bright orange flesh/pulp, are oblong to long in shape, weigh 4.5-14 kg, and have light green rind with blotchy stripes (National Watermelon Promotion Board 2003b). Desert King, Orangeglo, and Tender Sweet are all yellow-flesh type watermelons (National Watermelon Promotion Board 1999). Andrus (2005) has also listed some popular varities of watermelon in the world (Table 2.1)

Table 2. 1 Some popular varieties of watermelon

Varieties	
Sweet princess	Charleston Gray
Crimson sweet	Charleston Sweet
Improved Shipper	Sugar Baby
Jubilee	Special White

(Andrus, 2005)

2.4 Distribution of watermelon

In Ghana, watermelon is distributed throughout the country. The cultivation of watermelon although distributed throughout the country, is concentrated along the southern sector of the country (Greater Accra region, Ashanti region, Volta region, Western, Central and Eastern region) with much emphasis on the coastal savannah plain of the southern sector of the country (Agbetiameh, 2006). Some these areas include Ada, Weija, Kasoa, Ningo, Afienya, Tsopoli, Sege, Nsakena, Winneba, Potsin, Nkoranza, Todze, Sogakofe, Akatsi and Adidome. In addition to this, certain areas of the middle belt i.e. some parts of the Brong Ahafo region, upper Volta and parts of the three northern regions is also under cultivation. (Lamptey, 20210; Agbetiameh, 2006)

2.5 Health benefits of watermelon

Watermelon has been associated with a number of health benefits. A case in point is made for lycopene. Studies have shown that lycopene has the potential of reducing the risk of cancer of the lungs, prostate, colon and stomach. (Giovannucci, 1999). Additionally, the risk of developing heart attack and other cardiovascular diseases has been shown to be reduced by lycopene (Fuhrman *et al.*, 1997; Kohlmeier *et al.*, 1997) possibly due to its high cholesterol reducing effects.

Apart from lycopene, other beneficial phytochemicals and antioxidants such as, carotenoids, Vitamin C and beta-carotene has been indicated to be present in watermelon (Erhardt *et al.*, 2003). Vitamin C for an example helps prevent infections and viruses, and also helps slow the aging process and development of cataracts (National Watermelon Promotion Board, 2003). In addition, vitamin C aids in strengthening blood vessels and bones as well as helping repair damaged tissue and healing wounds (National Watermelon Promotion Board, 2003).Vitamin C is also an essential nutrient for humans because it plays a crucial role in the synthesis of collagen in addition to protecting against oxidative damage. Vitamin C consumption has also been shown to protect against cancers of the mouth and lungs, improve cholesterol, and prevent scurvy (Fontham *et al.*, 1988; Block, 1991; Ness *et al.*, 1996).

Small amounts of potassium, which can help alleviate muscle cramps, along with miniscule amounts of calcium and iron are also found in watermelons (National Watermelon Promotion Board, 2003).

2.6 Insect pests of watermelon

Watermelons are susceptible to several kinds of insect infestations. Aphids, cabbage loopers, cucumber beetles, cutworms, leafhoppers, thrips, leafminers and spider mites are all known to infest watermelon crops. However, all can easily be treated with pesticides or by biological means. Organisms such as lady beetles and lacewings, as well as foods like bran and molasses, can be used as alternate tools to manage pests (Sanders, 2001).

2.7 Diseases of watermelon

A variety of pathogens may cause postharvest decay of watermelon, but in the absence of any approved chemical control measures, the primary defence against the occurrence of decay is the exclusion of diseased fruit from the marketing chain through careful selection at harvest and appropriate grading (Rushing *et al.*, 2001; Postharvest Handling Technical Bullettin, 2003).

2.7.1 Black rot

Black rot, also referred to as gummy stem blight, is caused by the fungus *Didymella bryoniae.* Fruit lesions appear as small water-soaked areas and are nearly circular in shape. They rapidly enlarge to an indefinite size, up to 10 cm to 15 cm (4-6 inches) in diameter. Mature lesions are sunken, may show a pattern of concentric rings, and turn black. Lesions in stems and fruit may ooze or bleed an amber plant fluid, hence the name gummy stem blight. A brown streak may also appear at the blossom end of the fruit. The pathogen is transmitted from contaminated seed and is spread from plant to plant by splashing rain or wind. Inoculum is also found on old plant debris. The disease is controlled by planting clean seed in soils free of watermelon crop debris

(Postharvest Handling Technical Bullettin, 2003). Additionally, with good disease control in the field, the development of black rot (*Didymella bryoniae*) on watermelon is an unlikely event (Snowdon, 1992; Rushing *et al.*, 2001).

2.7.2 Anthracnose of watermelon

Anthracnose, caused by the fungus *Colletotrichum orbiculare*, is a common postharvest watermelon disease. Dormant infections may exist at the time of harvest, with no external evidence of the disease. During storage, the latent infections may become active at high temperatures or after exposure to chilling injury inducing conditions. Disease development is rapid at temperatures between 20°C and 30°C (68°F and 86°F). The fungus can penetrate the fruit surface and wounding may not be necessary for infection. Symptoms of anthracnose include sunken spots on the rind, which eventually become black. Red or orange coloured spores may also appear in the decayed areas. Anthracnose spores are spread by water, insects, or pickers' hands. Infection is particularly severe after prolonged wet periods. A combination of seed treatment, crop rotation, removal of infected debris, and fungicide applications are necessary for controlling this disease. Protective spray applications of the fungicide chlorothalonil should be made when vines start to run and should be continued at 7 to 10 day intervals during periods of humid or rainy weather. Also, storage of the fruit at 10°C (50°F) will retard the growth of this fungus (Postharvest Handling Technical Bulletin, 2003). With good disease control in the field, anthracnose (*Colletotrichum orbiculare*) rarely develops on watermelon (Rushing *et al.*, 2001; Snowdon, 1992).

2.7.3 Phytophthora Fruit Rot

Phytophthora fruit rot is caused by the soil borne fungus, *Phytophthora capsici.* The fruit rot appear as greasy blotches on the outer rind. A whitish mould is likely to be present on the greasy tissue. This disease is most likely to occur during or after periods of excessive rains where water remained in the field. Control of Phytophthora may be obtained by avoiding planting in low areas. In addition, foliar sprays of the systemic fungicide Ridomil provide some protection against this disease (Postharvest Handling Technical Bullettin, 2003).

2.7.4 Fusarium rot

Fusarium is a soil-borne fungus that attacks the roots, stems, and fruit of watermelons. The fungus can attack both sound and wounded tissue. Fruit symptoms first appear as spots on the underside of the fruit, and eventually spread to the upper surface (Postharvest Handling Technical Bullettin, 2003). Infected tissue is usually spongy or corky. Under humid conditions, the fruit may become covered with a white or pinkish mould. Decay may be shallow or it may extend deep into the flesh of the fruit. There is usually a sharp separation between healthy and rotted tissue (Postharvest Handling Technical Bullettin, 2003). The temperature range that favours Fusarium growth is 22° to 29°C (72°F to 84°F). Use of resistant varieties can minimize the risk of Fusarium. Rotating the planting site and removing and destroying all plant debris at the end of each growing season will also reduce the incidence of the disease. For watermelon, a minimum eight-year planting site rotation is recommended to avoid Fusarium. This disease may also be spread by planting previously saved seed that came from contaminated fruit (Postharvest Handling Technical Bullettin, 2003).

2.7.5 Stem-end Rot

Stem end rot is caused by the fungus *Lasiodiplodia theobromae*. The disease is first seen as a shrivelling and drying of the stem followed by browning of the area around the stem, which progressively enlarges as the disease develops. The cut flesh is noticeably softened and lightly browned. If the cut melon is exposed to the air for a few hours, the diseased areas become black. The disease develops rapidly in the fruit at temperatures greater than or equal to 25°C (77°F) but slowly or not at all at 10°C (50°F). In order to minimize the incidence of this disease, at least 2.5 cm of stem should remain attached to the fruit at harvest (Postharvest Handling Technical Bullettin, 2003).

2.7.6 Bacterial Soft Rot

Bacterial soft rot, caused by *Erwinia carotovora*, is the principal postharvest bacterial disease of watermelons. It is a secondary decay organism, requiring openings in the skin or wounded areas of the rind to enter. Insect damage, fungal decay, and mechanical injuries predispose fruits to infection. The disease causes rapid fruit rot and rancidity. Foul odours develop within a few days at ambient temperatures. The disease can be avoided by careful handling of the fruit to minimize rind damage (Postharvest Handling Technical Bullettin, 2003).

2.8 Postharvest and non-pathological Disorders

It is very important to note that there are certain physical disorders that are likely to be mistaken for a pathological disease. These physical disorders are otherwise known as non-pathological disorders and they are facilitated by environmental, climatic and genetic factors.

2.8.1 Mechanical Injury

Rough handling during harvest, loading, and unloading of watermelons will result in fruit bruising, cracking, and high amounts of postharvest loss. Internal bruising leads to premature flesh breakdown and mealiness. Watermelons should not be dropped, thrown, or walked on, as internal bruising and flesh breakdown will occur. (Postharvest Handling Technical Bulletin, 2003).

2.8.2 Chilling Injury

Watermelons develop chilling injury when stored below 10 °C for more than some few days (Rushing *et al.*, 2001). Lower temperatures will speed up the onset of injury. Symptoms appear as brown-staining of the rind, surface pitting, deterioration of flavour, fading of flesh colour, and increased incidence of decay when returned to room temperatures (Hardenburg *et al.*, 1986; Suslow, 1999; Rushing *et al.*, 2001). Conditioning fruit at 30 °C for about 4 days prior to cooling has been shown to induce some tolerance to chilling temperatures, but it does not completely alleviate the problem (Picha, 1986).

2.8.3 Sun burns

Sun scald/Sun burn is caused by the scorching effect of the sun's ultra violet rays directly on the fruit surface. The burns are characterized by brown patches on the surface of the fruit. Fruit wall integrity is lost and there is a loss in turgor pressure facilitating pathogenic attack (Agbetiameh, 2006).

2.8.4 Ethylene Damage

Watermelon belongs to a group of low ethylene producing fruits, with production rates in the range of 0.1 to 1.0 μL kg^{-1} h^{-1} at 20 °C. Even though production rates are low, fruits are extremely sensitive to ethylene. Studies have shown that, exposure to as little as 5 ppm ethylene causes softening, rind thinning, flesh colour fading, and over-ripeness (Elkashif *et al.*, 1989; Suslow, 1999). Interactions between ethylene concentration, temperature, and duration of exposure are not well defined. Flesh colour fades and has the appearance of being overripe. Higher concentrations of ethylene result in more rapid injury to the fruit. The ethylene absorbent potassium permanganate may be used to inactivate ethylene in enclosed areas but the recommended management protocol is to avoid any exposure to ethylene in the storage environment. This is primarily done by keeping watermelons away from other commodities that emit high amounts of ethylene (Postharvest Handling Technical Bullettin, 2003).

2.8.5 Hollow Heart

Hollow heart is a fruit disorder of pre-harvest origin, in which the internal flesh separates, creating an open cavity or hollow area. It is more problematic on crown-set fruit than lateral-set fruit. Cultivars differ in susceptibility and the severity of the disorder varies among growing locations and seasons. The exact cause of this disorder is unknown. It is also very difficult to externally distinguish fruits with hollow heart (Postharvest Handling Technical Bullettin, 2003).

2.9 Handling practices

Watermelon, like any perishable crop, needs an effective handling system so as to prevent both pre and postharvest losses. The handling practices of watermelon can be grouped under three main categories: pre-harvest practices, harvesting practices and postharvest practices.

2.9.1 Pre- harvest handling

Achieving good quality fruits that will appeal to the eyes of the consumers and meet good quality standards must begin before harvest. The selection of good quality seeds and desirable varieties is a crucial factor in determining the postharvest performance of the produce. Different varieties of watermelon possess different inherent characteristics such as insect pest and disease resistance, long shelf life, rind firmness and size uniformity. In addition to genetic traits or the inherent characteristics, environmental factors such us temperature, rainy weather at harvest and soil type can have adverse on the storage ability, shipment storage suitability and produce security (Agbetiameh, 2006).

Good cultural practices such as weed control, pest control, application of fertilizer, good spacing, pruning and crop rotation, to list a few are very important in achieving target levels of quality. Weeds compete with the crop for space, nutrients and sunlight. The resultant effect is malformed fruits as well as smaller than normal fruit size. Correct application of fertilizer hastens the development of large fruit sizes as well as sweeter ones and the development of an abscission layer for easy detachment during harvesting. Pruning serves as a disease control measure and ensures that diseases do not spread to other parts of the plant (Agbetiameh, 2006).

2.9.2 Harvest handling

The inherit quality of produce, and for that matter, watermelon quality cannot be improved after harvest but only be maintained for the expected window of time. Particularly, an accurate knowledge for successful postharvest handling is an accurate knowledge of its shelf life, an opportunity under the farmer's specific condition of production; season, method of handling and distance to market. In watermelon production, farmers harvest at or near peak ripeness more often than in many traditional systems (Robertson, 2005).

Harvesting

Harvesting is defined as the process of detaching the fruit from the main plant. In carrying out this process, it is very important that appropriate precautionary measures are fully employed to ensure that fruits do not sustain cracks, scratches and other physical blemishes. Some of these measures include the following;

- Harvesting must be done during the coldest time of the day to maintain low product respiration and prevent excessive loss of water through transpiration.
- Harvested produce in the field must be kept cool by shading with a reflective pad to prevent scorching of fruit surface, premature senescence and water loss.

- High quality product should not in any way be compromised by mixing with damaged, decayed or prone to decay products in a bulk or packed unit
- Wounding, bruising, crushing or damage from human and equipment should be avoided.
- Cleaned and sanitized packing material should be used always.
- Although watermelon can tolerate the sun for some time, the harvested produce should be kept in a cold storage facility as soon as possible.

2.9.3 Postharvest handling practices

Postharvest handling practices are the practices that ensure that the integrity of the produce are not compromised from the time of harvesting to the time the produce gets to the final consumer. An effective postharvest handling practice or management systems requires the full utilization of the concept and total quality management in order to achieve quality standards of both domestic and international repute. The postharvest practices that are employed include the following;

2.9.3.1 Pre-cooling:

Good temperature management is the most effective way to reduce postharvest losses and preserve quality of fruit and vegetables. Watermelon harvested from field, often carry field heat and have high rate of respiration. Rapid removal of heat by pre-cooling is so effective in achieving quality preservation. Currently used pre-cooling methods include room cooling, force-air cooling, water-cooling, vacuum cooling and packaging icing (Thompson, 2000).

Room cooling

Room cooling is one of the simplest methods of pre-cooling. The method requires a refrigerated room with adequate cooling capacity. The watermelon produce is packed in loosely stacked containers in the cooling room. This ensures that enough space is left between containers for each watermelon fruit to be exposed to the circulating cold air. Under the room cooling system, the rate of cooling is very slow because heat transferred by conduction from the container to the surface needs to be carried away by refrigerated air. It may take several hours to days for the conducted heat to be carried away and will depend on the size and nature of the container, the temperature and velocity of the circulating air (Thompson, 2000).

Forced Air Cooling

Forced air cooling system has a rapid response than room cooling. Cold air is forced to pass over fruits within containers so that the heat is carried away directly from the surface of the produce rather from the surface of the container. The air that flows through the container is produced by creating a pressure difference between the two perforated sides of the container. The containers are stacked inside a covered tunnel with exhaust fans fitted at one end of the perforated sides of the container (Thompson, 2000).

Hydro-cooling

This method also has a rapid response yet it is a less expensive method. In this method, the produce is brought into contact with cold water by dipping or showering. It must be noted that not all produce can tolerate hydro-cooling. The only disadvantage about this method is that hydro-cooled products are left with wet a surface which predisposes them to decay in some products. This method is therefore suitable for watermelon with waxy surface (Thompson, 2000).

Vacuum Cooling

This is the most efficient way to cool leafy vegetables. The produce placed inside a vacuum tube in which air pressure is reduced. When the pressure is lowered to 4.6 mm Hg water boils off at 0˚C from all over the produce surface (Thompson, 2000).

The boiling effect draws heat for vaporization and hence cools the produce. The cooling time is in the order of 20-30 minutes (Thompson, 2000). Unfortunately, the equipment needed for this procedure is very expensive and may not be a good choice for small-scale farming systems, as in the case of watermelon farming systems in southern Ghana. (Agbetiameh, 2006)

Ice Bank Cooler

This is the latest development in refrigeration with positive ventilation. Ice cool air passed through the boxes containing the produce under this system. This method also has a rapid response since large amount of heat is removed within a relatively shorter time. For watermelon produce, the store must maintain a temperature of 12˚C to 10˚C and relative humidity of 98% (Thompson, 2000).

Packaging Icing

This is the simplest way of cooling and it is sometimes referred to as top icing. In this method crushed ice, flat ice or slurry of ice is added to the produce in a container. It is necessary to choose varieties that are susceptible to ice cold temperatures. The disadvantage associated with this method is that, cooling wets both container and the produce generates water which must be drained to prevent rot, decay and microbial attack (Thompson, 2000).

2.9.3.2 Packaging

Packaging of watermelon has the potential of determining the extent to which the product quality and integrity is maintained. A good packaging material should be able to provide to the consumer convenience and protect the watermelon. Examples of packaging materials include polythene bags and paper cartons. In Ghana, cut watermelon is packaged in transparent polythene bags.

2.9.3.3 Transportation

Inland transportation of watermelon is usually by rail or road i.e. train or truck. Overseas transportation is by sea or air. In Ghana inland transportation of watermelon is by truck since most areas under cultivation do not have or have inadequate railway system. An effective transportation system ensures that the produce reaches its destination without defects (Agbetiameh, 2006)

2.9.3.4 Storage

The melons should be cooled to 10° to 16°C as soon as possible after harvest. Optimum storage conditions are 10° to 12°C for two to three weeks, 80 to 90% relative humidity, the exact temperature depending on the maturity at harvest (Thompson, 2000). Slightly immature fruit are stored at 16°C, while fully mature fruit are stored at 12°C; storage below 10°C will result in chilling injury or pitting which increases decay and loss of flavour and red flesh colour (Thompson, 2000).

Watermelons are usually harvested at peak maturity, and flavour generally will not improve with storage. It has been reported that rind thickness decreases with increase in maturity and with storage, and that the degree of redness in watermelon colour increases at certain storage temperatures. After watermelons reach optimum harvest maturity, soluble solids content does not increase during storage. Watermelon fruits should not be stored with ethylene-producing products, as exposure to ethylene will result in a reduction in fruit quality. Ripe or slightly under-ripe watermelons respond similarly to ethylene; after exposure to concentrations as low as 0.05 parts per million, the rind thickness and flesh firmness is reduced (Postharvest Handling Technical Bullettin, 2003; Agbetiameh, 2006).

2.10 Postharvest losses in watermelon

Postharvest losses are losses that occur from the time of harvest to the time the produce gets to the final consumer. The types of postharvest losses that occurs in perishables and for that matter watermelon can be classified into two main categories; qualitative losses and quantitative losses.

2.10.1 Qualitative losses

Quality is the extent to which a commodity conforms to a preferred standard. If the commodity or product does not conform to the preferred standard, there is a loss in quality. High quality watermelons should be well formed, symmetrical and uniform in shape with a waxy, bright appearance. The rind should be free of scars, sunburn, and abrasions with no bruising or other physical injury, free from anthracnose or other decay, and not overripe (Suslow, 1999; USDA, 1978). Qualitative losses associated with watermelon include; colour change, flavour change, physical damage, rot, insect and rodent pest attack and pathological disorders.

Colour change.

A change in colour of the watermelon can lead to the outright rejection of the watermelon by consumers. If the normal dark green colour is compromised by a lot of yellow patches sparsely distributed throughout the entire area of the rind, it will make consumers lose confidence in the integrity of the product. This in effect will lead to the rejection of the product by the consumer and it represents a loss to the producer. Consumers may also see pulp/flesh colour as an indicator for freshness, a specific flavour, a particular smell, and consumers may even use colour to determine the intensity of a flavour or smell. Francis (1995) stated that colour influences other sensory characteristics, which subsequently influences food acceptability, choice, and preference. Colour can be defined as the impact of the wavelengths of light in the visual spectrum from 390 to 760 nm on the human retina (Francis, 1995). According to Francis (1995), if the colour of a product is unacceptable to a consumer, the flavour and texture may not be considered at all. Colour may also be used as an indicator to determine the types and quantities of various carotenoids. Colour analysis is quick and simple and may provide more consistent results compared to carotenoid analysis (Francis, 1995).

Flavour change

Our perception of flavour depends on our sense of smell and taste. Four types of taste can be distinguished; sweet, sour, salty and bitter. In watermelon the sugars and organic acid determines the taste of the fruit however, the complex interaction of sugars, organic acids, phenolics and more specialized flavour compounds such as alcohols, esters, aldehydes determine the flavour of fruits. If a watermelon fruit does not conform to the normal taste or for an instance there is a reduction in sweetness, consumers will not buy such products (Ofosu-Anim, 2009)

Physical damage

Physical damage in watermelon includes; sun burns or scalds bruises, cuts, chilling injury and cracks. These damages predispose the fruit to microbial attack and hasten deterioration. Physical damage represents a qualitative loss because no one will buy watermelon with cuts or cracks. The rejection of such fruits with defects is a loss due to quality compromization (Ofosu-Anim, 2009).

Pathological disorder

Pathological disorders in watermelon arise because of disease conditions. Affected fruits normally begin to rot sooner than their expected shelf life. Sometimes pathogens release poisonous substances known as mycotoxin into fruits making them unsafe for consumption. A diseased fruit is sometimes unattractive and may appear abnormal however, it should also be noted that some diseased fruits might appear normal and look good until senescence sets in (Ofosu-Anim, 2009).

2.10.2 Quantitative loss

Quantitative losses are losses that represent a loss in weight of the produce. Watermelon fruits weigh between 2.5 Kg and 5 Kg (Agbetiameh, 2006). Any deviation below 2.5 Kg is a loss in quantity. It must be noted that the weight of produce can only be influenced by selecting appropriate variety and full employment of good agricultural practices.

2.11 handling losses

Losses may occur anywhere from the point where the food has been harvested or gathered up to the point of consumption.

Harvest

The separation of the commodity from the plant that produced it. In the case of roots, tubers and bulbs the commodity is lifted out the soil. The Knife or tool used in harvesting can bruise or scratch the surface of the watermelon

Preparation.

The preliminary separation or extraction of the edible from non-edible portion, e.g., the peeling of fruits and vegetables. In selling cut watermelon, losses may occur if they are not cut into desirable sizes or shapes as preferred by consumers.

Preservation

It is the prevention of lose and spoilage of foods. For example, the sun drying of fruit, the use of refrigeration and the use of fungicides to inhibit mould growth in fruits. When fungicides are not carefully applied to watermelon fruits, it can result in high residue level and consequently such fruits can be rejected on the export market.

Processing

It is the conversion of edible food into another form more acceptable or more convenient to the consumer, for example, the manufacture of fruit juice and the canning of fruits. If the bottling of fruit juice for an instance is not well done, it may result in contaminated fruit drinks which must be discarded since they are not wholesome for consumption.

Storage

It is the holding of foods until consumption. Most storage is common storage (ambient temperature) but there are extensive storage capacities that can hold food under refrigerated or controlled atmosphere conditions. In the situation where the storage room is not able to prevent insect and rodent pest infestation, allow for ventilation and maintain a good relative humidity, it can lead to losses.

Transportation

All forms of transportation are used to convey food from the point of production to the point of consumption. Some trucks used to transport watermelon may be in very poor condition and in addition to that bad loading and off-loading practices may result in losses.

Postharvest losses in fresh root/tuber/fruit crops have their origin in mechanical damage, physiological processes, infection by decay organisms and occasionally, pest infestation. The losses caused by these processes may occur during all stages of food supply system from crop maturity, through harvesting, transportation and storage. The degree of loss associated with these factors is determined by the plant material involved, the prevailing environmental conditions and management of the food supply system.

2.12 Waxing and its effects on the physico-chemical characteristics of fruits.

Fruits naturally have a layer of wax on their rind or skin but during harvesting, transportation, washing and cleaning, they tend to lose them. The application of exogenous wax to either replace or compliment the already existing wax aids in the overall extension of the shelf life of the fruit whilst maintaining its quality and organoleptic characteristics (Postharvest technical bulletin, 2004).

The quality of a food product depends on organoleptic, nutritional, and hygienic characteristics, but as explained, these change during storage and marketing (Debeaufort *et al.*, 1998). Consumers tend to prefer produce with a shiny or glossy appearance. Edible surface coatings, such as waxes, are often applied to improve the cosmetic features of fruit and vegetables. These coatings commonly contain ingredients such as polyethylene, carnauba, or candelilla, all of which reduce water vapour loss, and also provide a vehicle for fungicides (Hagenmaier and Baker, 1995; Debeaufort *et al.*, 1998; Alleyne and Hagenmaier, 2000). Many waxing materials have been studied for their effects on the shelf life, quality and sensory attributes of fruits.

2.12.1 Effects of waxing on Total Soluble Solids (°Brix).

Total soluble solids is most often than not associated with the sweetness of the fruit and is sometimes used as one of the main quality parameters in determining maturity (Wills *et al*., 1981; Tian *et al.*, 2007). For most fruits, waxing reduces the rate of increase in TSS as compared to non-waxed fruits however; there is gradual decline in TSS after attaining peak TSS. The rate of decline in TSS in waxed fruits is also slower than non-waxed fruits. Mejia-Torres *et al.*, (2009) studied the effects of carnauba wax on the °brix of tomatoes stored for some days. The study revealed that the TSS of tomatoes stored at 5°C was lower than that of non-waxed fruits at 12 days of ripening. Another study involving the use of bee wax on sweet orange (blood red variety), showed that treatment control retained maximum TSS (12.57 brix) throughout the storage period though statistically it was at par with 1% bee wax, which showed 12.11 brix in terms of TSS, respectively (Shahid and Abbasi 2011). Similar investigations by Contreras-Oliva *et al.*, 2011 show that the use of chitosan wax on mandarins had no significant effect on TSS.

2.12.2 Effects of waxing on Vitamin C

Vitamin C (ascorbic acid) is an important component of fruits and is necessary for preventing diseases as well as maintaining healthy body tissues. Vitamin C content can be used as an indicator of freshness for fruits and vegetables in terms of other nutrients. When vitamin C of the fruit juice is well retained, other nutrients may also be well retained (Marfil *et al.*, 2008). It is well-known that vitamin C is very sensitive to heat treatment. Marfil *et al.* (2008) reported that treatment temperature is directly related to degradation. Vitamin C is also highly susceptible to oxygen and therefore any waxing condition that encourages an aerobic or oxygenated atmosphere will lead to degradation in vitamin C whereas waxing conditions that do not encourage aerobic or oxygenated atmosphere will result in a higher retention of vitamin C.

Hu *et al.*, (2011) studied the effects of some waxes on pineapples following days of cold storage. The study revealed that the Vitamin C content in the control decreased during the first 14 days and increased gradually in the 3rd week and then decreased again in the last three days of storage. The vitamin C content of wax treatment decreased during the first 22 days of storage and increased gradually with prolonged storage time. Throughout the storage period, there were significant differences between control and wax-treatment ($P < 0.05$). The vitamin C content in wax-treatment was 146% higher than that in the control on the 24th day of storage. In another experiment involving the use of gamma irradiation, washing and waxing of *Citrus clementina*, Mahrouz *et al.*, (2002) discovered that washing and waxing treatment did not improve the quality of *C. clementina* but rather resulted in reduction of Vitamin C.

2.12.3 Effects of waxing on pH and Total Titrable Acids

The test that measures all the acids present in a given fruit is referred to as total titrable acids (TTA) whereas pH is a measure of the strength of these acids. Several investigations have been conducted into the effects of waxing on pH and TTA. Hu *et al.*, (2011) discovered that wax treatment reduced titrable acids of pineapple kept under cold storage conditions by approximately 6 and 5% compared with the control at 14 and 21 days of storage, respectively. However, preliminary investigation by Sugri *et al.*, (2010) suggests that thin layer waxing (<0.05 mm) using shea-butter did not influence pulp pH and total titrable acidity (TTA) of plantain varieties. Similarly, application of the antimicrobial edible coating did not (P > 0.05) affect the pH (5.2-0.3) of fresh cut watermelon (Sipahi *et al.,* 2013). Oyeleke and Odedeji (2011), also discovered that pawpaw fruits treated with palm kernel oil retained a higher pH than bee waxing treatment and chemical waxing treatment.

Increase in acidity of stored fruits is due to the formation of carbonic acid (acidosis) or due to the fermentation of sugars resulting in production of acids while, decrease in acidity is due to the fact that as fruit ripens, it diminishes it's malic and citric acid contents and favours the formation of sugars (Martinez *et al.,* 1978).

2.12.4 Effects of waxing on weight loss

Fruits stored at ambient tropical conditions will lose weight due to respiration and transpiration. Fruit waxing however, has been shown to prevent or delay the rate of weight loss by several investigators. Investigations done by Contreras-Oliva *et al.,* (2011) showed that commercial wax was the most effective in reducing weight loss of mandarins in general, although the reduction in weight loss in chitosan coated mandarins was lower than the uncoated (control) mandarins after 9 days of storage at 20 °C. Similar works by Mahajan *et al.,* (2011), also suggests that the percent loss in weight (PLW), in general, increased with the advancement of the storage period rather slowly in the beginning, but at a faster pace as the storage period advanced. It was also noticed that under ordinary market conditions, the lowest mean PLW was observed in fruits coated with citrashine and was closely followed by terpenoidal oligomer coated fruits.

Mejia-Tores *et al.,* (2009) also discovered similar trends in weight loss when tomatoes were waxed. In that study, it was discovered that waxed tomatoes had a lower loss in weight as compared to control treatment.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 An assessment of the watermelon Value Chain with emphasis on pre-harvest and post-harvest losses in the Ada-East district

A questionnaire (Appendix 1 and 2), designed to simulate primary activities (Figure 3.1) as described by Porter (1985), was administered. The questionnaire consisted of both close-ended and open-ended questions. The questions focused mainly on farming/husbandry practices, the types of losses, quantification of the losses and economic loss associated with the quantity of losses in one growing/harvesting season. Pre-harvest losses were estimated as; [a/(a+B)]x100% Postharvest losses were estimated as; [Ω/B]x100%, where a = no. of damaged fruits before harvest, B=total no. of fruits harvested and Ω=no. damaged fruits during and after harvest

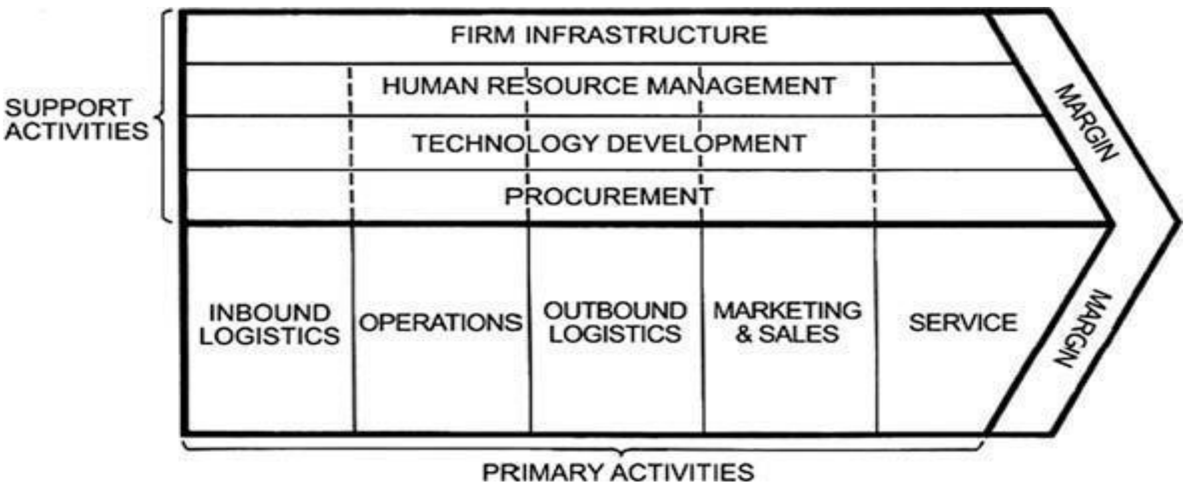


Figure 3. 1 The value chain model. Source: Porter (1985, p. 37).

The study was carried out at the Ada-East District of Ghana (Figure 3.2). A total of 50 farmers (out of 127 watermelon farmers in the District) and 50 dealers (out of 168 dealers) of watermelon were interviewed through the questionnaire. Watermelon dealers were defined to be those actors along the value chain who buy watermelon from farmers, transport and sell them to consumers/retailers.

The data collected was subjected to SPSS© version 16 and Microsoft Excel 2010 for data analysis using descriptive statistics after which inferences were made.

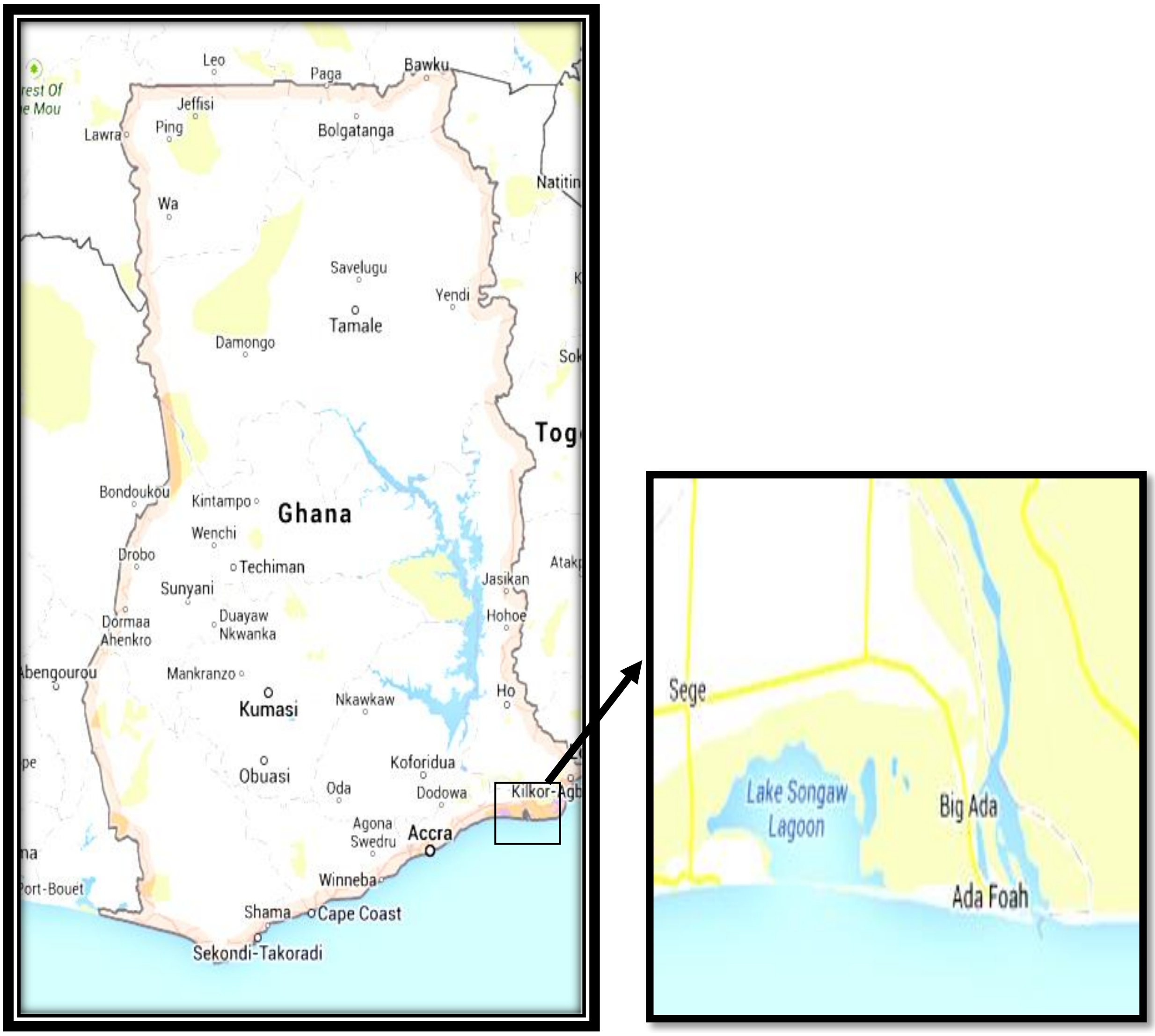


Figure 3. 2 Map of Ada East District of Ghana. Source: Google maps© (2010)

3.2 Experiment to achieve Objective 2

Determination of the effects of Neem/Shea-butter waxing (NSBW), Neem/Palm oil Waxing (NPW), Neem/Coconut oil Waxing and length of storage on the physico-chemical properties of watermelon

3.2.1 Materials used

All watermelon fruits used for the experiments were obtained from a local farmer in Ada-foah. The watermelon fruits were harvested at a physiologically matured stage and transported to the laboratory at the Department of Crop Science in the University of Ghana. Application of treatments followed by storage was done on the same day of harvesting. Except for fruits that were used for control set-up, all other fruits were washed in ordinary water and wiped clean with a towel after which waxing treatments were applied. All fruits used for the experiment were of similar sizes, weight, shape and same variety.

3.2.2 Experimental design

The experimental design used for Neem oil with Shea butter waxing (NSBW) was a 5×3 full factorial experiment carried out in a completely randomized design (CRD). The NSBW treatments were formulated out of four neem-shea butter concentrations and a control (Table 3.1). The days of storage treatment was based on 1, 4 and 7 days of storage. For Neem oil with Palm oil Waxing (NPW), a 5×5 full factorial experiment laid out in a completely randomized design was used. The NPW treatments were a formulated out of four neem-palm oil concentrations and a control (Table 3.2). The five levels of days of storage levels of treatment were 1, 4, 7, 10 and 14 days of storage. The experiment involving Neem oil with Coconut oil Waxing (NCW) was 5×6 full factorial experiment laid-out in a completely randomized design (CRD). The NCW treatments were formulated out of four neem-coconut oil concentrations and a control (Table 3.3). The days of storage treatments were based on 6 levels of days of storage i.e. 1, 4, 7, 10, 14 and 18 days of storage. All treatment combinations were replicated 5 times.

Table 3. 1 Treatment formulations for neem/shea butter treatment

Treatment	Formulation (neem:shea butter) %	Description of treatment
A	5:95	NSBW(5:95)
B	10:90	NSBW(10:90)
C	15:85	NSBW(15:85)
D	20:80	NSBW(20:80)
E	Control (no treatment)	NSBW(CTRL)

Table 3. 2 Treatment formulations for neem/palm oil treatment

Treatment	Formulation (neem:palm oil) % + 50% de-ionized water	Description of treatment
I	(1:99)	NPW(1:99)
II	(2:98)	NPW(2:98)
III	(3:97)	NPW(3:97)
IV	(4:96)	NPW(4:96)
V	Control (no treatment)	NPW(CTRL)

Table 3. 3 Treatment formulations for neem/coconut oil treatment

Treatment	Formulation (neem:coconut oil)% + 50% de-ionized	Description of treatment
P	(1:99)	NCW(1:99)
Q	(2:98)	NCW(2:98)
R	(3:97)	NCW(3:97)
S	(4:96)	NCW(4:96)
T	Control (no treatment)	NCW(CTRL)

3.2.3 Method of waxing and storage

Since Shea-butter is solid at room temperature, it was melted using a hot plate/stirrer and mixed according to the formulations in Table 3.1. After it had cooled off completely, samples of watermelon were waxed with the aid of a waxing brush to form an even thin film/coat on the fruit surface. For the NPW and NCW, 3 drops of Tween 20© was added to emulsify the oil and water suspension. Cotton wool was then dipped into the individual waxing formulations and was individually smeared on the surface of the fruits forming an even thin film/coat on the surface of the fruits. The samples were then labelled according to the various treatments and kept at ambient tropical room temperature and relative humidity (Appendix 4).

3.2.4 Parameters measured

The Total Soluble Solids (TSS), Total Titrable Acids (TTA), Vitamin C and pH determined at 1, 4, 7, 10, 14 and 18 days after storage. Watermelon fruits were weighed at day zero of storage using an electronic scale, and repeated after 1, 4, 7, 10, 14 and 18 days in order to observe the weight loss throughout the storage period. Additionally, CO_2/O_2 respiration rate of fruit samples (excluding NSBW fruit samples) were determined using a SCY 2A© head space CO_2/O_2 probe analyzer. An EL-USB 2^+ © thermohydrometer was also used to monitor the psychrometric parameters of the storage atmosphere.

3.3 Sensory evaluation of watermelon for their organoleptic properties following waxing and last day of storage

A five-point Hedonic scale as described by Sugri *et al*, (2010) was used to score samples for attractiveness, glossiness, flavour, skin/rind colour, pulp colour, mouth feel, texture, taste and overall acceptability (Appendix 3) following waxing treatments and final day of storage. Blindly Coded samples per waxing treatment were served to each member of a 20 untrained panellists for their sensory evaluation.

3.4 General methods

These methods explain the processes that were used for the determination of the various components of measurement including parameters such as TSS, TTA, Vitamin C, pH, total fruit weight loss, CO_2/O_2 respiration rates and psychrometric analysis of the storage atmosphere. Firstly, samples were cut-open, pulp removed, diced and squeezed out using a cheesecloth.

3.4.1 Method for the determination of TSS

TSS was determined using digital Hanna© refractometer 96801 at room temperature. In determining the TSS, a drop of distilled water was placed on the illumination plate and zeroed.

After zeroing, the water was wiped off the illumination plate. A drop was squeezed out of watermelon samples and placed on the illumination plate. The per cent brix was then read from the LCD monitor display on a scale of 0 to 85 % brix. The process of zeroing was repeated preceding each sample readings.

3.4.2 Method for the determination of Total Titrable Acidity (TTA)

In determining the TTA, 10 mL of squeezed samples was transferred into a 125 mL conical flask. 25 mL of distilled water was then added to the 10 mL sample followed by the addition of three drops of 1% `phenolphthalein indicator. A 0.1N NaOH was then titrated against the samples until there was a final colour change and the titre value recorded. The observed colour change was light pink. The TTA was adjusted with a correction factor as shown below (AOAC, 1990)

$$TTA(g/l) = \frac{mlNaOH \times Normality[NaOH] \times MW \times 1000}{sample(mL)volume}$$

Where MW is the molecular weight of the expected acid, in this case citric acid

Molecular weight of citric acid = 192.12 g/mol

Normality of NaOH = 0.1mol/L

3.4.3 Method for the determination of pH

The pH was determined using a 3330 pH meter calibrated with buffers at pH 4 and pH 7 according to Association of Official Analytic Chemist (AOAC) method No. 981.12-b (1990)

3.4.4 Method for the determination of total fruit weight loss

Total weight loss was expressed as a percentage of the original weight lost during the storage period (Park *et al*. 1994).

Total weight loss (TWL) % = $\frac{W_1 - W_2}{W_1} \times 100$

Where W_1 is original weight and W_2 is weight at the time of sampling.

3.4.5 Method for the determination of Vitamin C

The method used for the determination of vitamin C was done according to the method described by Helmenstine (2013) with a little modification. Firstly, a 0.25 g of Vitamin C standard was dissolved in 250 mL distilled water. A 25 mL aliquot of the standard solution was then pipetted into a 125 ml Erlenmeyer flask. Freshly prepared iodine solution was then titrated against the samples using 10 drops of 1% starch solution as indicator. The final colour change observed was a blue-black colour. The titration was repeated until the titre values agreed within 0.1 mL. This titre value was recorded as Vitamin C titre value for standard solution.

Similarly, 10ml aliquot of watermelon juice sample was pipetted into a 125 mL Erlenmeyer flask. The already freshly prepared iodine solution was then titrated against the juice sample using 10 drops of 1% starch solution as indicator. The final colour change was a blue-black colour and was repeated until the titre values agreed within 0.1 mL. This titre value was recorded as titre value for juice sample. The Vitamin C content was then determined by simple ratio and proportion. If X mL of iodine solution reacted with 0.25 g of Vitamin C standard then the amount of Vitamin C (g) in the juice sample will be dependent on the amount of iodine solution that reacted with the juice sample (Y ml). This relation is given by $\frac{X(mL)}{0.25g} = \frac{Y(mL)}{Vita\min C(g)}$, but the amount of iodine that was needed to react with the Vitamin C in the juice sample (Y mL) is known therefore the quantity of Vitamin C (g) in the juice sample was calculated for and converted to percent Vitamin C using the relation % Vitamin C = $\frac{Vita\min C(g)}{0.25g} \times 100\%$

3.4.6 Determination of CO_2/O_2 respiration rate and psychrometric analysis of the storage atmosphere

The method used for measuring respiration rate was that of a closed system. A gas-tight container of known volume (m^3) was filled with watermelon sample and the container, containing ambient air as the initial atmosphere, was closed according to the methods described by Cameron, Boylan-Pett, & Lee, 1989; Fishman, Rodov, & Ben-Yehoshua, 1996; Gong & Corey, 1994; Haggar, Lee, & Yam, 1992; Henig & Gilbert, 1975; Jacxsens, Devlieghhere, & Debevere, 1999; Maneerat, Tongta, Kanlayanarat, & Wongs-Aree, 1997; Ratti, Raghavan, & Gariépy, 1996; and Song, Kim, & Yam, 1992. Changes in the concentration of O_2 and CO_2 was determined using an SCY 2A© head space CO_2/O_2 probe analyzer and used to estimate respiration rates (Eqs. 1 and 2).

$$R_{O_2} = \frac{\left(y_{O_2}^{\ t_i} - y_{O_2}^{\ t_f}\right) \times V}{100 \times M \times \left(t_f - t_i\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$R_{CO_2} = \frac{\left(y_{CO_2}^{\ t_i} - y_{CO_2}^{\ t_f}\right) \times V}{100 \times M \times \left(t_f - t_i\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where R = respiration rate ($m^3\ kg^{-1}\ s^{-1}$), V= free volume (m^3), M = mass (Kg) of watermelon sample, y = volumetric concentration (%V/V) and t = time (s).

Free volume was calculated using the relation $\frac{1}{3} \times \Pi \times L\left(R^2 - r^2\right)$ where L is the length, (R) is the bigger radius and (r) is the smaller radius of the closed chamber (Figure 3.3)

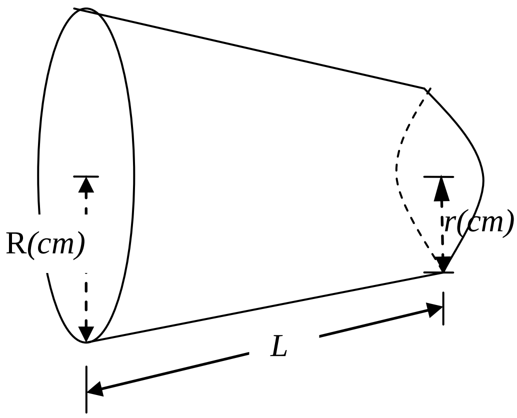


Figure 3. 3 Schematic view of the closed chamber in which the watermelon samples were held.

free volume (m^3) was calculated to be 28.8 m^3 where R= 14 cm, r = 9.5 cm, L= 26 cm. and $\pi = 22/7$. Volume in cm^3 was converted to m^3.

Psychrometric analysis of the storage atmosphere was monitored over the 21 days of storage using an EL-USB 2^+ © thermohydrometer.

3.4.7 Method for the culturing, isolation and identification of pathogens associated with watermelon rot.

Samples of diseased watermelon were cultured on Potato Dextrose Agar **(**PDA). This was done to investigate the pathogens responsible for the rot or postharvest disease in watermelon.

3.4.7.1 Preparation of Potato Dextrose Agar (P.D.A)

Potato Dextrose Agar (P.D.A) was prepared by mixing 7g of P.D.A in 200 ml of distilled water in a 250 mL conical flask. Having shaken the content to ensure a uniform dissolution, the flask was plugged with cotton wool and later covered with aluminium foil. The conical flask with its content was then autoclaved at 1.05 kg/cm square pressure at 121 °C for 15 minutes, after which it was cooled in a water bath. The content of the conical flask was later poured into Petri dishes that were sterilized using a hot air sterilizer at 175 ºC for about 2 hours in a laminar flow set. The laminar flow was sterilized with infiltration of air and the table of the laminar flow was sterilized with 70% alcohol before the isolation was carried out.

3.4.7.2 Isolation of pathogens

About 8-10 mm of the diseased sections was cut from the margin of the infected area. The cut sections was firstly immersed in distilled water to wash off dirt then into 1% Sodium hypochlorite for about 20-30 seconds to sterilize them. The sterilized sections were then picked out of the 1% Sodium Hypochlorite solution using sterilized forceps. The cut sections were then plated on the P.D.A at a rate of two cuts per plate and labelled according to the treatment and the date of plating. The plates were be then covered and placed in plain polyethylene bags and incubated at room temperature and examined for growth.

3.4.7.3 Identification of Pathogens

Identification of the isolated organism was conducted through preparation of slides of the isolates and observation under a compound microscope. The isolated organisms were identified using recommended books (Agrios, 1988, Barnett and Hunter, 1972) and with the help of the technicians at the pathology laboratory. Samsung i8 digital camera was used in taking micrographs of the pathogens through the lens of the compound microscope.

3.5 Data analysis

The data collected were subjected to analysis of variance using Gentsat© version 16 and Minitab© 14. Test of significance between treatment means was done using Fisher's Least Significance Difference (F-LSD) at 5% probability level. Further graphs showing trends in changes in these parameters was drawn using Microsoft Excel© 2010. A Friedman's rank test was also done to test the effects of waxing formulations/mixtures on overall acceptability. Identified pathogens responsible for rot were also described using recommended books and help from the technicians at the crop science pathology laboratory of the University of Ghana.

CHAPTER FOUR

4.0 RESULTS

4.1 Qualitative description of the value chain of watermelon

Pre-harvest stage

The study revealed that the value chain of watermelon followed some peculiar routine (Plate 4.1). Cultivation of watermelon starts with the preparation of the land and the sowing of seeds in rows. Maintenance activities such as weed control, insect pest control and disease control were carried out at regular intervals until fruits are harvested at a physiologically matured stage.

Harvesting stage

The study also revealed that watermelon dealers normally place intent of purchase on the fruits before the fruits are harvested and to that effect, farmers hardly encounter leftover fruits that remain un-purchased. Farmers normally demarcate an area of the farm for the dealer once the intent for purchase is made. Harvesting is only done once the fruits are matured and the dealers are present on the farm to make the purchase. As a result of this purchasing system, farmers hardly have to grumble with storage however, there were 2 cases where farmers were forced to harvest and store fruits until a buyer came or in the other case transported the fruits to the market at Ada-Kasseih junction to sell to whole-sellers.

Post-harvest stage

After harvesting, the fruits are sorted into 3 different sizes; No. 1, No. 2 and No. 3 in order of decreasing sizes respectively. They are then priced and sold. No. 1 goes for 5 to 6 cedis, No. 2 for 3 to 4 cedis and No. 3 for 1 to 2 cedis respectively. The determination of fruit size was based on farmer’s own judgement. After selling, fruits were transported in either kia© trucks, pick-up vehicle, vans or sometimes taxis. On arrival at the destination (either home or market centres), fruits were off-loaded and stored. They were then sold to either retailers or consumers directly. Retailers sold fruits to consumers as either whole fruits or cut-fruits.

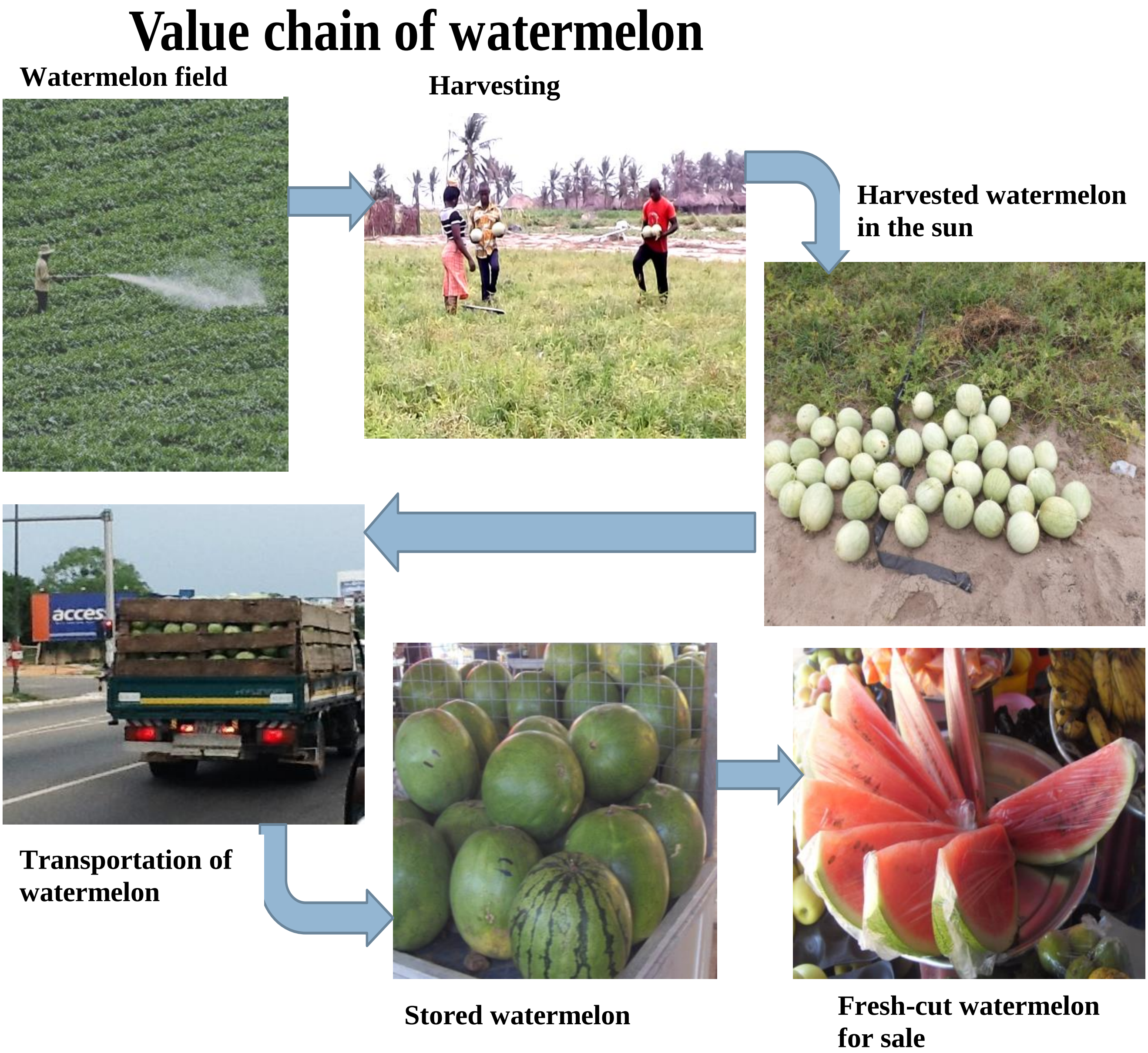


Plate 4.1 Description of the entire watermelon value chain in the Ada-East District

4.2 Educational level of respondents

The study also revealed that more than half (58%) of the farmers had successfully undergone middle school/JSS education (Figure 4.1) with 2% receiving only Islamic education. Farmers who had received Secondary/SSS education was 20% however, those who had education higher than secondary education was 4%. Six percent of the farmers on the other hand, had no formal education.

Watermelon dealers also attained various levels of highest education including primary, middle/JSS, secondary/SSS and Islamic education (Figure 4.1). The most popular level of highest education attained by dealers was middle/JSS education (46%). The study further revealed that 30% of dealers had only primary education and 22% had secondary/SSS education. Out of these highlights, only one dealer representing 2%, reported to have attained Islamic education. Records from the study also showed that no dealer had received education higher than secondary/SSS (Figure 4.1).

Comparing the level of education between farmers and dealers, it was discovered that dealers had more primary and secondary/SSS education than farmers (Figure 4.1). On the other hand, farmers had more Middle/JSS education than dealers.

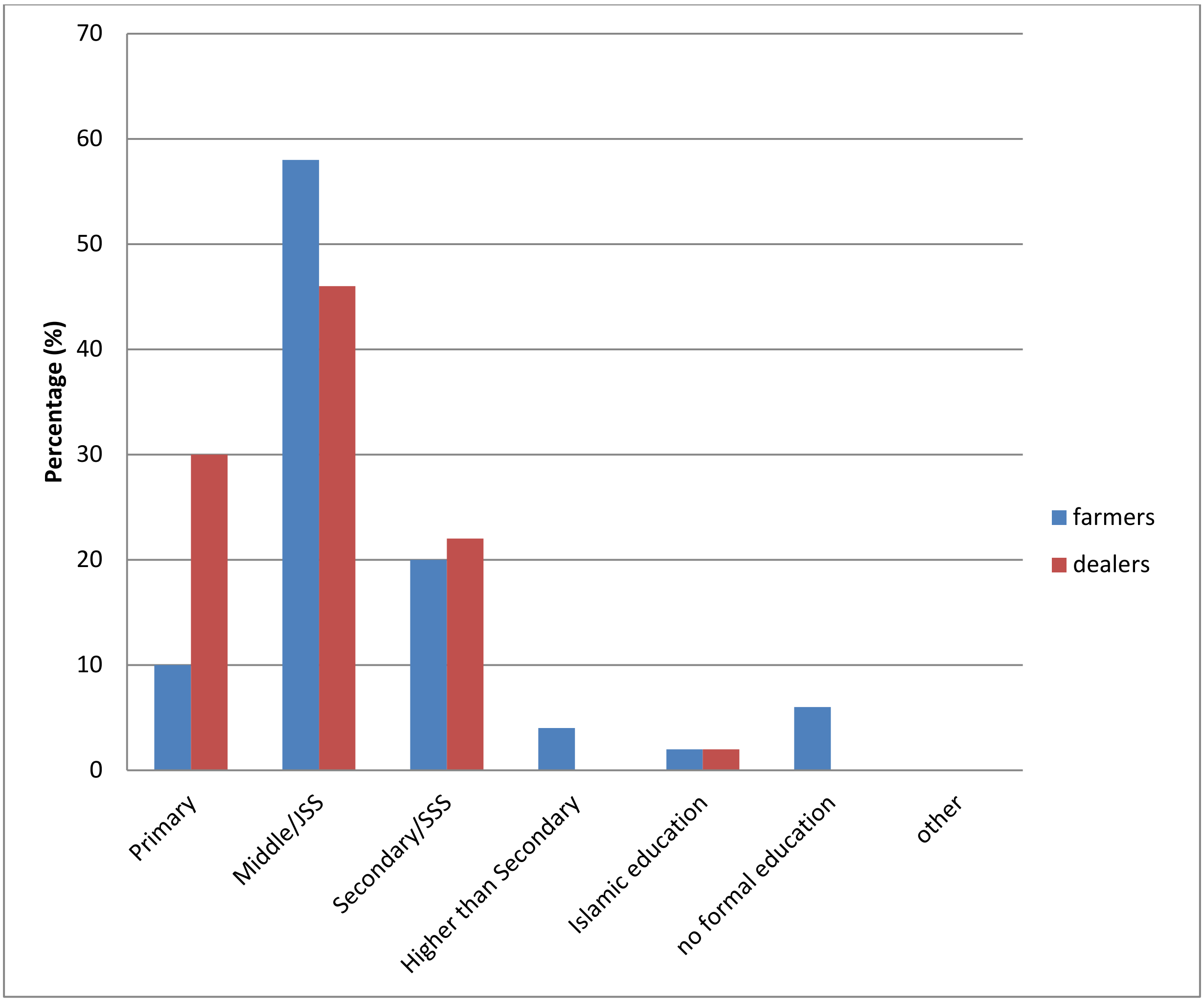


Figure 4. 1 Educational level of respondents

4.3 Access to information from Agric Extension Agents (AEA)

Majority of farmers (76%) responded in the affirmative to have received service/help from agric extension agents (Plate 4.2). Only 24% on the other hand responded in the negative to have received help from agric extension agents. Of those that received service from extension agents, the following includes the services that were listed;

- Correct use of agro-chemicals such as fertilizers, insecticides, pesticides, weedicides and fungicides.
- How to troubleshoot faulty knapsack sprayers and irrigation tubes.
- Other advisory services.

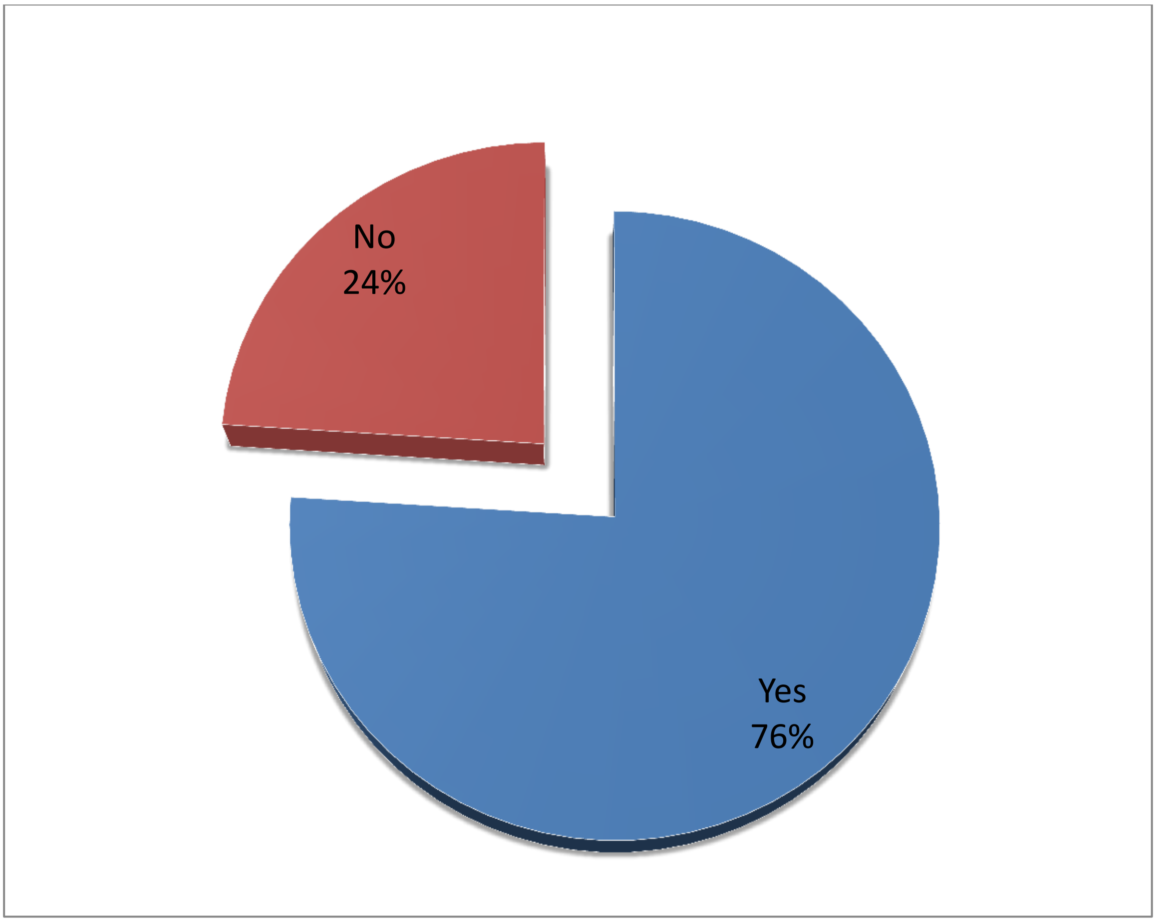


Plate 4.2 Response to receiving help from Agric Extension Agents (AEA)

4.4 Pre and Postharvest practices along the value chain

4.4.1 Disease control measures adopted by farmers

Farmers adopted several methods in the control of watermelon plant diseases (Plate 4.3). A vast majority of farmers used fungicides (66%) where as 20% used physical removal/isolation as a method of controlling diseases. The combination of physical removal and use of fungicides recorded the least (14%) amongst the listed methods of controlling diseases.

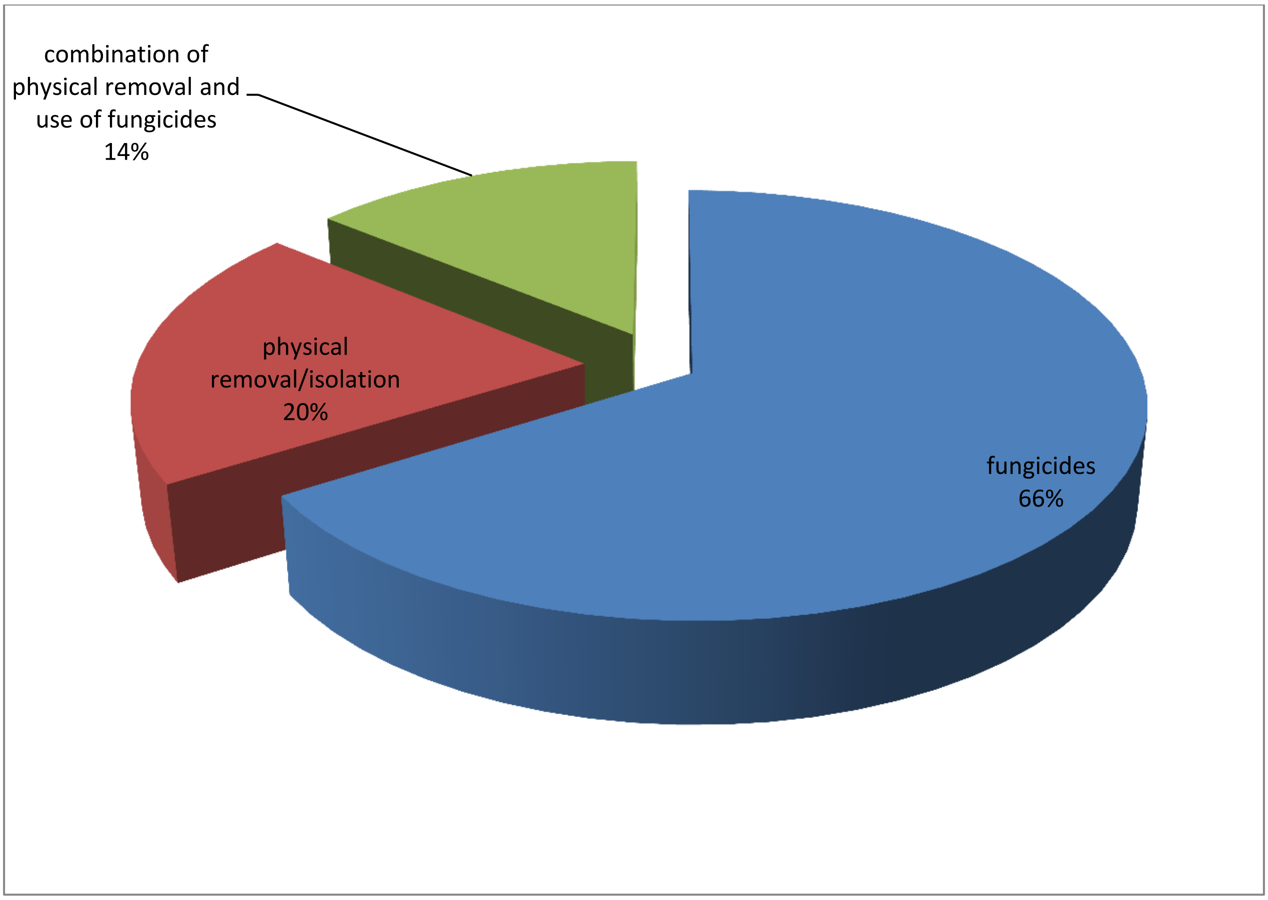


Plate 4.3 Methods used by farmers to control diseases

4.4.2 Harvesting indices used

Farmers also employed the use of several techniques in determining physiologically matured fruits that were ready for harvesting (Plate 4.4). The study revealed that the most popular means of determining physiologically matured fruits that were ready for harvesting was a combinational use of the knocking sound and dryness of stalk (32%). This was sharply followed by the use of knocking sound alone (20%) in determining matured fruits. The use of the colour of the pale patch that lies on the ground (8%) proved to be an unpopular index in determining matured fruits.

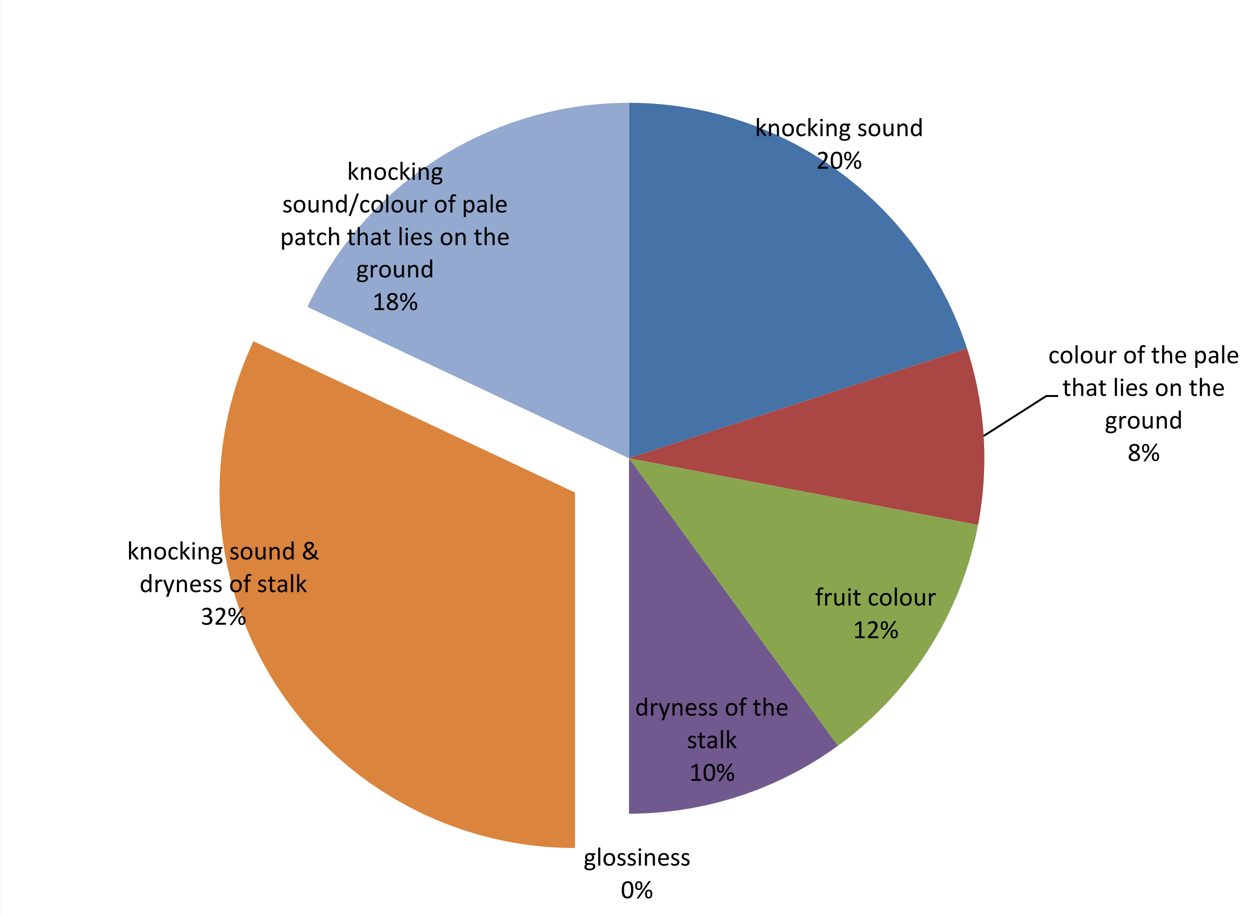


Plate 4. 4 Harvesting indices used by farmers to determine matured fruit

4.4.3 Materials used to cover fruits during transportation

Dealers used various materials to cover watermelon fruits during transportation (Figure 4.2). From the survey, it was seen that most of the dealers (54%) representing a count of 27 did not use any material to cover watermelon fruits during transportation (Figure 4.2). Others also resorted to the use of tarpaulin (28%), plain polythene sheets (12%) and black polythene (6%) however; there was no indication of the use of straw among dealers during the transportation of watermelon fruits.

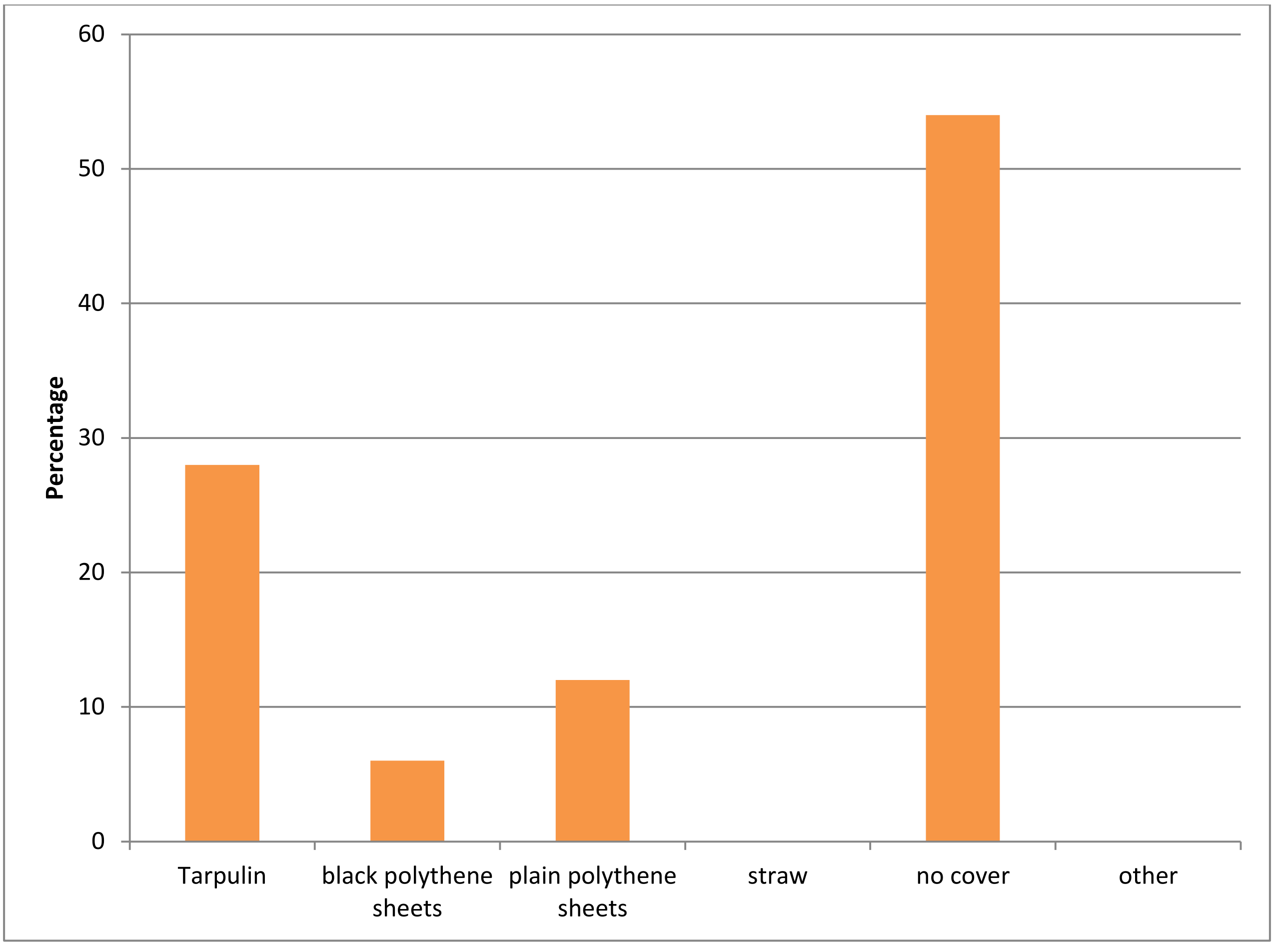


Figure 4.2 materials used by dealers to cover fruit during transportation

4.5 Challenges faced by farmers and dealers along the value chain

4.4.1 Major insects/rodents encountered by farmers

The major insects that were encountered on the farms prior to harvesting as reported by the farmers included beetles, moths/butterflies, aphids and grasshoppers (Figure 4.3). The most predominant insects encountered were aphids (44%), followed by beetles (34%), moths/butterflies (14%) and grasshoppers (8%). There were no reports of thrips, grasscutters and rats.

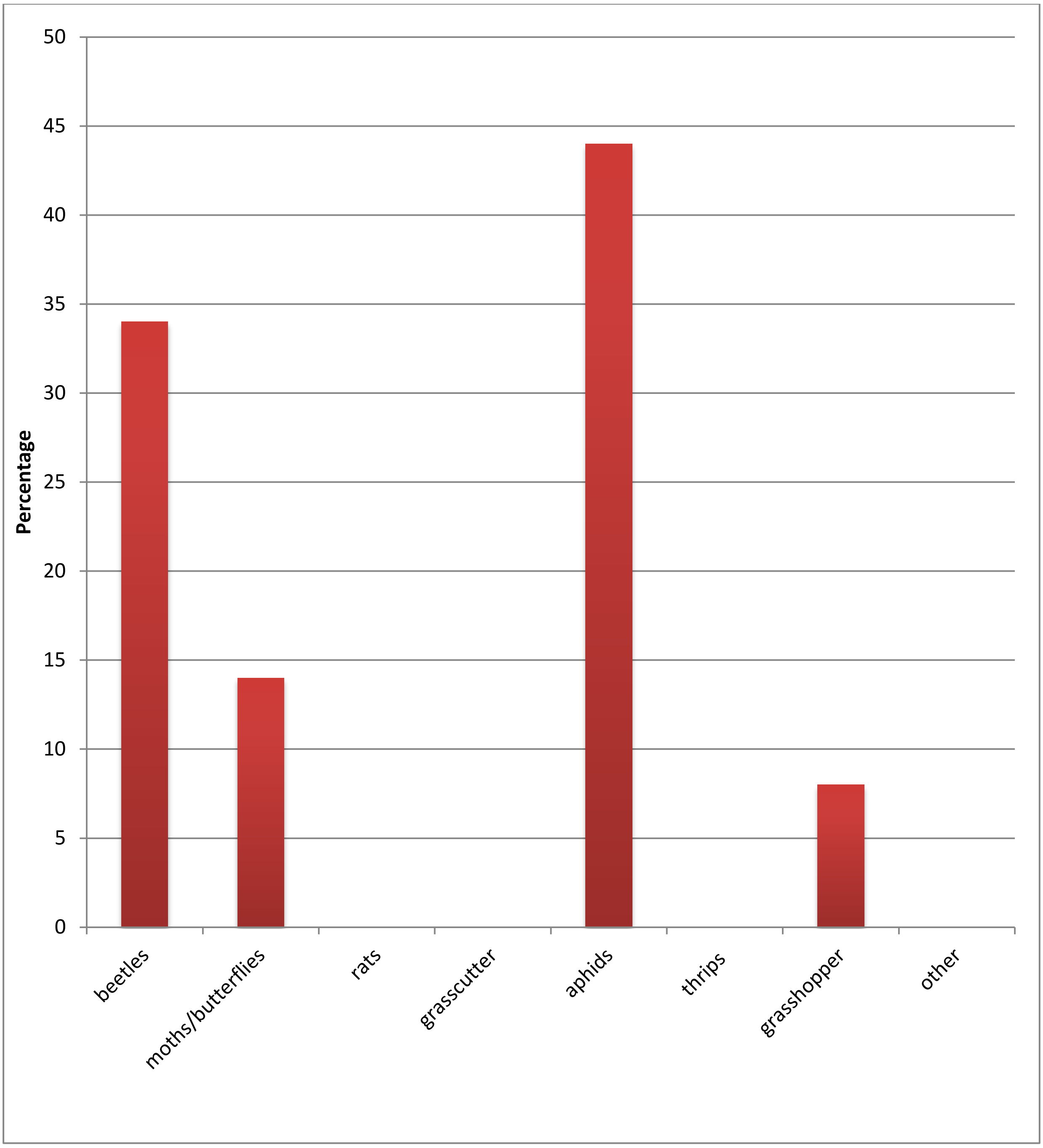


Figure 4.3 Major insects/rodents encountered by farmers prior to harvest

4.5.2 Storage problems faced by dealers

The major storage problems faced by dealers included rot, theft and attack by rodents (Figure 4.4). More than half (76%) of the major problems faced by dealers were due to rot. On the other hand, 18% were due to attack by rodents and 6% were because of thieves.

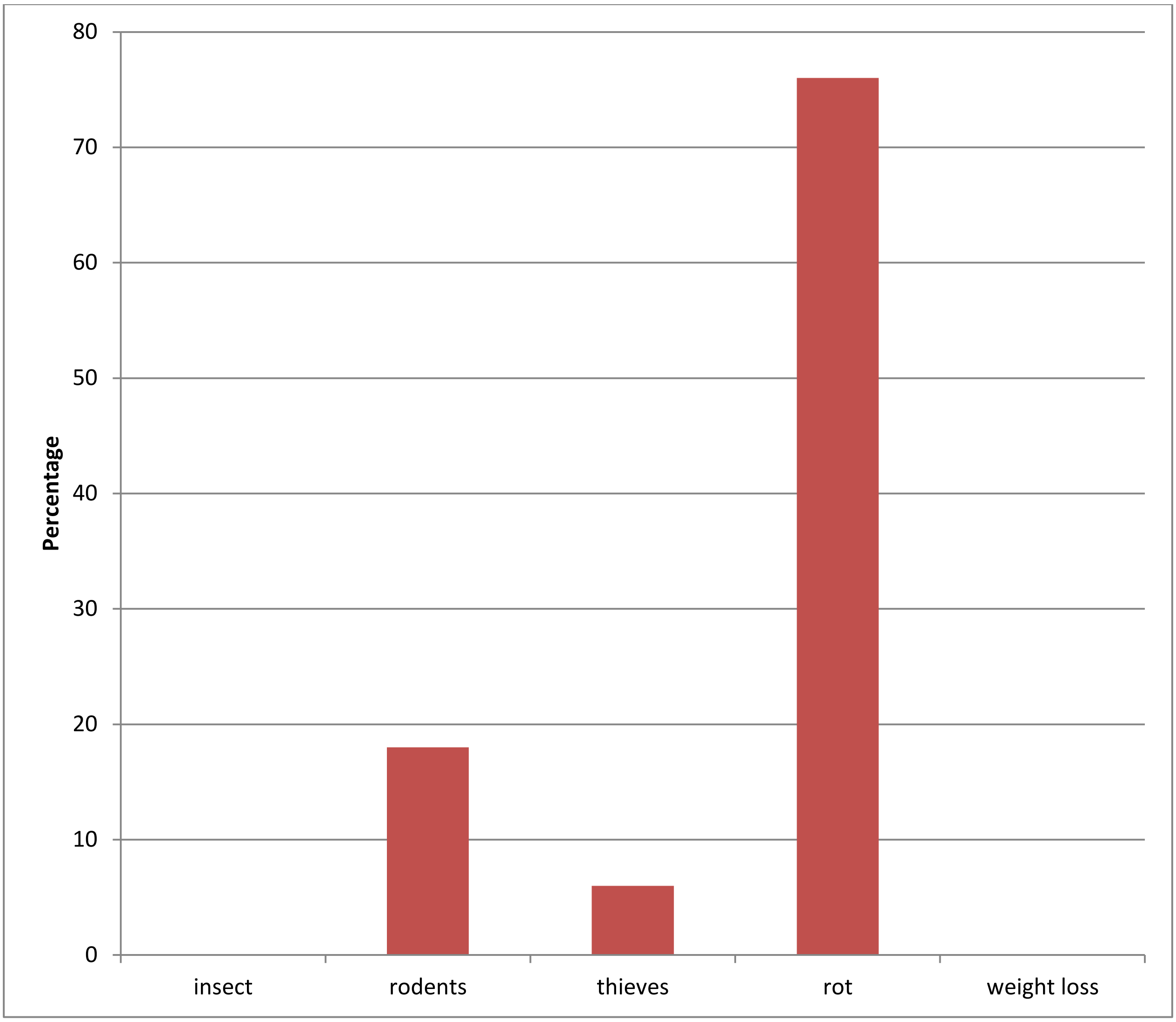


Figure 4.4 Major storage problems encountered by dealers

4.6 Contribution of pre-harvest and husbandry practices to losses

The losses associated with pre-harvest and husbandry practices were also evaluated (Table 4.1). The nature of losses associated with this stage of the value chain includes wilting & shrinking, rotting, bruising of fruits and feeding on leaves (Table 4.1). A greater percentage of the loss (1.29%) was due to over application of weedicides/careless weeding and the economic level of this loss was estimated to be GH₵ 7,345.00. On the other hand, the least percentage of loss was due to over application of fertilizer (0.68%) and the economic cost associated to this loss was evaluated to be GH₵ 3,200.00. In all, the total economic level of loss was to the tune of GH₵ 31,649.00 (Table 4.1)

Table 4. 1 Inappropriate pre-harvest and husbandry practices and their contribution to losses

Husbandry Practice	Nature of loss listed	Estimated losses based on 202,400 fruits harvested per season Quantity, (%)	Value of loss (GH¢)
Fertilizer application (over application)	wilting & shrinking	1380 (0.68%)	3,200.00
watering (too much watering)	rotting	1420 (0.7%)	4,544.00
Weed control (over application of weedicides & careless weeding)	-wilting & shrinking -bruising of fruits	1150 (0.56%) 1490 (0.73%) 2640 (1.29%)	2,875.00 4,470.00 7,345.00
Insect/disease control (over application of insecticides/fungicide)	wilting and shrinking	1530 (0.75%)	4,590.00
Insect/rodent attack	feeding on leaves	2070 (1.01%)	6,210.00
Disease attack	rotting	1920 (0.93%)	5,760.00
TOTAL			**31,649.00**

4.7 Contribution of harvesting and postharvest handling to losses

Harvesting and postharvest handling also led to some losses (Table 4.2). Dropping, cracking and bruising of fruits were listed as the nature of loss associated with this stage of handling. The highest level of loss (1.97%) was associated with harvesting operations and accounted for a total of GH₵ 12,120.00 in terms of economic evaluation. The least level of loss (0.58%) occurred during sorting and grading operations at the farm and the economic level of loss due to these operations was GH₵ 3,525.00. In its entirety, the total economic level of loss associated with harvesting and immediate postharvest handling was to the tune of GH₵ 23,837.00 (Table 4.2).

Table 4. 2 Harvesting and postharvest handling and their contribution to losses

Stages of Handling	Nature of loss listed	Estimated losses based on 202,400 fruits harvested per season Quantity (%)		Value of loss (GH¢)	
Harvesting operations	-dropping and cracking	2130 (1.04%)	4040 (1.97%)	6,390.00	12,120.00
	-bruising of fruits	1910 (0.93%)		5,730.00	
Gathering, transport, packing etc at farm or at purchase point	dropping and cracking	2520 (1.23%)		8,190.00	
Grading and sorting operations at farm,	Dropping and cracking	1175 (0.58%)		3,525.00	
Temporal processing (pre-cooling, washing, etc)	none	-		-	
Processing (specify)	none	-		-	
TOTAL				**23,835.00**	

4.8 Factors contributing to postharvest losses

Postharvest handling, transportation and marketing also contributed to some economic losses (Table 4.3). The most predominant nature of loss associated with this stage of handling was dropping and cracking. Most of these losses (0.93%) occurred during vehicular transportation to the market and was to the tune of GH₵ 7,480.00. The study further revealed that the least losses (0.43%) occurred during cleaning, grading and sorting activities. In all, the total loss associated with postharvest handling, transportation and marketing amounted to GH₵ 22,410.00.

Table 4. 3 Postharvest handling, transportation, marketing and their contribution to losses

Stage of handling	Nature of loss	Estimated losses based on 268,000 fruits bought from farmers per season Quantity (%)	Value of loss (GH¢)
Loading and off-loading	dropping & cracking	1,210 (0.45%)	3,630.00
During transport to market	dropping & cracking	2,490 (0.93%)	7,480.00
Cleaning and grading or sorting	dropping & cracking	1,150 (0.43%)	3,480.00
During wholesale points	dropping & cracking	1,270 (0.47%)	3,870.00
During retail points	dropping & cracking	1310 (0.49%)	3,950.00
During export points	none		
TOTAL			**22,410.00**

4.9 Storage losses

The various sites of storage employed by dealers also lead to some losses (Table 4.4). The nature of loss was due to either rot, rodents or thieves. Storage at market or point of sale recorded the highest loss (1.62%) representing GH₵ 11,715.00. It was followed closely by storage at home (1.48%) representing GH₵ 11,543.00 and lastly, storage at processing site (0.4%). The total contribution of storage to losses was to the tune of GH₵ 23,580.00.

Table 4. 4 Contribution of storage to losses

Site of storage	Nature of loss	Estimated losses based on 268,000 fruits bought from farmers per season Quantity (%)		Value of loss (GH¢)	
Storage at market or point of sale	rot	2580 (0.96%)	4335 (1.62%)	6,450.00	11,715.00
	rodents	1035 (0.39%)		3,105.00	
	thieves	720 (0.27%)		2,160.00	
Storage at home	rot	2140 (0.8%)	3955 (1.48%)	6,420.00	11,543.00
	rodents	1170 (0.44%)		3,510.00	
	thieves	645 (0.24%)		1,613.00	
Storage at processing site	rot	1055 (0.4%)		3,165.00	
TOTAL				**23,580.00**	

4.10 Effect of plant oils on the physical, chemical and organoleptic properties of watermelon.

Several changes in physical, chemical and organoleptic characteristics of watermelon were observed following waxing treatment and length of storage.

4.10.1 Percent Total Weight Loss (%TWL) following Neem oil/Shea-butter Waxing and days of storage

Generally, there was a significant increase in % TWL from day 2 to day 7 (Table 4.5) and among all the five NSBW levels, {NSBW (5:95), NSBW (10:90), NSBW (15:85), NSBW (20:80) and NSBW (CTRL)} however, there was no significant effect of NSBW/days of storage interactions on %TWL. NSBW (15:85) recorded the highest weight loss of 5.6% whiles NSBW (20:80) recorded the lowest % TWL however; the % TWL in NSBW (15:85) was not significantly different from NSBW (5:95) and NSBW (20:80) respectively (Table 4.5).

Table 4. 5 Effect of NSBW and days of storage on % TWL

		DAYS OF STORAGE FACTOR				MEANS (NSBW)
		1	2	4	7	
NSBW FACTOR	NSBW (5:95)	**	0.40	1.91	6.9	3.07^{c}
	NSBW (10:90)	**	0.82	2.95	5.95	3.24^{c}
	NSBW (15:85)	**	0.91	6.44	9.45	5.6^{a}
	NSBW (20:80)	**	0.32	2.87	5.26	2.81^{c}
	NSBW (CTRL)	**	0.93	4.48	7.33	4.25^{b}
MEANS (DAYS)		**	0.68$_{a}$	3.73$_{b}$	6.98$_{c}$	
LSD'^{S} (p=0.05)	NSBW=0.600		DAYS=0.465			NSBW*DAYS=NS

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other.
**Data was not taken due to power cut

4.10.2 Total Soluble solids (TSS) or % Brix following Neem oil/Shea-butter waxing and days of storage

The changes that occurred in Total Soluble Solids (TSS) or % brix (Appendix 6; Fig 2) showed that, there was a significant increase in TSS from day 1 to day 4 (Table 4.6). As storage proceeded from the fourth day to the seventh day, the pattern of rise in TSS continued for NSBW (5:95) and NSBW (10:90) however, there was a gradual decline in TSS for NSBW (15:85), NSBW (20:80) and NSBW (CTRL) (Appendix 6; Fig 2). Interestingly, there was no significant difference in neither the rise nor fall in TSS from the fourth to the seventh day (Table 4.6). There was however a significant effect of NSBW/days of storage interaction on TSS.

Table 4. 6 Effect of NSBW and days of storage on TSS (%Brix)

		DAYS OF STORAGE FACTOR			MEANS (NSBW)
		1	4	7	
NSBW FACTOR	NSBW (5:95)	5.90	8.48	5.68	6.687^{c}
	NSBW (10:90)	6.44	6.58	8.10	7.040^{c}
	NSBW (15:85)	8.20	9.02	5.84	7.687^{b}
	NSBW (20:80)	6.26	7.68	4.94	6.293^{d}
	NSBW (CTRL)	7.60	8.18	8.72	8.167^{a}
MEANS (DAYS)		6.880$_{a}$	7.988$_{b}$	6.656$_{b}$	
LSD'^{S} (p=0.05)	NSBW= 0.3645	DAYS= 0.2824		NSBW*DAYS= 0.6314	

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other

4.10.3 TTA following Neem oil/Shea-butter waxing and days of storage

The study showed that there was significant increase in Total Titrable Acids (TTA) from day 1 to day 7 (Table 4.7 and Appendix 6; Fig 3). NSBW (5:95) recorded the highest TTA and was significantly higher than the rest of the NSBW levels however; there were no significant differences between NSBW (10:90), NSBW (15:85), NSBW (20:80) and NSBW (CTRL). Several changes in TTA occurred as a result of days of storage and neem oil/shea-butter waxing (Appendix 6; Fig 3).

Table 4. 7 Effects of NSBW and days of storage on TTA (NSBW)

		DAYS OF STORAGE FACTOR			**MEANS (NSBW)**
		1	**4**	**7**	
NSBW FACTOR	NSBW (5:95)	4073	4534	7608	5405[a]
	NSBW (10:90)	4265	3689	4496	4150[b]
	NSBW (15:85)	2728	3996	5456	4060[b]
	NSBW (20:80)	3151	3189	6494	4278[b]
	NSBW (CTRL)	2651	4572	4419	3881[b]
MEANS (DAYS)		3374_{c}	3996_{b}	5694_{a}	
LSD'[S] (p=0.05)	**NSBW=402.5**		**DAYS=311.8**		**NSBW*DAYS=697.1**

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other.

4.10.4 pH following Neem oil/Shea-butter waxing and days of storage

It was noted that, there was a significant decrease in pH or a significant rise in acidity from day 1 to day 7 (Table 4.8). NSBW (CTRL) recorded the lowest pH however; it was not significantly different from NSBW (10:90). Additionally, there was no significant difference between NSBW (5:95) and NSBW (15:85) in effect on pH. The study also showed there was a significant effect on pH as a result of NSBW/days after storage interactions. The changes in pH of watermelon that occurred after 7 days of storage following Neem oil/Shea-butter waxing are shown in Appendix 6; Fig 4.

Table 4. 8 Effect of NSBW and days of storage treatments on pH

		DAYS			MEANS (NSBW)
		1	**4**	**7**	
NSBW FACTOR	NSBW (5:95)	6.508	6.464	5.210	6.0607^{a}
	NSBW (10:90)	6.478	6.140	5.180	5.9327^{c}
	NSBW (15:85)	6.696	6.130	5.402	6.0760^{a}
	NSBW (20:80)	6.524	6.232	5.214	5.9900^{b}
	NSBW(CTRL)	6.734	5.752	5.294	5.9267^{c}
MEANS (DAYS)		6.5880$_{a}$	6.1436$_{b}$	5.2600$_{c}$	
LSD'^{S} (0.05)	**NSBW=0.05462**		**DAYS=0.04231**	**NSBW*DAYS=0.09460**	

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other.

4.10.5 Percent Vitamin C following Neem oil/Shea-butter waxing and days of storage

The study revealed that there was a significant decrease in % vitamin C from day 1 to day 7 (Table 4.9). NSBW (CTRL) recorded the highest % vitamin C and was significantly higher from the rest of the NSBW levels. It was also observed that there was no significant difference in effect on % Vitamin C between NSBW (5:95), NSBW (15:85) and NSBW (20:80). Additionally, there were no significant differences in effect on % Vitamin C between NSBW (5:95), NSBW (10:90) and NSBW (15:85) (Table 4.9). NSBW/days of storage interaction also had a significant effect on % Vitamin C.

Table 4. 9 Effect of NSBW and days of storage on Vitamin C

		DAYS OF STORAGE FACTOR			MEANS (NSBW)
		1	**4**	**7**	
NSBW FACTOR	NSBW (5:95)	10.42	9.30	8.03	9.25^{b,c}
	NSBW (10:90)	12.25	7.46	7.04	8.92^{c}
	NSBW (15:85)	9.72	10.14	7.83	9.23^{b,c}
	NSBW (20:80)	10.85	9.80	8.45	9.70^{b}
	NSBW (CTRL)	12.11	10.28	9.01	10.47^{a}
MEANS (DAYS)		11.07$_{a}$	9.4$_{b}$	8.07$_{c}$	
LSD'^{S} (p=0.05)	**NSBW=0.738**		**DAYS= 0.572**		**NSBW*DAYS=1.279**

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other

4.10.6 Storage life of watermelon following Neem oil/Shea-butter waxing and days of storage

The storage life/ shelf life of watermelon following Neem oil/Shea-butter waxing is depicted in figure 4.5. The study revealed that watermelon samples that were treated with the various concentrations of Neem oil/Shea-butter lasted for a maximum of 7 days. After the seventh day, the fruits had started rotting and had turned dark with both white and black moulds forming on them. On the other hand, 100% of watermelon samples that received no NSBW treatment (NSBW control) maintained a shelf life of 18 days before they begun to rot.

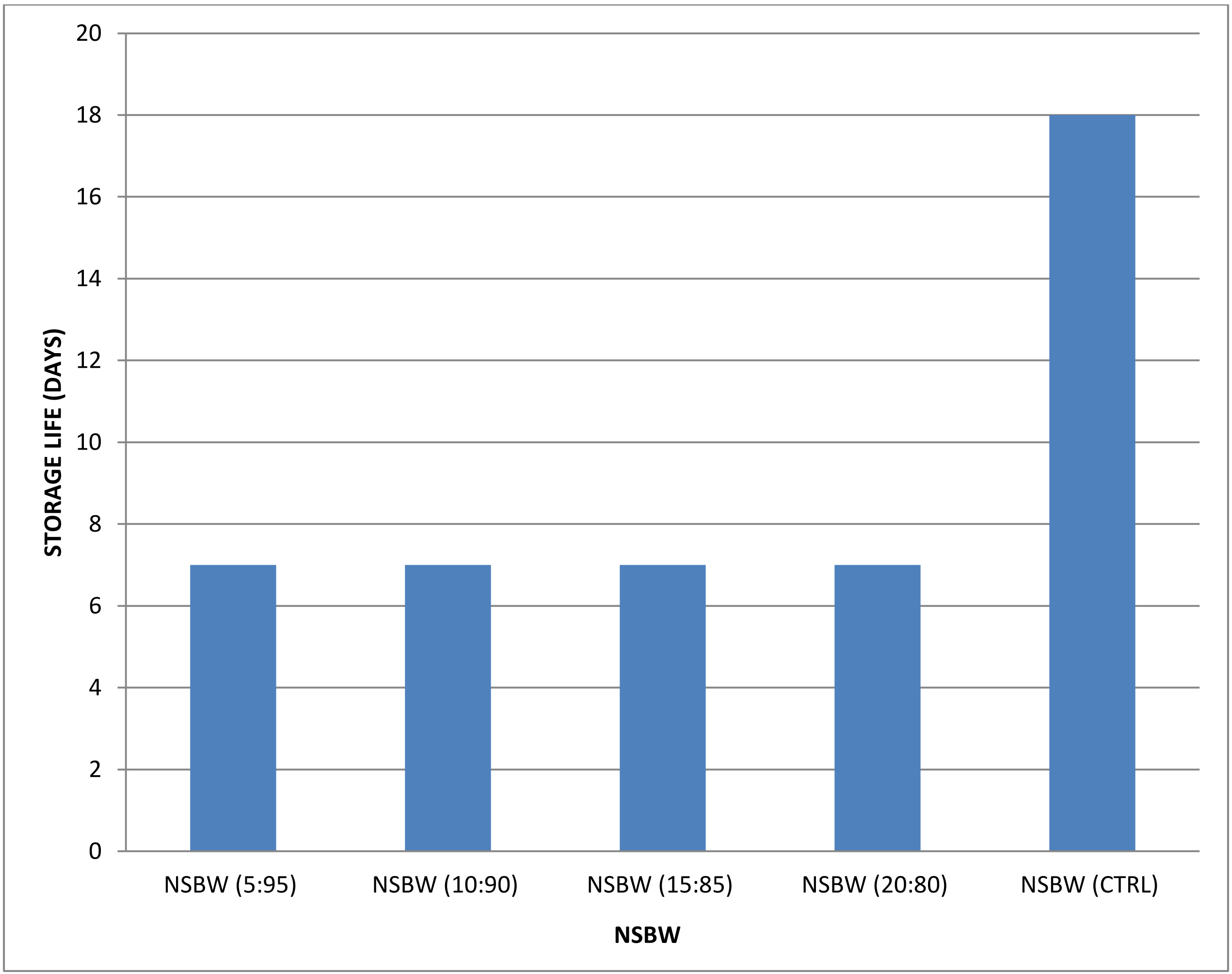


Figure 4. 5 storage life/ shelf life of watermelon following Neem oil/Shea-butter waxing

4.10.7 Percent Vitamin C following Neem oil/Palm oil waxing and days of storage

Neem oil/Palm oil waxing (NPW) followed by days of storage caused some effects and changes in % Vitamin C (Table 4.10 and Appendix 6; Fig 6). The results revealed that there was a significant decrease in % Vitamin C (8.56% to 3.88%) from day 1 to day 14 however; there was no significant reduction in % Vitamin C from day 7 to day 10. There were also significant differences in effect on % Vitamin C between NPW levels (Table 4.9). NPW (2:98) recorded significantly higher levels of % Vitamin C than all the other levels of NPW however; there were no significant differences between NPW (1:99), NPW (2:98) and NPW (4:96). The results also indicated there were no significant differences in % Vitamin C due to NPW and days of storage interaction effect.

Table 4. 10 The effects NPW and days of storage treatment on % Vitamin C

		DAYS OF STORAGE FACTOR					
		1	**4**	**7**	**10**	**14**	**MEANS (NPW)**
NPW FACTOR	NPW (1:99)	7.34	7.09	5.32	5.55	4.36	5.93^{b}
	NPW (2:98)	11.39	8.15	5.82	5.18	4.56	7.02^{a}
	NPW (3:97)	8.35	6.53	4.56	4.30	3.80	5.51^{b}
	NPW (4:96)	8.86	6.33	5.57	5.06	3.66	5.90^{b}
	NPW (CTRL)	6.84	3.97	3.21	3.29	3.04	4.07^{c}
MEANS (DAYS)		8.56_{a}	6.41_{b}	4.89_{c}	4.68_{c}	3.88_{d}	
LSD'^{S} (p=0.05)	**NPW=0.770**		**DAYS=0.770**		**NPW*DAYS=NS**		

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other.

4.10.8 TTA following Neem oil/Palm oil waxing and days of storage

According to the study, Neem oil/Palm oil waxing followed by storage from day1 to day 14 had some effects and caused some changes in Total Titrable Acids (TTA) (Table 4.11 and Appendix 6; Fig 7). Per the study, it was discovered that there was a significant decrease in TTA from day 1 to day 14. It also revealed that, there were significant differences in TTA due to NPW effect however; there were no significant differences in TTA considering NPW (1:99), NPW (2:98) and NPW (4:96). There were also no significant differences between NPW (3:97) and NPW (CTRL). Additionally, NPW and days of storage interactions showed significance (Table 4.11).

Table 4. 11 The effects of NPW and days of storage on TTA (g/L)

		DAYS OF STORAGE FACTOR					
		1	**4**	**7**	**10**	**14**	**MEANS (NPW)**
NPW FACTOR	NPW (1:99)	3727	4265	3689	3189	2613	3497^{a}
	NPW (2:98)	4457	4303	3381	4380	2229	3750^{a}
	NPW (3:97)	3650	4035	3112	2728	2421	3189^{b}
	NPW (4:96)	3535	4803	3497	2767	3151	3550^{a}
	NPW (CTRL)	3842	5226	2959	1460	1652	3028^{b}
MEANS (DAYS)		3842_{b}	4526_{a}	3328_{c}	2905_{d}	2413_{e}	
LSD'S (p=0.05)		**NPW= 307.6**		**DAYS= 307.6**		**NPW*DAYS= 687**	

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other.

4.10.9 pH following Neem oil/Palm oil waxing and days of storage

Results from the study showed that there were no significant effects of NPW on pH (Table 4.12). There was also no significant effect of NPW and days after storage interaction on pH. Conversely, there was a significant effect of days of storage on pH however; there was no significant difference in effect of day 1, day 4, day 7 and day 14 on pH. The changes in pH that were observed were irregular (Appendix 6; Fig 8). Firstly, there was a steady rise in pH from day 1 to day 4 however, from day 4 to day 10, it fell. From day 10 to day 14, pH began to rise.

Table 4. 12 The effects of NPW and days of storage on pH

		DAYS OF STORAGE FACTOR					
		1	**4**	**7**	**10**	**14**	**MEANS (NPW)**
NPW FACTOR	NPW (1:99)	5.240	5.284	5.246	4.784	5.224	5.156
	NPW (2:98)	5.370	5.370	5.378	4.866	5.232	5.243
	NPW (3:97)	5.298	5.318	5.132	4.880	5.122	5.150
	NPW (4:96)	5.206	5.218	5.498	4.944	5.182	5.210
	NPW (CTRL)	5.270	5.124	5.298	4.976	5.314	5.196
MEANS (DAYS)		5.277_{a}	5.263_{a}	5.310_{a}	4.890_{b}	5.215_{a}	
LSD'S (p=0.05)		**NPW= NS**		**DAYS= 0.1737**		**NPW*DAYS= NS**	

Means followed by the same subscript across rows are not significantly different from each other.

4.10.10 Percent TWL following Neem oil/Palm oil waxing and days of storage

Results from the investigations showed that there was a significant loss in percent total weight from day 1 to day 14 (Table 4.13). There was also a significant loss in % TWL due to NPW effect however; there were no significant differences in effect between NPW (3:97), NPW (4:96) and NPW (CTRL), and also between treatments NPW (1:99), NPW (2:98), NPW (3:97), and NPW (4:96) . The interaction effect of NPW and days of storage on % TWL also proved significance. Generally, the changes in % TWL that occurred was in an increasing order from day 1 to 14 (Appendix 6; Fig 9)

Table 4. 13 The effects of NPW and days of storage on %TWL

		DAYS OF STORAGE FACTOR					
		1	**4**	**7**	**10**	**14**	**MEANS (NPW)**
NPW FACTOR	NPW (1:99)	0	0.491	0.982	1.751	2.242	1.093^{b}
	NPW (2:98)	0	0.490	1.183	1.672	2.253	1.120^{b}
	NPW (3:97)	0	0.527	1.188	1.810	2.337	$1.172^{a,b}$
	NPW (4:96)	0	0.553	1.106	1.790	2.343	$1.158^{a,b}$
	NPW (CTRL)	0	0.966	1.932	2.795	3.761	1.891^{a}
MEANS (DAYS)		0_{e}	0.605_{d}	1.278_{c}	1.964_{b}	2.587_{a}	
LSD'^{S} (p=0.05)		**NPW= 0.1763**		**DAYS= 0.1763**		**NPW*DAYS= 0.3942**	

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other.

4.10.11 TSS or %Brix following Neem oil/Palm oil waxing and days of storage

From the studies, it was seen that there were significant changes in TSS due to days of storage effect (Table 4.14) however; there were no significant differences in TSS due to NPW effects as well as interaction effects. (Table 4.14). Also, there was no significant rise in TSS from day1 to day 4 but soon, TSS declined significantly after the fourth day up to the fourteenth day. In all, It was observed that there was a decline in TSS from day 1 to the last day of storage (Appendix 6; Fig 10)

Table 4. 14 The effects of NPW and days of storage on TSS (% Brix)

		DAYS OF STORAGE FACTOR					MEANS (NPW)
		1	**4**	**7**	**10**	**14**	
NPW FACTOR	NPW (1:99)	7.50	8.78	8.36	8.26	8.06	8.192
	NPW (2:98)	8.64	8.76	8.16	7.02	7.00	7.916
	NPW (3:97)	8.54	8.84	8.38	7.86	7.50	8.224
	NPW (4:96)	8.02	8.82	8.30	8.14	8.12	8.280
	NPW (CTRL)	8.96	8.98	8.00	7.88	7.24	8.212
MEANS (DAYS)		8.332$_{b}$	8.836$_{a}$	8.240$_{b}$	7.832$_{b,c}$	7.584$_{c}$	
LSD'^{S} (p=0.05)		**NPW= NS**			**DAYS= 0.5013**		**NPW*DAYS= NS**

Means followed by the same subscript across rows are not significantly different from each other.

4.10.12 Storage life of watermelon following Neem oil/Palm oil waxing and days of storage

It was discovered that watermelon samples that were coated with NPW (2:98), NPW (3:97), and NPW (4:96) maintained a storage life of 14 days respectively however; it was only 80% of the fruits coated with NPW (4:96) that maintained a storage life of 14 days. Samples coated with NPW (1:99) on the other hand maintained good storage life up to day 18 i.e. 60% of the fruits however; the control samples which were not coated with any NPW also maintained a storage life of 18 days (Figure 4.6).

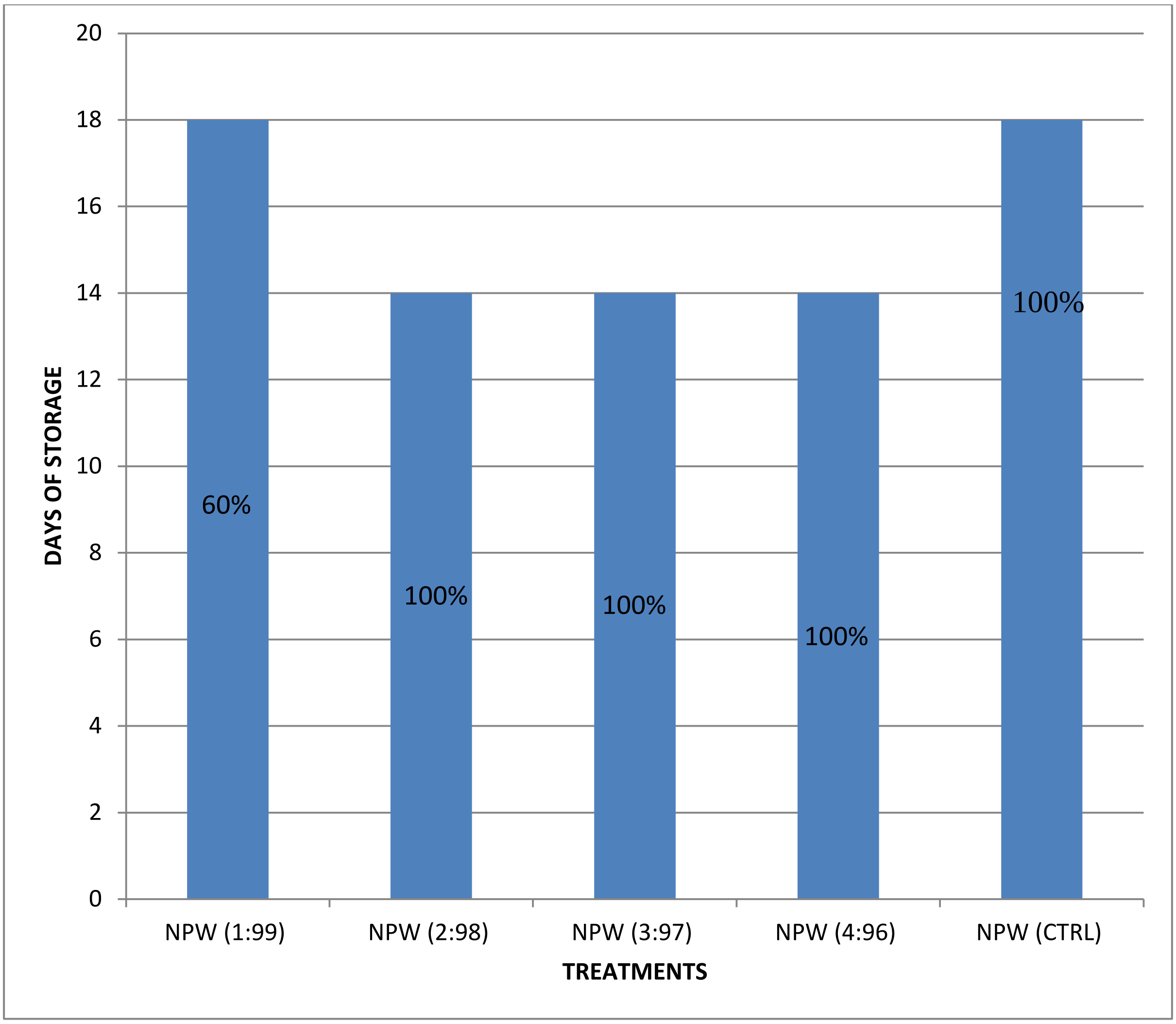


Figure 4. 6 Storage life of watermelon following Neem oil/Palm oil waxing and days of storage

4.10.13 Percent Vitamin C following Neem oil/Coconut oil waxing and days of storage

Results from the study indicated that there was a significant decrease in % Vitamin C form day 1 to day 18 however; there were no significant differences in effect on % Vitamin C between day 7, day 10, day 14 and day 18 (Table 4.15). There were also significant differences in % Vitamin C among Neem oil/Coconut oil Waxing (NCW) levels. NCW (CTRL) recorded the lowest % Vitamin C of 4.799% which was significantly different from % Vitamin C of 5.773% recorded for NCW (3:97) No significant differences in effect on % Vitamin C were found between NCW (1:99), NCW (2:98), and NCW (3:97). There was however a significant effect on % Vitamin C due to NCW and days of storage interactions. Several changes in % Vitamin C of a decreasing trend was also observed as the days of storage progressed following waxing treatments (Appendix 6; Fig 11).

Table 4. 15 Effect of NCW and days of storage on % Vitamin C

		DAYS OF STORAGE FACTOR						MEANS (NCW)
		1	**4**	**7**	**10**	**14**	**18**	
NCW FACTOR	NCW (1:99)	8.354	5.570	4.304	4.810	4.69	4.497	$5.371^{a,b}$
	NCW (2:98)	7.089	6.076	4.477	5.542	5.548	4.702	$5.572^{a,b}$
	NCW (3:97)	8.194	5.530	5.823	5.316	5.063	4.710	5.773^{a}
	NCW (4:96)	6.582	6.402	4.557	4.732	4.810	4.497	5.263^{b}
	NCW (CTRL)	8.101	4.361	3.967	4.304	4.051	4.011	4.799^{c}
MEANS (DAYS)		7.664_{a}	5.588_{b}	4.625_{c}	4.941_{c}	4.832_{c}	4.483_{c}	
LSD'S (p=0.05)		**NCW= 0.4507**			**DAYS= 0.4938**		**NCW*DAYS=0.014**	

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other.

4.10.14 TTA (g/L) following Neem oil/Coconut oil waxing and days of storage

The study revealed that there was a significant decrease in Total Titrable Acids (TTA) due to days of storage effect i.e. from day 1 to day 14 (Table 4.16 and Appendix 6; Fig 12) however; there were no significant differences in effect of day of storage between day 10, day 14 and day 18 on TTA. On the other hand, the effects of NPW and days of storage interaction showed no significant effect on TTA (Table 4.16). Similarly, NPW had no significant effect on TTA.

Table 4. 16 The effects of NCW and days after storage on TTA (g/L)

		DAYS OF STORAGE FACTOR						MEANS (NCW)
		1	**4**	**7**	**10**	**14**	**18**	
NCW FACTOR	NCW (1:99)	4649	4649	2767	2651	2382	2036	3189
	NCW (2:98)	3612	4726	2690	2574	2344	2075	3003
	NCW (3:97)	3497	4303	2382	2536	2382	2229	2888
	NCW (4:96)	4265	3958	2767	2805	2651	2997	3240
	NCW (CTRL)	4227	4380	2613	2305	2190	2152	2978
MEANS (DAYS)		4050_{b}	4403_{a}	2644_{c}	$2574_{c,d}$	$2390_{c,d}$	2298_{d}	
LSD'S (0.05)		**NCW=NS**			**DAYS=319.4**		**NCW*DAYS= NS**	

Means followed by the same subscript across rows are not significantly different from each other.

4.10.15 pH following Neem oil/Coconut oil waxing and days of storage

Findings from the study showed that there was a significant rise in pH due to days of storage effect and Neem oil/Coconut oil waxing (NCW) effect (Table 4.17 and Appendix 6; Fig.13). Similarly, there was a significant difference in pH due to NCW and days of storage interactions effects. In terms of days of storage, day 18 recorded the highest pH (5.488) and it was significantly different from the rest of the days of storage. In terms of NCW treatments, NCW (1:99) recorded the highest pH however, it was not significantly different from NCW (2:98) and NCW (CTRL).

Table 4. 17 The effects of NCW and days of storage on pH

		DAYS OF STORAGE FACTOR						
		1	**4**	**7**	**10**	**14**	**18**	**MEANS (NCW)**
NCW FACTOR	NCW (1:99)	5.146	5.122	5.312	5.326	5.656	5.668	5.372^{a}
	NCW (2:98)	5.142	5.198	5.390	5.202	5.414	5.568	5.319^{a,b}
	NCW (3:97)	5.016	5.186	5.662	5.008	5.076	5.098	5.174^{c}
	NCW (4:96)	5.156	5.126	5.130	5.302	5.380	5.408	5.250^{b,c}
	NCW (CTRL)	4.976	5.246	5.312	5.314	5.456	5.700	5.334^{a,b}
MEANS (DAYS)		5.087$_{d}$	5.176$_{c,d}$	5.361$_{b}$	5.230$_{b,c}$	5.396$_{b}$	5.488$_{a}$	
LSD'S (0.05)		**NCW= 0.1167**		**DAYS=0.1278**		**NCW*DAYS=0.2858**		

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other

4.10.16 Percent Total Weight Loss following Neem oil/Coconut oil waxing and days of storage

From the study, it was observed that there was a significant increase in percent Total Weight Loss (% TWL) as the days of storage progressed and there were significant differences in effect of days of storage on % TWL (Table 4.18 and Appendix 6; Fig.14). NCW (4:96) recorded the lowest % TWL and was significantly different from the effect of all the other NCW levels on TTA. Additionally, there were no significant differences in effect on TTA between NCW (1:99), NCW (2:98), NCW (3:97) and NCW (CTRL) and similarly, between NCW (1:99) and NCW (2:98).

Table 4. 18 The effect of NCW and days of storage on % TWL

		DAYS OF STORAGE FACTOR						
		1	**4**	**7**	**10**	**14**	**18**	**MEANS (NCW)**
NCW FACTOR	NCW (1:99)	0	0.394	0.940	1.334	2.198	3.709	1.429[b]
	NCW (2:98)	0	0.436	1.146	1.655	2.536	3.974	1.624[a,b]
	NCW (3:97)	0	0.431	1.219	2.253	3.035	3.730	1.778[a]
	NCW (4:96)	0	0.093	0.527	0.800	1.233	1.582	0.706[c]
	NCW (CTRL)	0	0.804	1.504	2.103	2.692	4.244	1.891[a]
MEANS (DAYS)		0_f	0.432_e	1.067_d	1.629_c	2.339_b	3.448_a	
LSD'S (0.05)		**NCW= 0.2817**			**DAYS= 0.3086**		**NCW*DAYS= 0.6901**	

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other

4.10.17 TSS (% Brix) following Neem oil/Coconut oil waxing and days of storage

The study showed that there was a significant rise in Total Soluble Solids (TSS) by the fourth day however; it began to decline after the fourth day until the eighteenth day when the lowest TSS due to days of storage effect was recorded (Table 4.19 and Appendix 6; Fig.15). There was also a significant difference in TSS due to Neem oil/Coconut oil waxing (NCW) effect however; it was only NCW (3:97) that was significantly different from the rest of the NCW levels effects. The interaction effect of NCW and days of storage on TSS however proved insignificant.

Table 4. 19 The effect of NCW and days of storage on TSS (% Brix)

		DAYS OF STORAGE FACTOR						
		1	**4**	**7**	**10**	**14**	**18**	**MEANS (NCW)**
NCW FACTOR	NCW (1:99)	7.94	7.68	7.62	7.56	7.48	7.38	7.61[b]
	NCW (2:98)	7.82	8.32	8.38	7.50	7.44	7.04	7.75[b]
	NCW (3:97)	8.58	8.54	8.18	8.26	8.12	8.06	8.29[a]
	NCW (4:96)	7.24	7.88	7.78	7.64	7.30	7.28	7.52[b]
	NCW (CTRL)	8.26	9.22	7.92	7.82	6.94	6.70	7.81[b]
MEANS (DAYS)		$7.968_{a,b}$	8.328_a	$7.979_{a,b}$	$7.756_{b,c}$	$7.456_{c,d}$	7.292_d	
LSD'S (0.05)		**NCW= 0.3841**			**DAYS= 0.4207**		**NCW*DAYS=NS**	

Means followed by the same superscript within columns are not significantly different from each other. Means followed by the same subscript across rows are not significantly different from each other

4.10.18 Storage life of watermelon following Neem oil/Coconut oil waxing

The study showed that watermelon samples coated with different NCW levels including NCW (CTRL) lasted for a total of 18 days with the exception of NCW (4:96) which lasted for 21 days however, it was only 60% of the fruits maintained a storage life of 21 days (Figure 4.7)

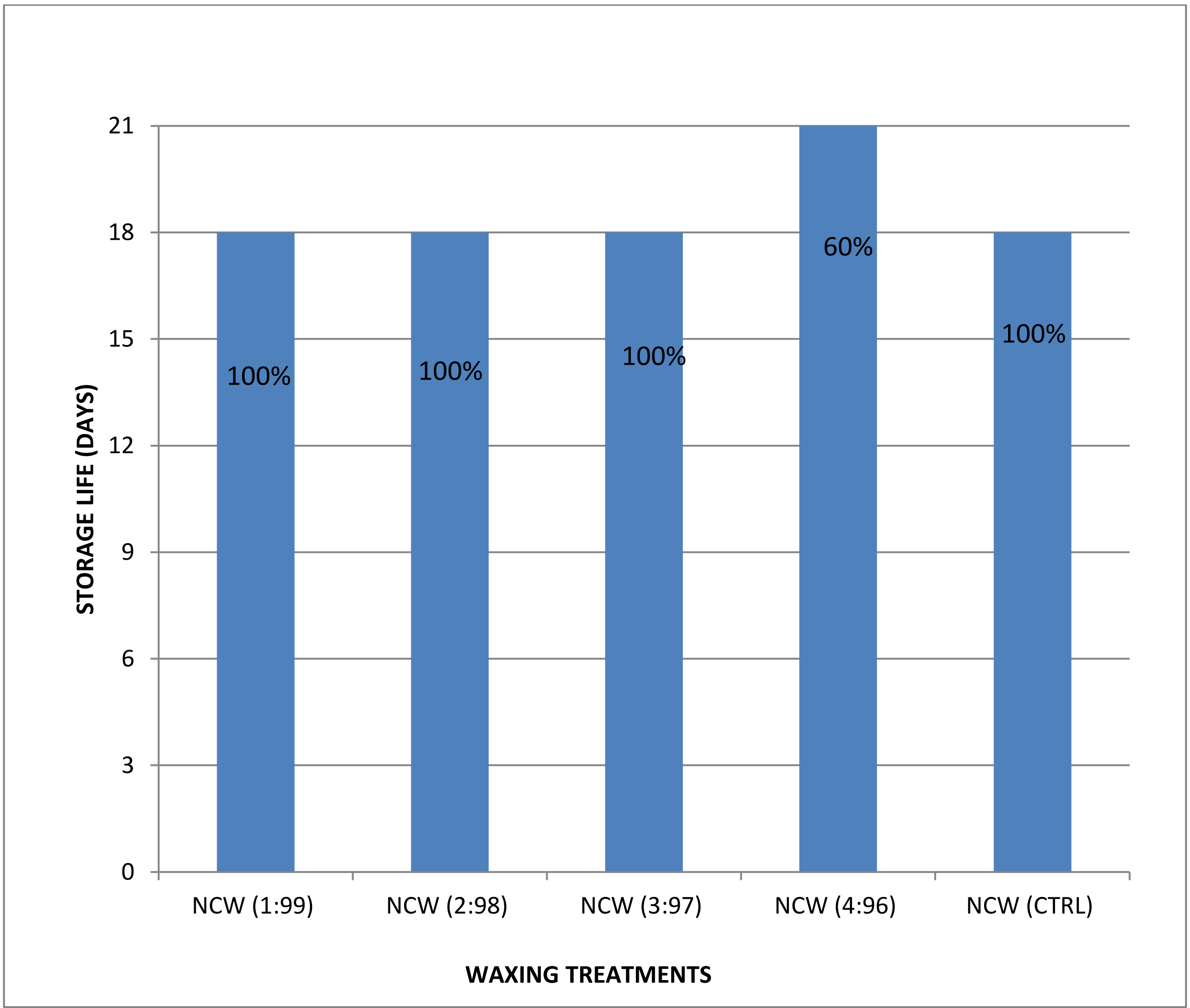


Figure 4. 7 Storage life of watermelon following Neem oil/Coconut oil waxing

4.11 Sensory evaluation following waxing and last day of storage

The study revealed that there were significant effects of Neem/Shea-butter waxing (NSBW) on all the sensory attributes (Table 4.20). NSBW (CTRL) for an instance had a significantly higher effect on all the sensory attributes with the exception of glossiness. NSBW (5:95) on the other hand, had a significantly higher effect on the glossiness sensory attribute of watermelon.

Results from the effects of Neem oil/Palm oil waxing (NPW) on sensory attributes revealed that, there were no differences in effect of NPW on glossiness, pulp colour and rind (skin) colour (Table 4.21). On the other hand, the effect of NPW (1:99) on attractiveness was significantly higher than the rest of the other treatment but with the exception of NPW (2:98) which was not significantly different from NPW (1:99). The effect of NPW (1:99) on flavour (aroma/smell) which recorded the highest score was also not significantly higher than the effect of NPW (2:98) and NPW (CTRL) on flavour (Table 4.21). Similarly, there were no significant differences in effect on mouth feel between NPW (1:99) and NPW (2:98). Effect on overall acceptability showed that there was no significant difference in effect between NPW (1:99) and NPW (2:98); between NPW (2:98) and NPW (CTRL) and also between NPW (3:97), NPW (4:96) and NPW (CTRL).

It was also discovered that Neem oil/Cococnut oil (NCW) had no significant effects on attractiveness, flavour, glossiness, mouth feel, taste (sweetness) and overall acceptability however; there were significant effects of NCW on pulp colour, rind (skin) colour and texture (Table 4.22). In terms of the effects of NCW on pulp colour, there were no significant differences in effect between treatments NCW (3:97), NCW (4:96) and NCW (CTRL) and also between NCW (2:98) and NCW (4:98). Also in terms of effect of NCW on rind colour, there were no significant differences in effect between NCW (1:99), NCW (2:98), NCW (4:96), and NCW (CTRL) and also between NCW (1:99), NCW (3:97) and NCW (CTRL). The study also showed that the effects of NCW (1:99), NCW (2:98), NCW (4:96) and NCW (CTRL) on texture were not significantly different from each other.

Table 4.20 Effects of NSBW on sensory attributes of watermelon

		SENSORY ATTRIBUTES								
		ATTRACTIVENES	FLAVOUR (SMELL/ AROMA)	GLOSSINESS	MOUTH FEEL	PULP COLOUR	SKIN (RIND) COLOUR	TASTE SWEETNESS	TEXTURE	OVERALL ACCEPTABILITY
NSBW	NSBW (5:95)	1.70[c]	2.30[c]	3.40[a]	2.40[b,c]	2.95[b]	2.1[c]	2.35[b,c]	2.90[b]	2.25[c]
	NSBW (10:90)	3.00[b]	3.25[b]	2.45[b]	2.70[b]	3.15[b]	3.65[b]	2.70[b]	3.55[a]	2.95[b]
	NSBW (15:85)	1.55[c]	1.95[c]	2.15[b]	1.85[c]	1.55[c]	2.2[c]	1.35[d]	2.60[b]	1.55[d]
	NSBW (20:80)	1.55[c]	1.95[c]	1.95[b]	1.90[c]	3.35[a,b]	1.85[c]	1.85[c,d]	1.70[c]	1.70[d]
	NSBW (CTRL)	4.15[a]	4.35[a]	1.85[b]	4.15[a]	3.95[a]	4.60[a]	3.85[a]	3.75[a]	3.95[a]
	LSD (P=0.05)	**0.4933**	**0.5917**	**0.7110**	**0.5068**	**0.6370**	**0.5793**	**0.5327**	**0.6290**	**0.4854**

Means followed by the same superscript within a column are not significantly different from each other

Table 4.21 Effects of NPW on sensory attributes of watermelon

		SENSORY ATTRIBUTES								
		ATTRACTIVENES	**FLAVOUR (SMELL/ AROMA)**	**GLOSSINESS**	**MOUTH FEEL**	**PULP COLOUR**	**SKIN (RIND) COLOUR**	**TASTE SWEETNESS**	**TEXTURE**	**OVERALL ACCEPTABILITY**
NPW	NPW (1:99)	3.50[a]	3.85[a]	2.4	3.40[a]	3.55	3.70	3.55[a]	3.55[a]	3.50[a]
	NPW (2:98)	3.10[a,b]	3.40[a,b]	2.45	3.30[a]	3.45	3.45	3.20[a]	3.00[a]	3.30[a,b]
	NPW (3:97)	2.60[b,c]	2.75[c]	2.40	2.30[b]	2.00	3.55	1.75[b]	3.10[a]	2.15[c]
	NPW (4:96)	2.55[c]	2.95[b,c]	2.20	2.55[b]	3.40	3.50	2.45[b]	2.30[c]	2.45[c]
	NPW (CTRL)	2.80[b,c]	3.45[a,b]	1.75	2.75[b]	4.50	3.20	2.30[b]	2.95[b]	2.70[b,c]
	LSD (p=0.05)	**0.5143**	**0.5938**	**NS**	**0.5307**	**NS**	**NS**	**0.6078**	**0.5757**	**0.6073**

Means followed by the same superscript within a column are not significantly different from each other

Table 4.22 Effects of NCW on sensory attributes of watermelon

		SENSORY ATTRIBUTES								
		ATTRACTIVENES	FLAVOUR (SMELL/ AROMA)	GLOSSINESS	MOUTH FEEL	PULP COLOUR	SKIN (RIND) COLOUR	TASTE (SWEETNESS)	TEXTURE	OVERALL ACCEPTABILITY
NCW	NCW (1:99)	2.85	3.65	2.65	3.00	2.25[c]	3.65[a,b]	2.70	3.4[a]	3.00
	NCW (2:98)	3.25	3.55	2.30	2.95	2.85[b]	3.90[a]	2.95	3.10[a]	3.10
	NCW (3:97)	2.85	3.60	2.0	3.30	3.50[a]	3.25[b]	3.15	2.35[b]	2.95
	NCW (4:96)	3.40	3.70	2.75	3.40	3.10[a,b]	3.90[a]	3.05	3.20[a]	3.40
	NCW (CTRL)	3.15	3.90	2.15	3.45	3.60[a]	3.40[a,b]	3.20	3.60[a]	3.35
	LSD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**0.4550**	**0.5100**	**NS**	**0.5356**	**NS**

Means followed by the same superscript within a column are not significantly different from each other

4.11.1 Effects of waxing formulation on overall acceptability using Friedman's rank test

Results from Friedman's rank test showed that, panellists ranked NSBW (CTRL) better than the rest of the waxing formulation (Table 4.23). This was followed by NSBW (10:90), NSBW (5:95), NSBW 20:80 and NSBW (15:85) respectively. The P value also suggested that median ranks were not equal (P<0.05)

Panellists also ranked NPW (1:99) better than the remaining Neem oil/ Palm oil treatments. It was then followed by NPW (2:98), NPW (CTRL), NPW (4:96) and NPW (3:97) respectively (Table 4.24). There was also an indication that median ranks were not equal (P<0.05).

Results from the Friedman's rank test of overall acceptability following Neem oil/Coconut oil and last day of storage conversely suggested that median ranks were equal to each other (P>0.05) even though NCW (4:96) received the highest ranking from panellists (Table 4.25).

Table 4.23 Friedman Test: OVERALL ACCEPTABILITY (NSBW) versus TRT blocked by Panellists

TRT	N	Est Median	Sum of Ranks
NSBW (5:95)	20	2.300	53.0
NSBW (10:90)	20	3.000	77.0
NSBW (15:85)	20	1.700	36.5
NSBW (20:80)	20	2.000	39.0
NSBW (CTRL)	20	4.000	94.5

S = 50.43 DF = 4 P = 0.000
S = 57.97 DF = 4 P = 0.000 (adjusted for ties)

Table 4.24 Friedman Test: OVERALL ACCEPTABILITY (NPW) versus TRT blocked by Panellists

TRT	N	Est Median	Sum of Ranks
NPW (1:99)	20	3.1000	78.5
NPW (2:98)	20	3.1000	72.0
NPW (3:97)	20	2.0000	39.5
NPW (4:96)	20	2.0000	52.0
NPW (CTRL)	20	2.3000	58.0

S = 19.49 **DF** = 4 **P** = 0.001
S = 24.44 **DF** = 4 **P** = 0.000 (adjusted for ties)

Table 4. 25 Friedman Test: OVERALL ACCEPTABILITY (NCW) versus TRT blocked by Panellists

TRT	N	Est Median	Sum of Ranks
NCW (1:99)	20	3.0000	55.5
NCW (2:98)	20	3.0000	59.0
NCW (3:97)	20	2.9000	53.5
NCW (4:96)	20	3.1000	68.5
NCW (CTRL)	20	3.0000	63.5

S = 2.96 **DF** = 4 **P** = 0.565
S = 3.79 **DF** = 4 **P** = 0.434 (adjusted for ties)

4.12 Rate of respiration of watermelon following waxing and days after storage

The study revealed that, there was a gradual drop in oxygen respiration rate whiles carbon dioxide respiration rate increased steadily in all the treatments as the storage period proceeded (Table 4.26 and Table 4.27).

It was also seen that, the point at which carbon dioxide and oxygen respiration rates reached equilibrium was higher with each increase in the concentration of neem oil and the reduction in the concentration of either palm oil or coconut oil respectively(Table 4.26 and Table 4.27).

The study further revealed that, respiration rate reached equilibrium after ten days of storage when waxed with neem oil/palm oil wax where as in fruits waxed with neem oil/coconut oil, it took 14 days to reach equilibrium (Table 4.26 and Table 4.27). This phenomenon suggests that neem oil/coconut oil waxing delayed rate of respiration as compared to neem oil/palm oil waxing.

It was also noted that, the rate of oxygen respiration was higher than the rate of carbon dioxide respiration. Normally, it is expected that the rate of carbon dioxide respiration will be almost the same as the rate of oxygen respiration giving a respiration quotient of approximately 1.

Table 4. 26 Respiration rate of watermelon following Neem oil/Palm oil waxing (NPW) and days of storage

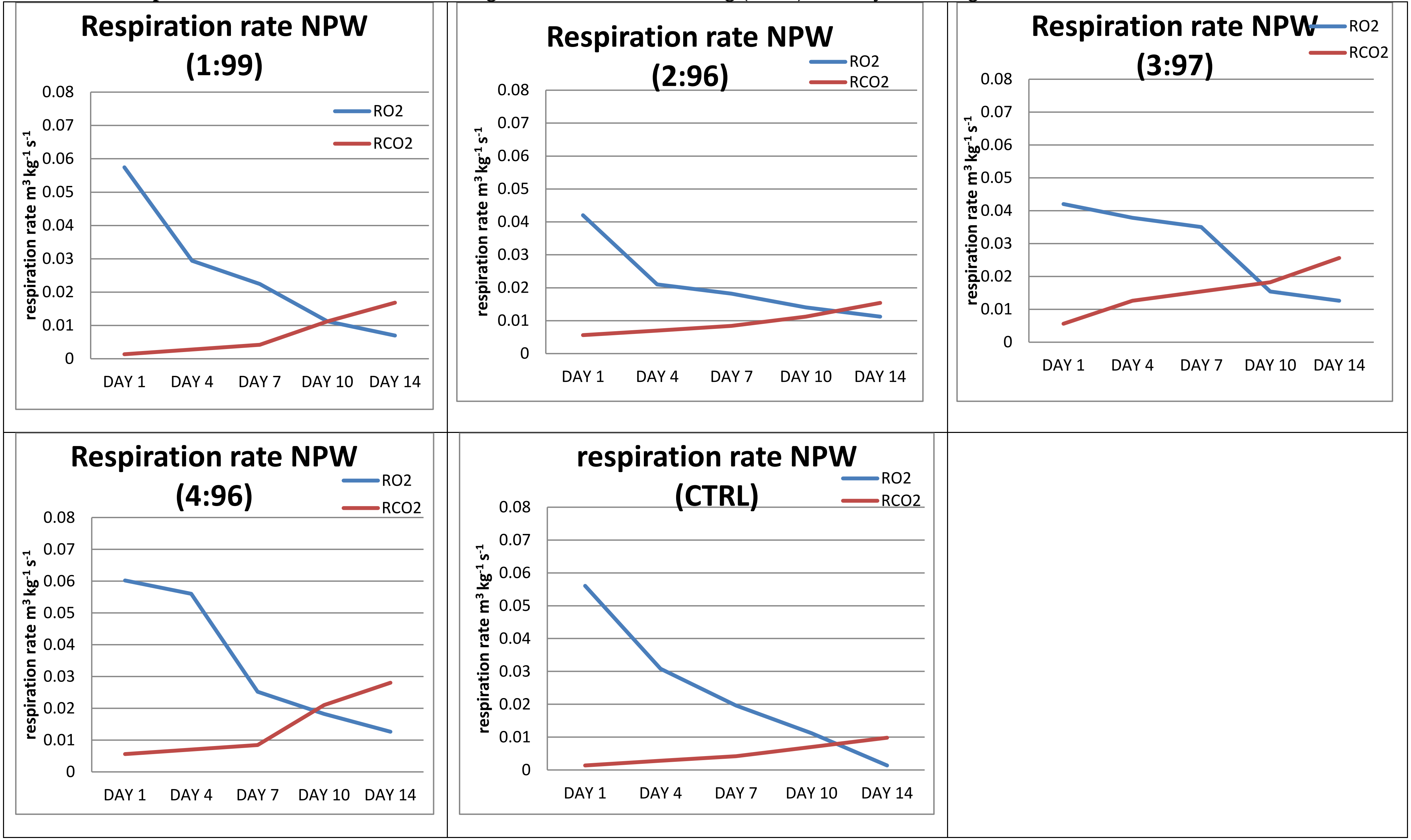
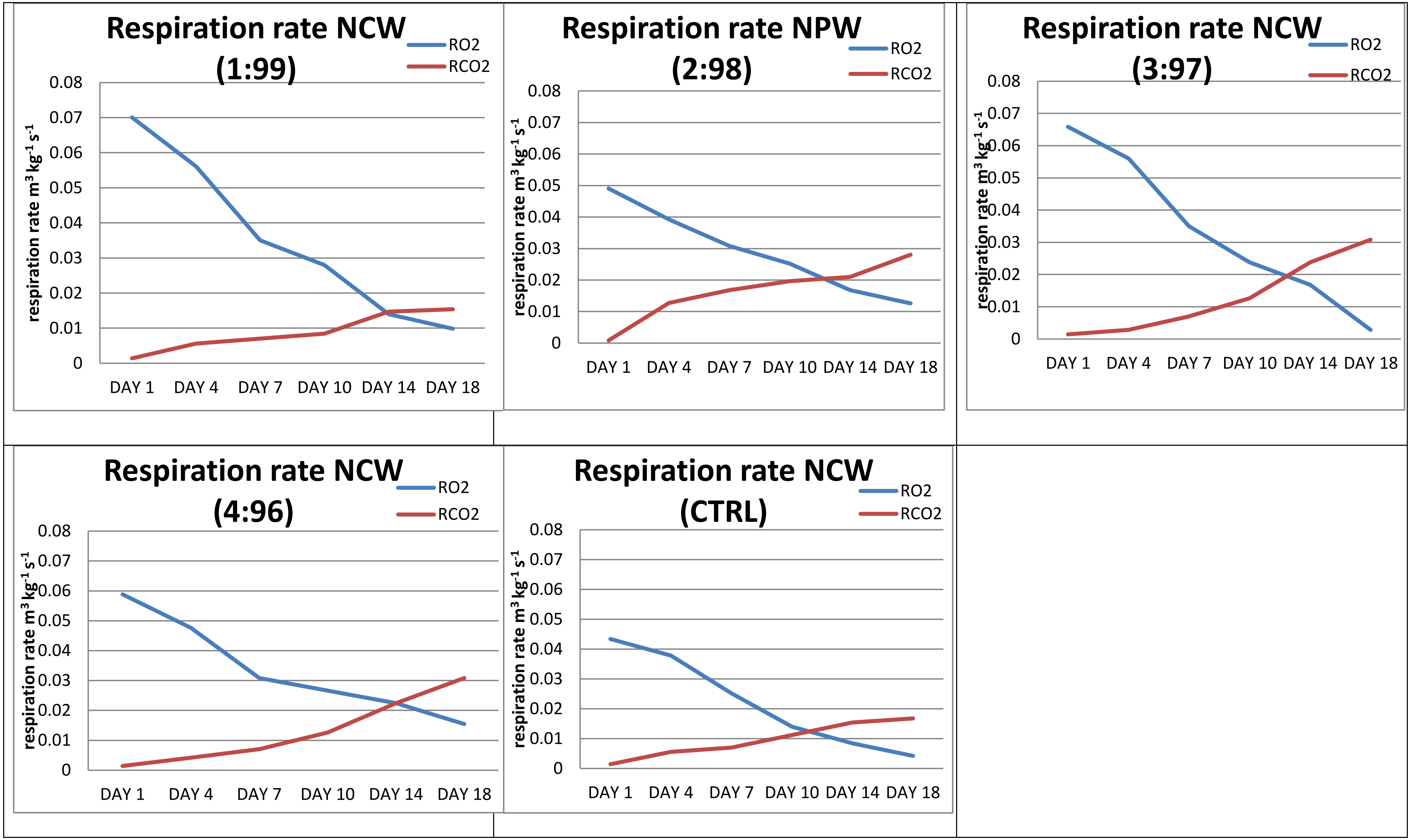


Table 4. 27 Respiration rate of watermelon following Neem oil/Coconut oil waxing (NCW) and days of storage



4.13 Organisms identified after isolation

Organisms that were identified after isolation were suspected to be *Mycosphaerella citrullina* and *Fusarium sp*. (Plate 4.6 and Plate 4.7). The *Mycosphaerella citrullina* Grossenb. also known as *Didymella bryionae* (Auersw.) Rehm showed a black fluffy mass growing on the surface of the diseased fruits, other sections of the fruits had developed characteristic blackish to grey lesions with gum exuding from the affected fruit (Plate 4.6c). After 10 days of culturing, the micrograph showed a pycnidiospore with the characteristic fused septate line (Plate 4.6a [white arrow]). By the 15th day, the septate line had completely separated forming a two celled conidia (Plate 4.6b [red arrow]).

Fruits that were suspected to be affected with *Fusarium sp*. showed the characteristic white cotton-like mass growing on the surface of the affected fruits (Plate 4.7c). Following 10 days of culturing, a micrograph of the Fusarium sp. showed a simple conidia (Plate 4.7a) and conidia borne on phialades (Plate 4.7b)

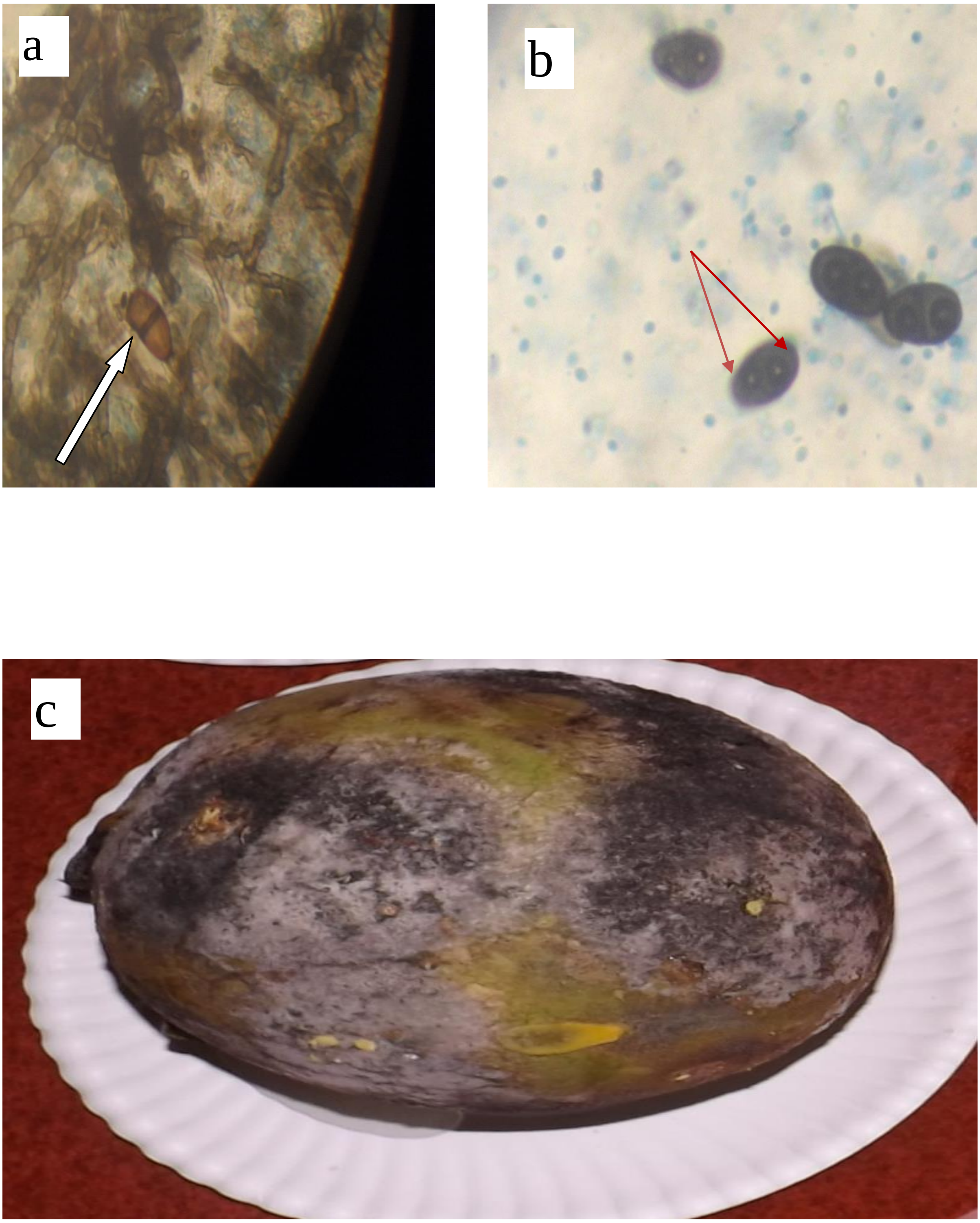


Plate 4. 5 A micrograph of *Didymella bryoniae* 10 days (a) and 15 days (b) after culturing (x400) and watermelon sample (c) showing symptoms of black rot disease.

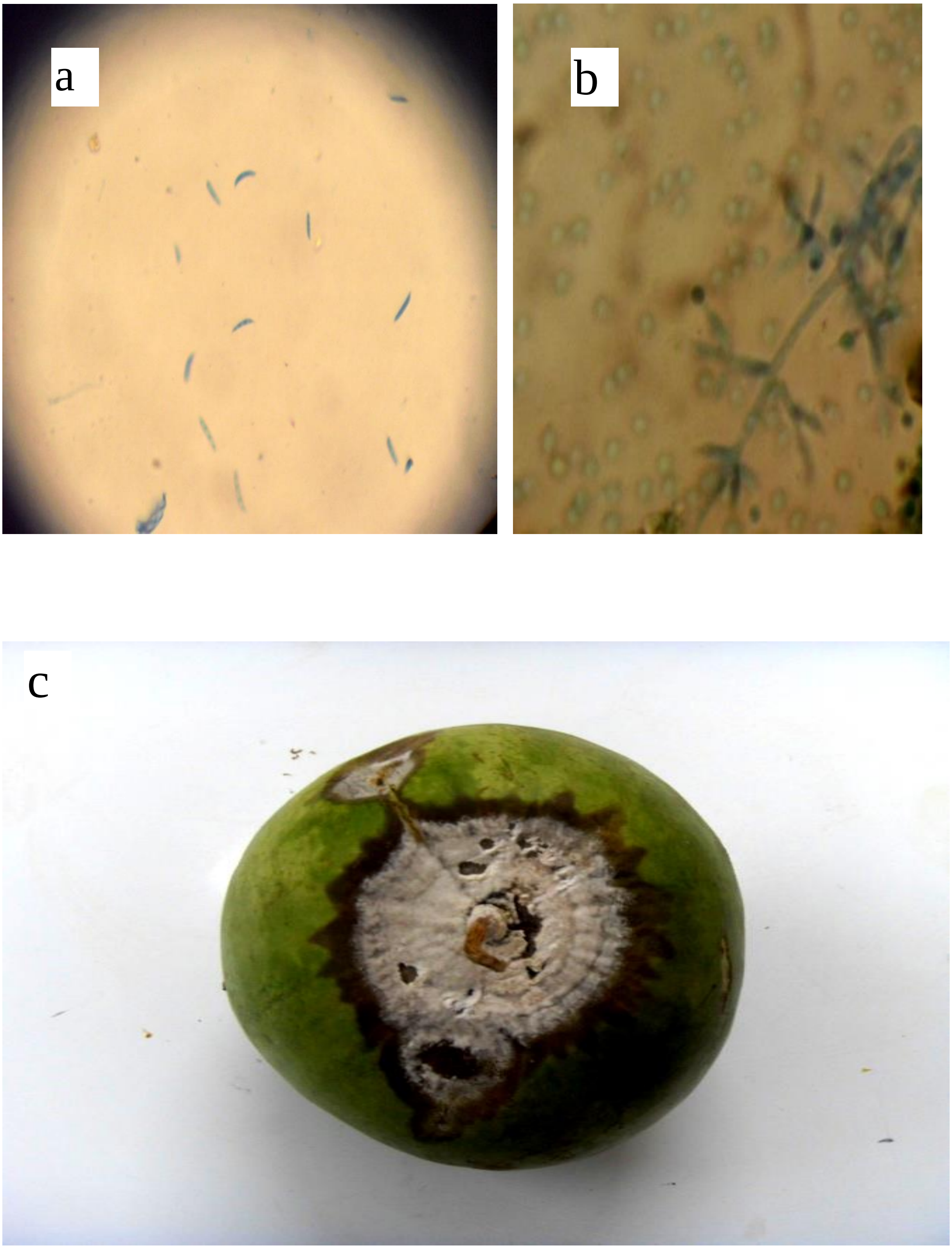


Plate 4. 6 A micrograph of Fusarium sp. showing simple conidia (a) and conidia borne on phialades (b) after 10 days of culturing (x400) and a watermelon sample (c) showing disease symptom of fusarium rot.

CHAPTER FIVE

5.0 DISCUSSION

5.1 The postharvest value chain of watermelon in the Ada-East district

The kind of purchasing system practised by farmers leads to little or no loss on the farm. This helps farmers deal with the problems of storing harvested fruits on the farm i.e. problems such as attacks by rodents and insects, diseases, sunburns and thieves. Grading of watermelon into various sizes or grades also affords the opportunity of accurately determining the price for the various sizes of watermelon sold. The use of vans and taxis in transporting fruits is not the best of transportation practices. It can lead to bruising of fruits since vans and taxis are not designed for transporting fruits. On the other hand, dealers can employ the use of cushioning materials that can mitigate the forces of impact during transportation with vans or taxis. Selling fruits as cut fruits to consumers also comes in handy especially to consumers who are always on the move but would not like to carry around one big whole fruit.

5.2 Level of education

Since the bulk of the respondents had either primary or JSS/Middle school education (Plate 4.2 and Figure 4.2), it suggests that they may lack the basic knowledge to meet the challenges of postharvest losses. This situation poses a great danger so far as issues of postharvest losses and its effect on food security and safety are concerned. This is because it will take a lot of time and resources to teach the stakeholders in the watermelon industry to understand appreciate and adopt the relevance of postharvest losses. This assertion also confirms a research conducted to investigate the effects of education on agricultural productivity under traditional and improved technology in northern Nigeria; using an endogenous regression analysis. The research suggested that schooling not only enhances agricultural productivity following technology, but also promotes adoption (Arega and Manyong, 2006).

5.3 Effects of insects and rodents on watermelon on the field and in storage

Insects cause a wide range of losses in watermelon production. Aphids for an instance suck sap from the vines and tendrils of watermelon leaving the leaves dead. The dead leaves are no longer capable of aiding the photosynthetic pathway and this can lead to near zero yields if aphids are not detected early and controlled. The feeding behaviour of insects and rodents also predispose fruits to attack by disease causing organisms and may also promote the physiological rotting of the fruits. Rotten fruits are undesirable quality characteristics that consumers will not like to see on watermelon fruits they may want to purchase.

5.4 Implications of harvesting indices

Harvesting refers to the process of detaching the fruit from the main plant. Before fruits are harvested, it is very important to determine whether they are matured or not since the maturity has a direct effect on the quality of fruits purchased. According to Postharvest Handling Technical Bulletin, 2003 watermelons will usually not improve in taste (sugar) and colour after harvesting. Watermelon fruits therefore have to attain full maturity before they are harvested. Farmers therefore employ the use of a variety of techniques in determining physiologically matured fruit. The present study showed that most of the farmers do not rely on only one harvesting index as full proof in determining maturity but use only two. This is not line with the recommendation of the postharvest handling technical bulletin, 2003. The bulletin suggests that at least three indicators should be used in determining matured fruits. In a sharp contrast to this, Kouno *et al.*, 1993 showed that an automated acoustic device that taps melon and transmits the pitch of the sound to receiver can adequately predict the maturity of watermelon therefore no need to rely on many other parameters to determine maturity.

5.6 Pre and postharvest losses

Any situation or condition that prevents fruits from being used for its intended purpose is a loss. Losses could be compositional, economic, qualitative or quantitative. The study showed that the total economic loss before harvest amounted to GH₵ 31,649.00 (Table 4.1) whiles economic losses during and after harvest amounted to GH₵ 69,825.00 (Table 4.2; Table 4.3 and Table 4.4). The principal causes of the losses included insect and rodent attack, dropping and cracking during loading, transportation and off-loading operations and finally, rot due to disease attack.

Insect and rodents bore holes into fruits precipitating the rotting of watermelon in the field as well as after harvest (Figure 4.3). Green leaves that are used by plants in the photosynthetic pathway can also be destroyed by the action of insects. Consequently, it may result in the formation of malformed fruits which in itself is a loss to the farmer. Attack by diseases (Figure 4.4) may also result in similar effects. Disease attack may lead to discolouration of fruits as well as development of off-flavours It could also lead to rejection by consumers as well as loss in consumer confidence.

During manual loading and off-loading operations, watermelon harvesters/dealers toss the fruits from one person to the other. In the process, they are likely to drop the fruits if they lose grip of the fruit or lose their balance/coordination. Although this practice confirms a popular norm in the watermelon industry (Postharvest Handling Technical Bulletin, 2003), it is not the best of practices.

The kind of material used to cover fruits during transportation also contributed to some losses. The use of tarpaulin in covering fruits during transportation creates an unsuitable warm condition although it may prevent dust. Similarly, both plain (transparent) and black polythene sheets used in covering fruits may also trap heat and cause an undesirable warm condition that precipitates deterioration. These findings are similar to the findings of

Lamptey, (2010). In that study, it was seen that some transporters engaged in the use of plane or black polythene sheets and tarpaulin, which resulted in huge losses during transportation of watermelon fruits.

Storage problems also contributed to some losses. The major problem encountered was rot (Figure 4.4) i.e. both physiological and pathological. Diseases may result in discolouration of fruits and may also lead to the development of undesirable flavours which is a loss in quality of the fruit. Consequently, it can lead to outright rejection by consumers as well as far-reaching cases of economic losses.

5.7 Total Soluble Solids (TSS) or % Brix

TSS is most often than not, used as a criteria for determining the level of maturity and quality in fruits such as melons, citrus and grapes (Wills *et al*., 1981; Tian *et al.*, 2007). Results from all the three experiments show that there was a significant ($p<0.05$) reduction in TSS due to days of storage effects. The declining trend in TSS due to days of storage confirms earlier works that has been reported by several authors. Yau *et al.*, (2010), discovered that TSS reduced significantly following 14 days of watermelon storage. Picha (1988) also found out that TSS in watermelon reduced significantly following 19 days of storage at 23°C. The declining nature in TSS was due to the rate of respiration or oxidation during the storage period. During respiration, there is an oxidative breakdown of complex molecules such as starch, sugars and organic acids into simpler molecules such as carbon dioxide and water (Yau *et al.*, 2010).

The results from experiment NSBW showed that the control, NSBW (CTRL) retained a significantly higher level of TSS than all the other levels of NSBW (Table 4.6). This suggests that NSBW had a negative impact on TSS. It also suggests that fruits waxed with NSBW became of inferior quality than fruits that were not waxed. NPW on the other hand had no significant effect on TSS. Though NPW (4:96) caused a higher retention of TSS than all the other levels of NPW, their effects on TSS were not significantly different from each other (Table 4.14). This trend also suggests that the decline in TSS was not due to NPW factor, but was only due to the days of storage factor. Results from the effect of NCW and days of storage on TSS however suggest that NCW had a significant effect on TSS (Table 4.19). The effect of NCW(3:97) on retaining TSS was significantly higher than the rest of the NCW levels. This is probably due to the slower respiration rate of fruits waxed with NCW. When respiration rates are slow, fruits tend to retain most of their initial characteristic such as TSS. It also connotes that fruits waxed with NCW (3:97) were of higher quality than the rest of the fruits after 18 days of storage.

5.8 Vitamin C (%)

Vitamin C also known as ascorbic acid is an important nutrient required by the body for the repair of worn out tissues and the general promotion of good health. The significant ($P<0.05$) effect of days of storage and waxing type on % Vitamin C and the trends that were seen in all the three experiments are similar to the findings of Hu *et al.*, (2011) and Mahrouz *et al.*, (2002).

Hu *et al.*, (2011) studied the effects of some waxes on pineapples following days of cold storage. The study revealed that the Vitamin C content in the control decreased during the first 14 days and increased gradually in the 3rd week and then decreased again in the last three days of storage. The vitamin C content of wax treatment decreased during the first 22 days of storage and increased gradually with prolonged storage time. Throughout the storage period, there were significant differences between control and wax-treatment ($P<0.05$). The vitamin C content in wax-treatment was 146% higher than that in the control on the 24th day of storage. In another experiment involving the use of gamma irradiation, washing and waxing of *Citrus clementina*, Mahrouz *et al.*, (2002) discovered that washing and waxing treatment did not improve the quality of *C. clementina* but rather resulted in reduction of Vitamin C.

The higher retention of vitamin C in NSBW (CTRL) waxed fruits suggests that NSBW was not effective in retaining vitamin C. The gradual decrease in vitamin C as a result of days of storage could also be due to the rate of CO_2 respiration. Similarly, the NPW (2:98) that had a significantly higher retention of vitamin C than the rest of the treatments can be suggested to be a good waxing material for the purposes of retaining vitamin C. The study also suggests that NCW (1:99), NCW (2:98) and NCW (3:97) are all good waxing materials in retaining vitamin C.

5.9 TTA and pH

The test that measures all the acids present in a given fruit is referred to as total titrable acids (TTA) whereas pH is a measure of the strength of these acids. The various changes in pH and TTA that occurred were in consonance with the work of several authors.

The reduction in TTA as seen in NPW were similar to the discovery of Hu *et al.*, (2011). According to Hu *et al.*, (2011), wax treatment reduced titrable acids of pineapple kept under cold storage conditions by approximately 6 and 5% compared with the control at 14 and 21 days of storage, respectively. However, a contrary finding as seen in the case of NCW's inability to affect pH also confirms preliminary investigations by Sugri *et al.*, (2010). Per their study, thin layer waxing (<0.05 mm) using shea-butter did not influence pulp pH and total titrable acidity (TTA) of plantain varieties. Similarly, application of the antimicrobial edible coating did not ($P > 0.05$) affect the pH (5.2-0.3) of fresh cut watermelon (Sipahi *et al.*, 2013).

The higher pH in NCW recorded is also in agreement with Oyeleke and Odedeji (2011) who discovered that pawpaw fruits treated with palm kernel oil retained a higher pH than bee waxing treatment and chemical waxing treatment. Increase in acidity of stored fruits are due to the formation of carbonic acid (acidosis) or due to the fermentation of sugars resulting in production of acids while, decrease in acidity is due to the fact that as fruit ripens, it diminishes it's malic and citric acid contents and favours the formation of sugars (Martinez *et al.*, 1997). The increase or decrease in either pH or TTA that was seen in all the experiments can therefore be explained by these bio-chemical processes.

5.10 Percent Total Weight Loss (%TWL)

Fruits stored at ambient tropical conditions will lose weight due to respiration and transpiration. The lower loss in weight compared to control that was seen in fruits coated with NSBW, NPW and NCW are consistent with the findings of several investigators. Investigations done by Contreras-Oliva *et al.*, (2011) showed that commercial wax was the most effective in reducing weight loss of mandarins in general, although the reduction in weight loss in chitosan coated mandarins was lower than the uncoated (control) mandarins after 9 days of storage at 20 °C. Similar works by Mahajan *et al.*, (2011), also suggests that the percent loss in weight (PLW), in general, increased with the advancement of the storage period rather slowly in the beginning, but at a faster pace as the storage period advanced. It was also noticed that under ordinary market conditions, the lowest mean PLW was observed in fruits coated with citrashine and was closely followed by terpenoidal oligomer coated fruits. Mejia-Tores *et al.*, (2008) also noted similar trends in weight loss when tomatoes were waxed. In that study, it was discovered that waxed tomatoes had a lower loss in weight as compared to control treatment.

When fruits are waxed, it builds a moisture barrier that is able to prevent transpiration of water vapour hence a lower loss in weight as compared to un-waxed fruits.

5.11 Storage life

Storage life refers to the period between which fruits are harvested and the time it becomes unfit for the market or consumption/use. The shorter storage life compared to control of fruits that were waxed with NSBW (Figure 4.10) and NPW (Figure 4.16) respectively may be due to the build-up of internal carbon dioxide. It could also be due to a higher respiration rate that occurred among waxed fruits.

On the other hand, the shorter storage life of watermelon fruits that were waxed with NCW (4:96) as compared to control could only mean that, the waxing material slowed down the rate of respiration and did not encourage the rapid build-up of carbon dioxide. This result confirms similar findings by Qiuping and Wenshui, (2007). In that study, it was asserted that treatment with the combination of 1-methylcyclopropene (1-MCP) and Chitosan (CTS) coating improved the storage life of Indian jujube fruit at room temperature storage.

5.13 Sensory evaluation

The strong dislike showed by consumers for all fruits waxed with the different formulation of NSBW suggests that, panelists were not satisfied with the action of NSBW in terms of their sensory attributes/organoleptic properties. Panelists rather preferred the control and gave high scores for the control treatment (Table 4.20). Panelists also showed strong acceptability for NPW (1:99) and NPW (2:98) as compared to the control treatment. NPW also did not cause any significant ($P<0.05$) changes in glossiness, pulp colour and rind colour (Table 4.21). Consumers indifference ($P<0.05$) on overall acceptability of fruits waxed with different NCW formulations also suggests that NCW did not significantly affect consumers acceptability of fruits waxed with NCW (Table 4.22).Results from the Friedmans rank test also confirms that panelists gave almost similar ranks to all the NCW treatments. It is also an indication that, NCW did not affect panellist’s acceptability in any way (Table 4.25).

5. 14 Respiration rate

The delayed rate of respiration that was seen in NCW as compared to NPW also implies that NCW is a better waxing material than NPW (Table 4.26 and Table 4.27) and possibly NSBW. The slow respiration rate in NCW also explains why panelists from the sensory analysis gave higher scores for flavour, taste, mouth feel and overall acceptability although it was not significantly different from the control (Table 4.22). The slow respiration rate also explains the higher retention of Vitamin C and longer storage life that was seen in NCW(4:96) treatment.

5.15 Post harvest diseases

Many pathogens cause postharvest diseases of watermelon but in the present study, only *Didymella bryoniae* and *Fusarium sp*. were identified. Postharvest diseases change the colour of fruits, lead to the development of off-flavours and finally causes rot that leads to a decrease in the storage life of affected fruits. This situation has the potential of causing both financial and economic loss to dealers as well as consumers. It also destroys consumer confidence that is imposed on the quality of product bought from dealers.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion and recommendations for the postharvest value chain of watermelon in the Ada-East district

From the study, it can be concluded that the postharvest value chain of watermelon starts form land preparation and ends at the point it gets to the final consumer. The key players along the chain are farmers, dealers (transporters and sellers i.e. both whole sellers and retailers) and consumers. The losses that are incurred starts on the farm during cultivation and harvesting. Losses also occur during loading, vehicular transportation and off-loading activities. Additionally inappropriate storage conditions also results in losses. The main causes of the losses were seen to be attack by disease causing organisms, insect pest attack, dropping and cracking of fruit, thieves and inappropriate materials used to cover fruits during transportation. The total losses before harvest amounted to the tune of GH₵ 31,649.00 per season whiles total losses during and after harvest is projected to stand at GH₵ 69,825.00 per season. It is therefore recommended that farmers pay a particular attention to the onset of diseases and take quick measures such as immediate use of fungicides as well as physical removal of affected fruits. Extra care should be taken when handling fruits especially during loading and off-loading operations. Vehicles used in transporting watermelon fruits should be types that are designed for carrying agricultural goods. These may include trucks with cooling systems and cushioning materials that mitigates the forces of impact; responsible for causing internal injury and cracks.

6.2 Conclusion and recommendations following the use of plant oils in waxing watermelon

In conclusion, this study suggests that Neem oil/Shea-butter Wax (NSBW) and Neem oil/Palm oil (NPW) are not able to prolong the storage life of watermelon however, NCW

(4:96) of the Neem oil/Cococnut oil Wax (NCW) treatment is able to prolong the storage life and reduce percent total weight loss (%TWL) of watermelon by reducing rate of respiration. Generally, NCW also retains the vitamin C content of fruits better than non-waxed fruits especially when waxed with NCW (1:99), NCW (2:98) and NCW (3:97). Additionally, NCW does not affect some organoleptic and chemical properties such as attractiveness, flavour (smell/aroma), glossiness, mouth feel, taste, overall acceptability and Total Titrable Acids (TTA). NCW (3:97) also retains % brix better than any of the NCW treatments.

It can also be put forward that, long term storage of watermelon without NCW waxing also reduces some organoleptic properties and creates undesirable chemical and physical properties. It is therefore recommended that NCW be considered a possible watermelon waxing material to prolong the storage life of watermelon as well as maintaining the physical, chemical and organoleptic properties. Additionally, it is advised that the use of Shea-butter and palm oil should not be considered in the future for waxing watermelon.

References

Agbetiameh, F.T. (2006). Postharvest handling of watermelon in southern Ghana. A Dissertation Presented to the Crop Science Department, the College of Agriculture and Consumer Sciences, University of Ghana, Legon.

Agrios, G.N. (1988). Plant pathology. Academic press, New York. 11:274-280.

Alleyne, V. and Hagenmaier, R. (2000). Candelilla-shellac: an alternative formulation for coating apples. HortScience 35, 691–693.

Allotey, J. and Dankwah, J. (1994). Some aspects of the biology and control of C. Maulatus (F.) on some stored soyabean, Glycine max (L.) Mertt varieties under tropical conditions. Proceedings Ghana Science Association, 26; 14-18

Andrus, C.F. (2005). Watermelon Breeder. Curcubit Breeding Horticultural Science. University of Carlifornia, ANR, Oakland, USA.

AOAC (1990). *Official Methods of Analysis*, 15th Edition. Association of Official Analytical Chemists, Washington, DC

Arega, D. A and Manyong, V.M. (2006). The effects of education on agricultural productivity under traditional and and improved technology in northern Nigeria: an endogenous switching regression. *Emperical Economics*, Physica Verlag 32; 141-159

Baldwin, E.A., Nisperos-Carriedo M., Shaw P.E. and Burns, J.K. (1995). Effect of coatings and prolonged storage conditions on fresh orange flavour volatiles, degrees Brix, and ascorbic acid levels. *Journal of Agriculture and Food Chemistry*. 43;1321–1331.

Barnett, H.L and Hunter, B.B. (1972). Illustration Genera of Imperfect Fungi. 3rd Edition. Burgess Publishing Company. 239 pp

Block, G. (1991). Vitamin C and cancer prevention: the epidemiologic evidence. *American Journal of Clinical Nutrition*. 53: 270-282.

Cameron, A. C., Boylan-Pett, W., and Lee, J. (1989). Design of modified atmosphere packaging systems: modeling oxygen concentrations within sealed packages of tomato fruits. *Journal of Food Science* 54; 1413–1416,1421.

Cobbina, J.R. and Appiah-Kwarteng, J. (1989). Effects of neem products on stored maize weevil, Sitophilus zeamais (Motsch). Insect Science and its Application, 10 (1); 89-92.

Contreras-Oliva A., Pe´rez-Gago, M.B., and Rojas-Argudo, C. (2011) Effects of chitosan coatings on physicochemical and nutritional quality of clementine mandarins cv.'Oronules'. *Food Science and Technology International.* 18(4) 303–315.

Debeaufort, F., Quezada-Gallo, J.-A., Voilley, A., (1998). Edible films and coating: tomorrow's packagings: a review. Crit. Rev. Food Sci. 38, 299–313.

Drake, S.R. and J.W. Nelson. 1990. Storage quality of waxed and non-waxed 'Delicious' and 'Golden Delicious' apples. *Journal of Food Quality*. 13:331–341

Fontham, E., Pickle, L., Haenszel, W., Correa, P., Lin, Y., and Falk, R. (1988). Dietary Vitamins A and C and Lung Cancer Risk in Louisiana. Cancer. 62(10): 2267-2273.

Francis, F. (1995). Quality as Influenced by Color. *Food Quality and Preference*. 6(3): 149-155.

Fuhrman, B., Elis, A. and Aviram, M. (1997). Hypocholesterolemic effect of lycopene and β-carotene is related to suppression of cholesterol synthesis and augmentation of LDL receptor activity in macrophages. *Biochemical and Biophysical Research Communications*. 233(3); 658-662.

Elkashif, M.E., Huber, D.J. and Brecht, J.K. (1989). Respiration and ethylene production in harvested watermelon fruit: evidence for non-climacteric respiratory behaviour. *Journal of the American Society for Horticultural Science.* 114; 81-85.

Erhardt, J.G., Meisner, C and Bode, J.C. (2003). Lycopene, beta-carotene, and colorectal adenomas. *American Journal Clinical Nutrition* 78(6);1219-24.

Fishman, S., Rodov, V., & Ben-Yehoshua, S. (1996). Mathematical model for perforation effect on oxygen and water vapor dynamics in modified-atmosphere packages. *Journal of Food Science* 61; 956–961.

Gichimu, B.M., Owuor, B.O. and Dida, M.M. (2008). Agronomic performance of three most popular commercial watermelon cultivars in Kenya as compared to one newly introduced cultivar and one local landrace grown on dystric nitisols under sub-humid tropical conditions. *ARPN J. Agri. Biol. Sci*. 3: 65-71.

Giovannucci, E. (1999). Tomatoes, tomato-based products, lycopene, and cancer: Review of epidemiologic literature. *J Natl Cancer Inst*. 91(4); 317-31.2

Gong, S., & Corey, K. A. (1994). Predicting steady state oxygen concentrations in modified atmosphere packages of tomatoes. *Journal of the American Society for Horticultural Science*. 119; 546–550.

Goreta, S., Perica, S., Dumicic, G., Bucan, L. and Zanic, K. (2005). Growth and yield of watermelon on polyethylene mulch with different spacing and nitrogen rates. *Journal of the American Society for Horticultural Science*. 40(2); 366-369

Guner, N. and Wehner, T.C. (2004). The genes of watermelon. *Journal of the American Society for Horticultural Science*. 39(6); 1175-1182.

Hagenmaier, R.D. and Baker, R.A. (1994). Internal gases, ethanol content and gloss of citrus fruit coated with polyethylene wax, carnauba wax, shellac or resin at different application levels. *Proceedings of Florida State Horticultural Society*. 107; 261–265.

Hagenmaier, R.D. and Baker, R.A., (1995). Layers coatings to control weight loss and preserve gloss of citrus fruit. HortScience 30; 296–298.

Haggar, P. E., Lee, D. S., & Yam, K. L. (1992). Application of an enzyme kinetics based respiration model to closed system experiments for fresh produce. *Journal of Food Process Engineering* 15; 143–157.

Hardenburg, R.E., Watada, A.E. and Wang, C.Y. (1986). The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. USDA-ARS Handbook. 66; 12, 62pp.

Helmenstine, A. M. (2013). Vitamin C determination by iodine titration. Accessed from; http://chemistry.about.com/od/demonstrationsexperiments/ss/vitctitration_4htm. 25/04/2013

Henig, Y. S., & Gilbert, S. G. (1975). Computer analysis of the variables affecting respiration and quality of produce packaged in polymeric films. Journal of Food Science 40; 1033–1035.

Hu, H., Li1, X., Dong, C. and Chen, W. (2011). Effects of wax treatment on quality and postharvest physiology of pineapple fruit in cold storage. *African Journal of Biotechnology*. 10(39); 7592-7603.

ISSER, (2009). State of the Ghanaian Economy Report in 2008. Institute of Statistical and Social Economic Research. University of Ghana, Legon.

ISSER, (2011). State of the Ghanaian Economy Report in 2010. Institute of Statistical and Social Economic Research. University of Ghana, Legon.

Jacxsens, L., Devlieghhere, F., & Debevere, J. (1999). Validation of a systematic approach to design equilibrium modified atmosphere packages for fresh-cut produce. *Lebensmittel Wissenschaft und Technologie* 32; 425–432.

Kader, A. (2005). Increasing food availability by reducing post-harvest losses of fresh produce. *Acta Horticulture* 682; 2169 – 2175.

Kohlmeier, L., Kark, J., Gomez-Garcia, E., Martin, B., Steck, S., Kardinaal, A., Ringstad, J., Thamm, M., Masaev, V., Riemersma, R., Martin-Moreno, J., Huttunen, J. and Kok, F. (1997). Lycopene and Myocardial Infarction Risk in the EURAMIC Study. *American Journal of Epidemiology*. 146(8); 618-626.

Kouno, Y., Mizuno, T. and Maida, H. (1993) Internal quality analysis of watermelons by an acoustic technique and its application in Japan. In: Postharvest Handling of Tropical Fruit; Poster papers abstract (1): July 19-23.

Krochta, J.M., Baldwin, E. A. and Nisperos-Carriedo, M. O. Eds., (1994). Edible Coatings and Films to Improve Food Quality, Lancaster, Pennsylvania: Technomic, ISBN 9781566761130, p. 37

Lamptey, S. (2010). Postharvest losses in watermelon. A Dissertation Presented to the Crop Science Department, the College of Agriculture and Consumer Sciences, University of Ghana, Legon.

Maneerat, C., Tongta, A., Kanlayanarat, S., &Wongs-Aree, C. (1997). A transient model to predict O2 and CO2 concentrations in modified atmosphere packaging of bananas at various temperatures. In J. R. Gorny (Ed.), *Proceedings of the 7th international controlled atmosphere research conference*: Vol. 5 (pp. 191–197), Davis, CA, USA.

Mejía-Torres, S., Vega-García, M., Valverde-Juárez, J., López-Valenzuela J. and Caro-Corrales, J. (2009). Effect of wax application on the quality, lycopene content and chilling injury of tomato fruit. *Journal of Food Quality* 32:735–746.

Mahajan, B. V. C., Singh, J. and Dhillon, W. S. (2011): Effect of different edible coatings on quality and shelf life of pears under supermarket and ordinary market conditions. *International Journal of Fruit Science* 11(3); 207-219

Mahrouz, M., Lacroix, M., D'aprano, G., Oufedjikh, H., Boubekri, C. and Gagnon, M. (2002). effect of *gamma* irradiation combined with washing and waxing treatment on physicochemical properties, vitamin c, and organoleptic quality of *Citrus clementina* Hort. Ex. Tanaka. *Journal of Agricultural and Food Chemistry* 50; 7271-7276.

Marfil, P., Santos, E. and Telis, V. (2008). Ascorbic acid degradation kinetics in tomatoes at different drying conditions. *LWT Food Science and Technology*. 41(9): 1642-1647.

Martinez, J.K.,. Mann, S. S, and Randawa, J.S. (1978). Preliminary studies on effect of wax emulsion and growth regulators on storage behaviour of Kinnow mandarins at ambient storage conditions. Prog. Hort. 3: 35-41.

National Watermelon Promotion Board (1999). "Watermelon Production." www.watermelon.org./productn.

National Watermelon Promotion Board (2003). "Watermelon's Healthy Place in Your Diet." *Boost Your Health Esteem Promotion Packet*. Orlando, Florida.

National Watermelon Promotion Board (2003a). "The NWPB: Promoting Watermelon 24/7, Producing Year-Round Demand." *Boost Your Health Esteem Promotion Packet.* Orlando, Florida.

National Watermelon Promotion Board (2003b). "Facts for Food Service." *Food Service Merchandising Kit.* Orlando, Florida.

Ness, A., Khaw, K. T., Bingham, S., and Day, N. E. (1996). Vitamin C status and serum lipids. *European Journal of Clinical Nutrition*. 50(11): 724-729.

Okine, P. (2011). Postharvest losses in watermelon; A case study of the Dangbe-West District of Ghana. A Dissertation Presented to the Crop Science Department, the College of Agriculture and Consumer Sciences, University of Ghana, Legon.

Obeng-Ofori, D. and Akuamoah R.K., (2000). Efficacy of plant extracts and oils for protection of cowpea against infestation by *Callososbruchus maculatus. IOBC Bulletin* 23 (10):177-187.

Ofosu-Anim, J. (2009). Postharvest physiology of horticultural crops. Postharvest technology course handout. Crop science department, University of Ghana, Legon.

Owusu-Akyaw, M., (1991). Evaluation of plant products for the control of cowpea and maize storage insects. *Proceedings Joint SAFGRAD Research Network Workshop*. Niamey, Niger, 8-14

Oyeleke, W.A. and Odedeji, J.O. (2011). Effect of different waxing materials on some chemical properties, minerals and antinutrients composition of pawpaw (*Carica papaya*). *Pakistan Journal of Nutrition* 10 (11); 1008-1012.

Parades-Lopez, O. Camargo-Rubio, E. and Gallardo-Navarro, Y. (1974). Use of coatings of candelilla wax for the preservation of limes. *J. Sci. Food Agr*. 25:1207–1210.

Park, H.J., Chinnan, M.S. and Shewfelt, R.L. 1994. Edible coating effects on storage life and quality of tomatoes. *Journal of Food Science* (59); 568–570.

Picha, D.H. (1988). Storage temperature influences watermelon quality. *Louisiana Journal of Agriculture* 31; 4-5.

Picha, D.H. (1986). Postharvest fruit conditioning reduces chilling injury in watermelons. *HortScience* 21; 1407-1409.

Porter, M. (1985). Competitive Advantage. Free Press, New York, NY. p. 37

Postharvest Handling Technical Bullettin, (2003). Watermelon Postharvest Care and Market Preparation. Technical Bulletin (6); 7-10

Postharvest Handling Technical Bullettin, (2004). Waxing frutis and Vegetables. Technical Bulletin (33); 1-13

Qiuping, Z. and Wenshui, X. (2007). Effect of 1-methylcyclopropene and/or chitosan coating treatments on storage life and quality maintenance of Indian jujube fruit. LWT 40;404–411.

Ratti, C., Raghavan, G. S. V., and Gariépy, Y. (1996). Respiration rate model and modified atmosphere packaging of fresh cauliflower. *Journal of Food Engineering*, 28, 297–306.

Robertson, H. (2005). *Citrullus lanatus* (watermelon, Tsamma). Cape University Press, South Africa.

Rushing, J.W., Fonseca, J.M. and Keinath, A.P. (2001). Harvesting and Postharvest Handling In: Watermelons Handbook. Maynard, D.N. (ed) American Society of Horticultural. Science Press 10; 156-164

Saftner, R.A., Conway, W.S. and Sams, C.E.(1998). Effects of postharvest calcium and fruit coating treatments on postharvest life, quality maintenance, and fruit-surface injury in 'Golden Delicious' apples. *Journal of the American Society for Horticultural Science* 123:294–298.

Sackett, C. (1974). Watermelons. Fruit and Vegetable Facts and Pointers. United Fresh Fruit and Vegetable Assoc. Alexandria, VA

Sanders, D.C., ed. (2001). "Vegetable Crop Guidelines for the Southeastern U.S." North Carolina Cooperative Extension Service.

Schmutterer, H., (1985). Which insect pest can be controlled by application of neem kernel extracts under field conditions? *Journal of Applied Entomology*, 100; 468-475

Shahid, M.N. and N.A. Abbasi. (2011). Effect of bee wax coatings on physiological changes in fruits of sweet orange CV. "blood red". *Sarhad Journal of Agriculture*. 27(3): 385-394

Sipahi , R.E., Castell-Perez, M.E., Moreira, R.G., Gomes C. and Castillo A. (2013). Improved multilayered antimicrobial alginate-based edible coating extends the shelf life of fresh-cut watermelon (Citrullus lanatus). *LWT - Food Science and Technology* 51; 9-15.

Song, Y., Kim, H. K., & Yam, K. L. (1992). Respiration rate of blueberry in modified atmosphere at various temperatures. *Journal of the American Society for Horticultural* Science 117; 925–929.

Sugri, I., Norman, J.C., Egyir, I. and Johnson, P.N.T (2010). Preliminary assessment of shea butter waxing on the keeping and sensory qualities of four plantain (*Musa* aab) varieties. *African Journal of Agricultural Research* 5(19); 2676-2684**.**

Suslow, T.V. (1999). Watermelon. "Fresh Produce Facts." Univ. of Calif., Davis CA. http://postharvest.ucdavis.edu/produce/producefacts/fruit/watermelon.html

Snowdon, A.L. (1992). Colour atlas of postharvest diseases and disorders of fruits and vegetables 2; 18, 51pp.

Tanzubil, P.B., Schmutterer, R. and Ascher, J.R.S. (1897). The use of neem products in controlling the cowpea beetle *Callosobruchus maculatus*. In Natural pesticides from the neem tree (*Azadirachta indica* A. Juss) and other tropical plants. Proceedings of the 3rd International Neem Conference, Nairobi, Kenya, pp. 517-523.

Tian, H. Q., Ying, Y. B., Lu, H. S., Fu, X. P. and Yu, H.Y. (2007). Measurement of soluble solids content in watermelon by Vis/NIR diffuse transmittance technique. *J Zhejiang Univ Sci B 8(2); 105-110*

Thompson, J. F., Brecht, P. E., Hinsch T., and Kader A. A. (2000). Marine container transport of chilled perishable produce. University of California, ANR publication 21595.

USDA. (1978). U.S. standards for grades of watermelons. Agricultural Marketing Service. www.usda.gov.

Wills, R.H.H, Lee, T.H., Graham, D., McGlasson, W.B. and Hall E.G. (1989). Postharvest: An Introduction to the Physiology and Handling of Fruit and Vegetables. New South Wales University Press Limited. Australia.

Yau, E. W., Rosnah, S., Noraziah, M., Chin, N. L. and Osman, H. (2010). Physico-chemical compositions of the red seedless watermelons (*Citrullus Lanatus*). *International Food Research Journal* 17; 327-334

Appendix 1

Evaluating the postharvest knowledge system: Simulating postharvest losses from Field to Market

Questionnaire for Watermelon Farmers

A. General Information *Date of Interview:*

1. District: ………………………

2. Town/Village: ………………………..

3. Name of respondent………………………

4. Gender of respondent: 1= male 2= female

5. Educational status of respondent. Tick as appropriate

1=Primary 2=Middle/JSS 3=Secondary/SSS 4=Higher than Secondary/JSS
5=None 6=Islamic education 7=Other (specify)………………………

6. What is your Household Income?

1= 0-100 2=101-200 3= 201-300 4= greater than 301

7. What is your household size/number?

1= less than 3 2= 3 to 6 3= 7 to 10 4= 11 to 14 4= 15 or more

9. What type(s) of work do you do in addition to farming?

1 =Pito/alcohol Brewing
2 =Sheabutter/groundnut oil extraction
3 =Charcoal/firewood selling
4 =Basket weaving
5 =Fishing
6 = Sell cutlasses, hoe, fertilizer, etc
7 =Hire out equipment (tractor, bullock, donkey, etc)
8 =Mason, construction work, etc
9 =Mining (quarrying, gold-winning, etc)
10 =Artisan (blacksmith, carpentry, tailoring)
11 =General trade in agricultural produce
12 =General trade in non-agricultural produce
13 =Farm Hand
14 =Pottery

10. Do you receive any form of help from Agric Extension Agents (AEA's) 1=Yes 2=No

11. If yes, describe the nature and type of services you receive from extension agents?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

12. Where are seeds obtained from?

1= from Agric Extension Agents (AEA)
2= from MOFA offices
3= from fellow farmers or friends
4= from certified dealers/sellers
5= Other (specify)......................

13. What time of the year do you plant seeds?

....
....
....

14. How are seeds sown?

....
....
....

15. What are the general husbandry practices you adopt on the farm?

1= weeding
2= rodent control
3= watering/irrigation
4= insect control
5= application of fertilizer
6= other (specify)..................................

16a. How is watering done?

1= irrigation 2= watering can 3= rain fed

16b. If not rain fed, please indicate the source of water used

1=dug-out well 2=river 3=stream 4.other (specify)..........................

17. How often is watering done in a day/ or week

....
....
....

18. What time of the day is watering done?

1= 6am to 9am
2= 9:01am to 12pm
3= 12:01pm to 3pm
4= 3:01pm to 6pm
5= after 6pm

19. How is weed controlled?

1= weedicides 2= mechanical 3= manual 4= other (specify)........................

20. When is weed control done and how often?

....
....
....

21. What are the major insects and rodents encountered on the farm?

1= beetles 2=moths 3= birds 4=rats 5= grass-cutter
6= Other (specify)

22. How are insects/rodents controlled?

1=chemical control 2=biological control 3=Physical control 4=IPM

23. How often are insects/rodents controlled?

....
....
....

24. Please list the diseases or pathological disorder encountered on the farm

....
....
....

25. How are diseases controlled?

1=Fungicides 2= clean seeds 3= Pruning of infected leaves
4= removal and destruction of infected fruits 5= Other (specify)......................

26. Please list the kind of fertilizers used

....
....
....

27. When are the fertilizers applied?

………
………
………

B. HUSBANDRY AND PRE-HARVEST PRACTICES

28. Describe the types, quantity and value of losses you incur during husbandry and pre-harvest operations

	Nature of loss listed	Quantity of produce harvested (no. of fruits)	Estimated losses (Quantity, %)	Value of loss (GH¢)
Fertilizer application (over application)				
watering (too much watering)				
Weed control (over application of weedicides & careless weeding)				
Insect/disease control (over application of insetcticides/fungicide)				
insect/rodent attack				
disease atatck				

1=Weight loss 2= Bruising of fruits 3=Sun burn/heat injury 4=dropping and cracking 5= Destruction by rodents/birds 6= Boring by insects 7 =Rotting of fruits 8=Wilting and shrinking 9=Microbial or disease infections 10=Others (specify)

29. How long are fruits planted before they are harvested?
………
………

30. What days in the week is harvesting done?
………
………

31. What harvesting indices are used in determining matured fruits?

1= knocking sound 2=colour of the pale patch that lies on the ground
3=glossiness 4=fruit colour 5=Other (specify)...................................

32. What time of the day is harvesting done?..

33. How is the produce harvested? Tick the appropriate responses

1=Manual with/without cutlass/knife
2=Employ additional labour using the sickle/knife
3=Use a machine harvester
4=Hand harvesting
5=Others (specify)..

34. What criteria is used in grading and sorting?...
....
....
....
....

35. How is pricing done?...

36. Who do you sell watermelons to?...

C. HARVESTING AND POST-HARVEST HANDLING LOSS ASSESSMENT

37. Describe the types, quantity and value of losses you incur during harvesting, immediate post-harvest processing, purchasing and immediate post-purchase period.

Stages of Handling	Nature of loss (see code below)	Quantity of produce harvested (no. of fruits)	Estimated losses (Quantity, %)	Value of loss (GH¢)
Harvesting operations				
Gathering, transport,				

packing etc at farm or at purchase point				
Grading and sorting operations at farm,				
Temporal processing (pre-cooling, washing, etc				
Processing (specify)				

1=Weight loss 2= Bruising of fruits 3=Sun burn/heat injury 4=dropping and cracking 5= Destruction by rodents/birds 6= Boring by insects 7 =Rotting of fruits 8=Wilting and shrinking 9=Microbial or disease infections 10=Others (specify)

D. STORAGE LOSS ASSESSMENT

38. Describe the types, quantity and value of losses incurred during storage at home or farm.

site of storage	Nature of loss (see code below)	Quantity of produce harvested (no. of fruits)	Estimated losses		Value of loss (GH¢)
			Quantity	%	
Storage on farm					
Storage at home					

1=Weight loss 2= Bruising of fruits 3=Sun burn/heat injury 4=dropping and cracking 5= Destruction by rodents/birds 6= Boring by insects 7 =Rotting of fruits 8=Wilting and shrinking 9=Microbial or disease infections 10=Others (specify)

39. Where are fruits stored?

1=on the farm 2=at home 3=other (specify)…………………

40. Briefly describe how fruits are stored

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

…………………………………………………………………………………………………
…………………………………………………………………………………………………

41. Describe the environment/conditions under which fruits are stored

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

42. What are the major problems encountered during storage on the farm?

1=Insect 2=rodents 3=weeds 4=thieves 5=rot 6=weight loss 7=other (specify)

43. Please use the spaces provided below to make brief recommendations that could mitigate problems in the production of watermelon

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Appendix 2

Evaluating the postharvest knowledge system: Simulating postharvest losses from Field to Market

Questionnaire for Watermelon dealers

A. General Information ***Date of Interview:***

1. District: ………………………
2. Town/Village: ………………………..
3. Name of respondent………………………
4. Gender of respondent:

1= male
2= female

5. Educational status of respondent. Tick as appropriate

1=Primary 2=Middle/JSS 3=Secondary/SSS 4=Higher than Secondary/JSS
5=None 6=Islamic education 7=Other (specify)

6. What is your Household Income?

1= 0-100 2=101-200 3= 201-300 4= greater than 301

7. What is your household size/number?

1= less than 3 2= 3 to 6 3= 7 to 10 4= 11 to 14 4= 15 or more

10. Where do you obtain your raw produce from? Tick the appropriate responses

1=Own farm
2=Purchase from farmers
3=Purchase from wholesalers
4=Purchase from retailers

B. TRANSPORTATION AND MARKET LOSS ASSESSMENT

11. Please describe the losses incurred, including the quantity and value of losses during transportation, storage and marketing of your produce.

Stage of handling	Nature of loss (see code below)	Quantity of produce bought from farm (no. of fruits)	Estimated losses (Quantity, %)	Value of loss (GH¢)
Loading and off-loading				
During transport to market				
Cleaning and grading or sorting				
During wholesale points				
During retail points				
During export points				

1=Weight loss 2= Bruising of fruits 3=Sunburn/heat injury 4=dropping and cracking 5= Destruction by rodents/birds 6= Boring by insects 7 =Rotting of fruits 8=Wilting and shrinking 9=Microbial or disease infections 10=Chilling injury 11=Others (specify)

12. How is loading and off-loading done?

1=manual (use of human labour) 2=mechanical (use of conveyors)
3=other (specify)……………………………………………

13. Briefly describe the nature of road and vehicle used in transporting fruits

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

14.What is/are the major challenge(s) of transporting watermelon from farm to desired destination?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

15. What is the nature of road used to transport fruits from farm to destination?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………………………………………

16. Describe the nature of vehicle used in transporting fruits

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………………………………

17. What materials are used to cover fruits during transportation?

1=tarpaulin 2=black polyethene sheets 3=plain polyethene sheets 4=straw
5=no cover 6=other (specify)……………………………………………

18. How are fruits sorted or graded?

1=according to size/weight 2=according to shape 3=according to fruit colour
4=according to glossiness 5=other (specify)………………………………

19. How are fruits cleaned?

1=ordinary water 2=other (specify)………………………………

20. How are fruits priced?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………......................…

21. In what form are fruits sold?

1=whole fruit 2=cut fruit 3=juiced 4=other (specify)………………………

C. STORAGE LOSS ASSESSMENT

22. Please describe the losses incurred, including the quantity and value of losses incurred during storage

Site of storage	Nature of loss (see code below)	Quantity of produce bought from farm (no. of fruits)	Estimated losses (Quantity, %)	Value of loss (GH¢)
Storage at market or point of sale				
Storage at home				
Storage at processing site				

1=Weight loss 2= Bruising of fruits 3=Sunburn/heat injury 4=dropping and cracking 5= Destruction by rodents/birds 6= Boring by insects 7 =Rotting of fruits 8=Wilting and shrinking 9=Microbial or disease infections 10=Chilling injury 11=Others (specify)

23. Where are fruits stored?

1=at the market 2=at home 3=in a warehouse/store room
4=other (specify)……………………………

24. How are fruits stored?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……….................................…………………

25. Describe the environment/conditions under which watermelon fruits are stored

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……...............................………………

26. What is/are the major challenge(s) encountered during storage of watermelon fruits?

1=Insect 2=rodents 3=thieves 4=rot
5=weight loss 6=other (other)……………………

27. Do you perform any form of preservation? 1=Yes 2=No

28. Please give reasons for your answer in question 27

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………………...

29. Please use the spaces provided below to make brief recommendations that could mitigate problems in the postharvest system of watermelon

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………………...
....

Appendix 3

Name...Sex...
Contact.. Date.. Sample code..

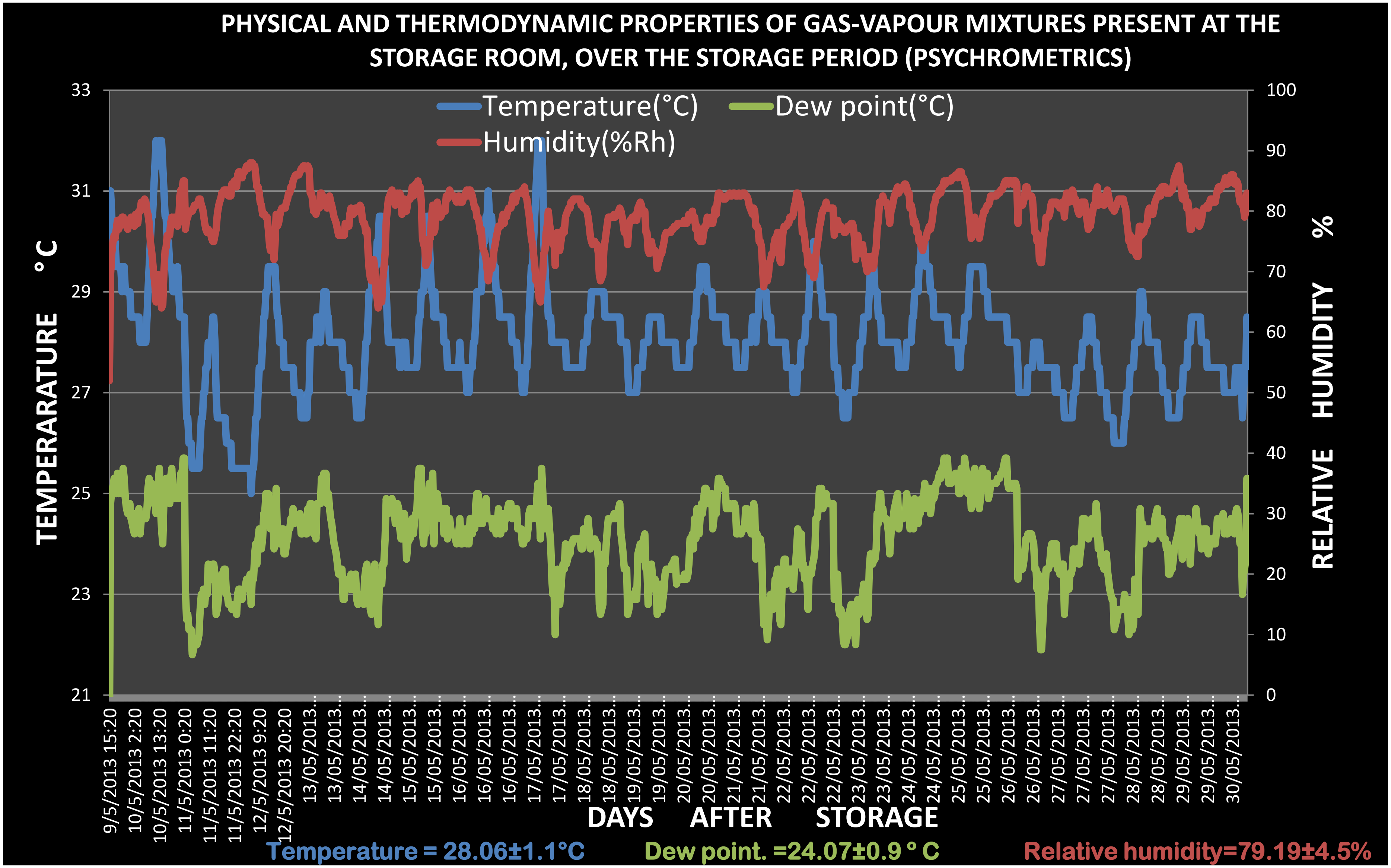
Please you are receiving coded samples of watermelon evaluated under different waxing formulations for their keeping and sensory qualities. Make your individual assessment /judgement after a moderate amount of observation and consideration. You give a more objective assessment by scoring without consulting fellow assessor/panellist. Take a sip of water, pause for a while before testing the next sample. Please score the samples as best as possible using the scale below.

Score	**Skin/rind colour**	**Glossiness (rind)**	**Attractiveness (rind)**	**Taste (sweetness)**	**Flavour (characteristic) smell and aroma**	**Mouth feel**	**Pulp colour**	**Texture**	**Overall acceptability**
5	Very bright	Extremely glossy	Extremely attractive	Extremely sweet	Very pleasant	Like extremely	Extremely red	Very crunchy	Like extremely
4	bright	Very glossy	Very attractive	Very sweet	pleasant	Like very much	Very red	crunchy	Like very much
3	dull	Glossy	attractive	sweet	unpleasant	Like	red	Slightly crunchy	Like
2	Very dull	Slightly glossy	unattractive	Slightly sweet	slightly unpleasant	dislike	Slightly red	soft	dislike
1	Extremely dull	Not glossy	Very unattractive	Not sweet	very unpleasant	Dislike very much	Off colour	Very soft	Dislike very much
Please write or tick boldly your score in the appropriate column									
5									
4									
3									
2									
1									

Thank you for participating

Appendix 4

A thermohydrograh showing the thermodynamic properties of gas-vapour mixtures present at the storage room, over the storage period.(Psychrometrics)



Appendix 5

ANOVA 1 : Variate: VIT_C NSBW

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
NSBW	4	21.764	5.441	5.32	<.001
DAYS	2	112.843	56.422	55.22	<.001
NSBW.DAYS	8	39.127	4.891	4.79	<.001
Residual	60	61.306	1.022		
Total	74	235.040			

ANOVA 2: Variate: TTA NSBW

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
NSBW	4	21934439	5483610	18.06	<.001
DAYS	2	72149884	36074942	118.81	<.001
NSBW.DAYS	8	33368694	4171087	13.74	<.001
Residual	60	18218823	303647		
Total	74	145671839			

ANOVA 3 : Variate pH: NSBW

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
NSBW	4	0.291432	0.072858	13.03	<.001
DAYS	2	22.848536	11.424268	2042.97	<.001
NSBW.DAYS	8	1.468224	0.183528	32.82	<.001
Residual	60	0.335520	0.005592		
Total	74	24.943712			

ANOVA 4 : Variate: TWL NSBW

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
NSBW	4	79.107	19.777	7.33	<.001
DAYS	2	497.028	248.514	92.06	<.001
NSBW.DAYS	8	36.988	4.624	1.71	0.114
Residual	60	161.967	2.699		
Total	74	775.090			

ANOVA 5: Variate: TSS NSBW

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
NSBW	4	34.1885	8.5471	34.32	<.001
DAYS	2	25.4339	12.7169	51.06	<.001
NSBW.DAYS	8	56.4555	7.0569	28.33	<.001
Residual	60	14.9440	0.2491		
Total	74	131.0219			

ANOVA 6 : Variate; VITAMIN_C (NPW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
NPW	4	113.393	28.348	15.04	<.001
DAY	4	341.746	85.437	45.34	<.001
NPW.DAY	16	42.773	2.673	1.42	0.148
Residual	100	188.435	1.884		
Total	124	686.347			

ANOVA 7: Variate; TTA NPW

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
NPW	4	8437352.	2109338.	7.02	<.001
DAY	4	67221845.	16805461.	55.93	<.001
NPW.DAY	16	28487506.	1780469.	5.93	<.001
Residual	100	30044817.	300448.		
Total	124	134191520.			

ANOVA 8: Variate; TWL NPW

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
NPW	4	11.50198	2.87549	29.14	<.001
DAY	4	106.72796	26.68199	270.37	<.001
NPW.DAY	16	5.17263	0.32329	3.28	<.001
Residual	100	9.86864	0.09869		
Total	124	133.27121			

ANOVA 9: Variate; TSS NPW

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
NPW	4	2.0411	0.5103	0.64	0.636
DAY	4	23.3051	5.8263	7.30	<.001
NPW.DAY	16	14.8309	0.9269	1.16	0.312
Residual	100	79.8080	0.7981		
Total	124	119.9851			

ANOVA 10: Variate; pH NPW

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
NPW	4	0.15085	0.03771	0.39	0.813
DAY	4	2.94852	0.73713	7.70	<.001
NPW.DAY	16	0.69832	0.04364	0.46	0.962
Residual	100	9.57820	0.09578		
Total	124	13.37588			

ANOVA 11: Variate: VIT_C NCW

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
NCW	4	16.1847	4.0462	5.20	<.001
DAY	5	78.0785	35.6157	45.81	<.001
NCW.DAY	20	30.5537	1.5277	1.97	0.014
Residual	120	93.2914	0.7774		
Total	149	318.1083			

ANOVA 12: Variate: TTA NCW

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
NCW	4	2660972.	665243.	2.05	0.092
DAY	5	105593628.	21118726.	64.92	<.001
NCW.DAY	20	8772299.	438615.	1.35	0.163
Residual	120	39036116.	325301.		
Total	149	156063015.			

ANOVA 13: Variate: TWL NCW

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
NCW	4	26.4121	6.6030	21.74	<.001
DAY	5	202.2918	40.4584	133.23	<.001
NCW.DAY	20	16.6018	0.8301	2.73	<.001
Residual	120	36.4409	0.3037		
Total	149	281.7467			

ANOVA 14: Variate: TSS NCW

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
NCW	4	10.7133	2.6783	4.74	0.001
DAY	5	17.9020	3.5804	6.34	<.001
NCW.DAY	20	14.1198	0.7060	1.25	0.226
Residual	120	67.7385	0.5645		
Total	149	110.4736			

ANOVA 15: Variate: pH (NCW)

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
NCW	4	0.73196	0.18299	3.51	0.009
DAY	5	2.83801	0.56760	10.90	<.001
NCW.DAY	20	2.65343	0.13267	2.55	<.001
Residual	120	6.24880	0.05207		
Total	149	12.47220			

ANOVA 16:Variate: ATTRACTIVENESS (NSBW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	107.1400	26.7850	43.39	<.001
Residual	95	58.6500	0.6174		
Total	99	165.7900			

ANOVA 17: Variate: FLAVOUR_SMELL_AROMA (NSBW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	85.8400	21.4600	24.16	<.001
Residual	95	84.4000	0.8884		
Total	99	170.2400			

ANOVA 18:Variate: MOUTH_FEEL (NSBW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	70.1000	17.5250	26.90	<.001
Residual	95	61.9000	0.6516		
Total	99	132.0000			

ANOVA 19:Variate: PULP_COLOUR (NSBW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	63.040	15.760	15.29	<.001
Residual	95	97.950	1.031		
Total	99	160.990			

ANOVA 20:Variate: SKIN_RIND_COLOUR (NSBW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	113.6600	28.4150	33.37	<.001
Residual	95	80.9000	0.8516		
Total	99	194.5600			

ANOVA 21:Variate: TASTE_SWEETNESS (NSBW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	71.9600	17.9900	24.99	<.001
Residual	95	68.4000	0.7200		
Total	99	140.3600			

ANOVA 22: Variate: TEXTURE (NSBW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	53.500	13.375	13.30	<.001
Residual	95	95.500	1.005		
Total	99	149.000			

ANOVA 23:Variate: OVERALL_ACCEPTABILITY (NSBW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	78.1600	19.5400	32.68	<.001
Residual	95	56.8000	0.5979		
Total	99	134.9600			

ANOVA 24: Variate: MOUTH_FEEL (NPW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	18.1400	4.5350	6.34	<.001
Residual	95	67.9000	0.7147		
Total	99	86.0400			

ANOVA 25:Variate: PULP_COLOUR (NPW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	63.860	15.965	1.63	0.174
Residual	95	931.700	9.807		
Total	99	995.560			

ANOVA 26: Variate: SKIN_RIND_COLOUR (NPW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	2.6600	0.6650	0.95	0.437
Residual	95	66.3000	0.6979		
Total	99	68.9600			

ANOVA 27: Variate: TASTE_SWEETNESS (NPW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	41.7000	10.4250	11.12	<.001
Residual	95	89.0500	0.9374		
Total	99	130.7500			

ANOVA 28:Variate: TEXTURE (NPW)

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TRT	4	16.0600	4.0150	4.77	0.001
Residual	95	79.9000	0.8411		
Total	99	95.9600			

ANOVA 29: Variate: OVERALL_ACCEPTABILITY (NPW)

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TRT	4	25.8600	6.4650	6.91	<.001
Residual	95	88.9000	0.9358		
Total	99	114.7600			

ANOVA 30: Variate: ATTRACTIVENESS (NCW)

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TRT	4	4.8000	1.2000	1.96	0.107
Residual	95	58.2000	0.6126		
Total	99	63.0000			

ANOVA 31: Variate: FLAVOUR_SMELL_AROMA (NCW)

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TRT	4	1.4600	0.3650	0.54	0.707
Residual	95	64.3000	0.6768		
Total	99	65.7600			

ANOVA 32: Variate: GLOSSINESS (NCW)

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TRT	4	8.2600	2.0650	2.36	0.059
Residual	95	83.0500	0.8742		
Total	99	91.3100			

ANOVA 33: Variate: MOUTH_FEEL (NCW)

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TRT	4	4.2600	1.0650	1.72	0.152
Residual	95	58.9000	0.6200		
Total	99	63.1600			

ANOVA 34: Variate: PULP_COLOUR (NCW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	23.7400	5.9350	11.30	<.001
Residual	95	49.9000	0.5253		
Total	99	73.6400			

ANOVA 35: Variate: SKIN_RIND_COLOUR (NCW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	6.8600	1.7150	2.60	0.041
Residual	95	62.7000	0.6600		
Total	99	69.5600			

ANOVA 36: Variate: TASTE_SWEETNESS (NCW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	3.1400	0.7850	0.85	0.498
Residual	95	87.8500	0.9247		
Total	99	90.9900			

ANOVA 37 Variate: TEXTURE (NCW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	18.1600	4.5400	6.24	<.001
Residual	95	69.1500	0.7279		
Total	99	87.3100			

ANOVA 38: Variate: OVERALL_ACCEPTABILITY (NCW)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	4	3.3400	0.8350	1.32	0.268
Residual	95	60.1000	0.6326		
Total	99	63.4400			

Appendix 6

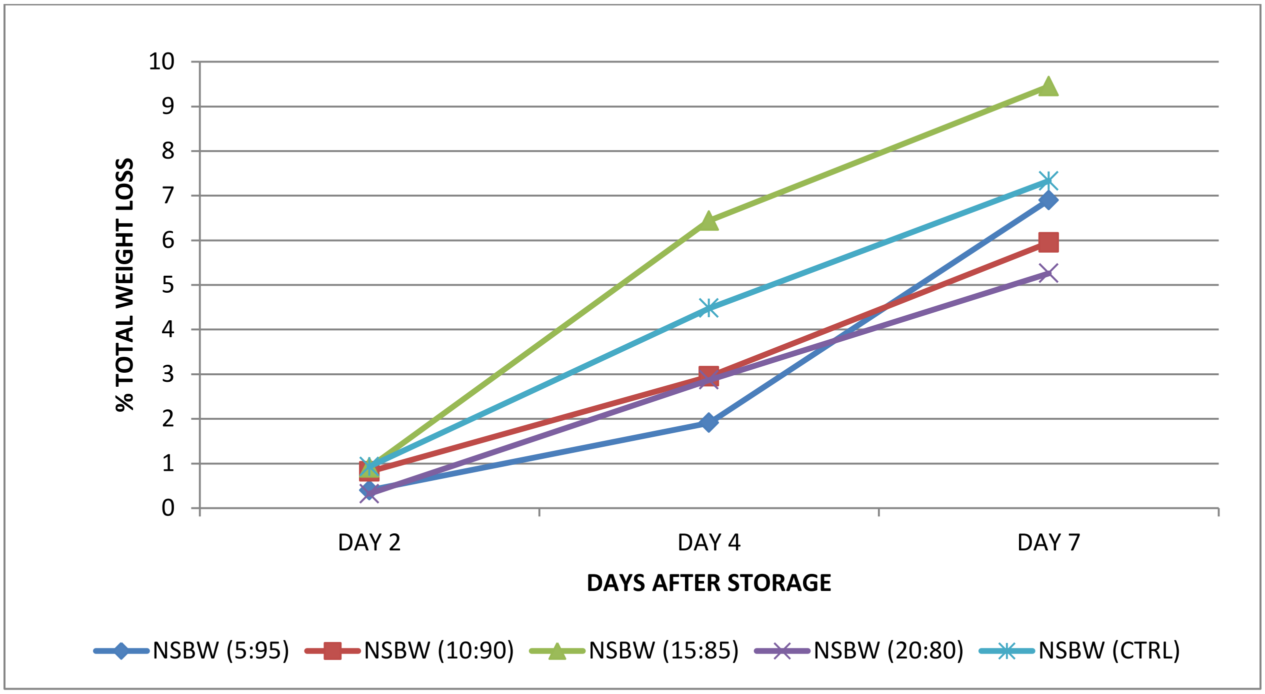


Figure 1: Changes in %TWL after days of storage and Neem oil/Shea-butter waxing

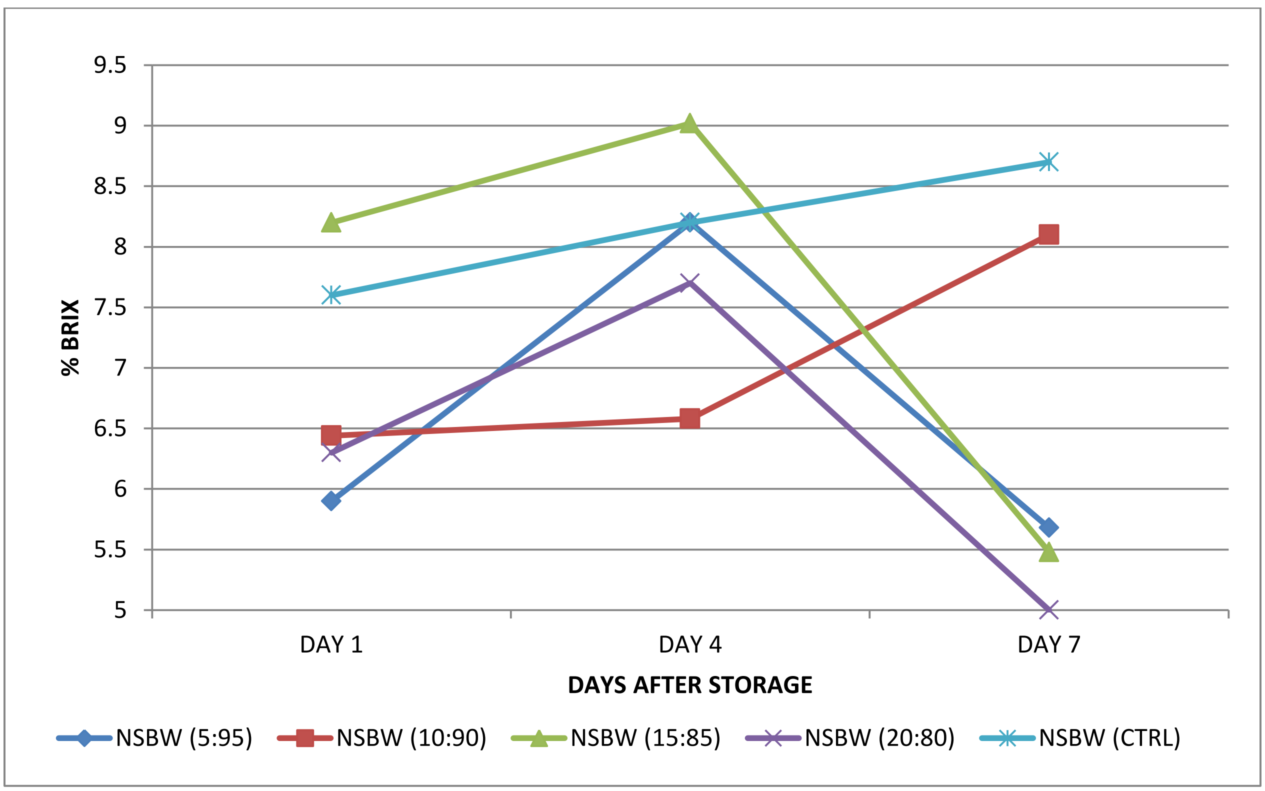


Figure 2: Changes in TSS after days of storage and Neem oil/Shea-butter waxing

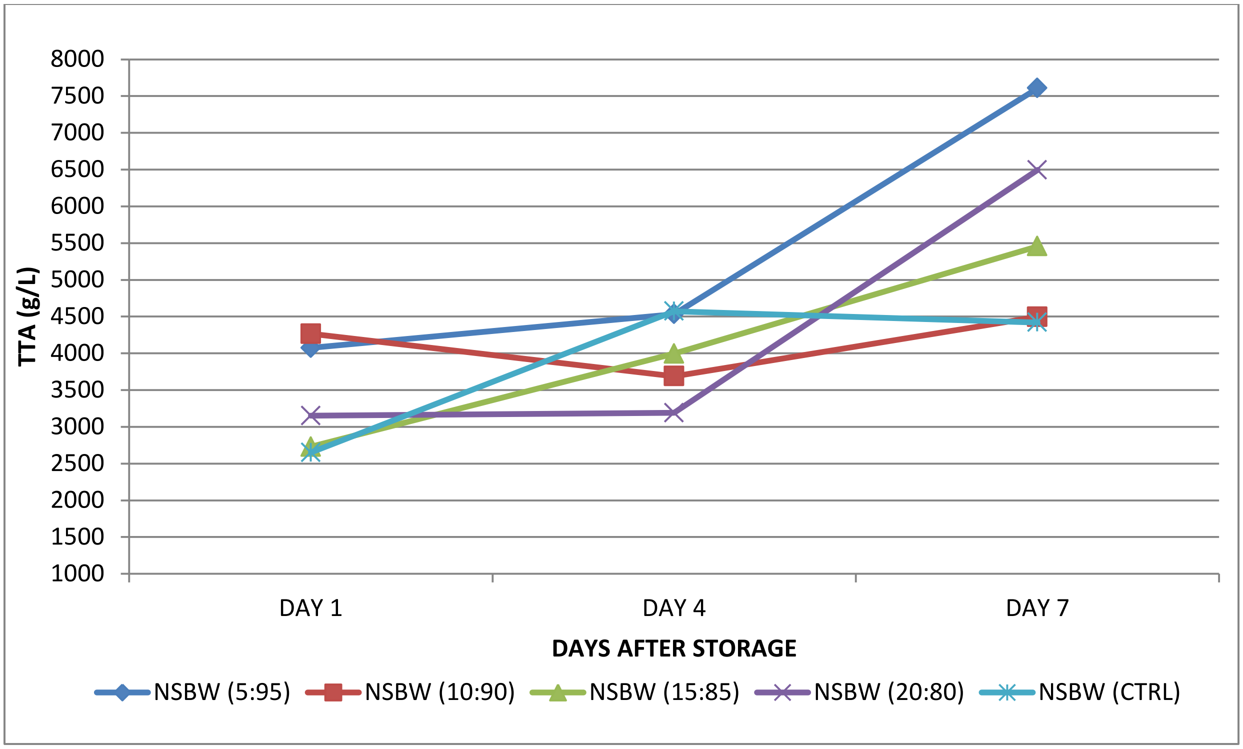


Figure 3: Changes in TTA (g/L) of watermelon following Neem oil/Shea-butter waxing and days of storage

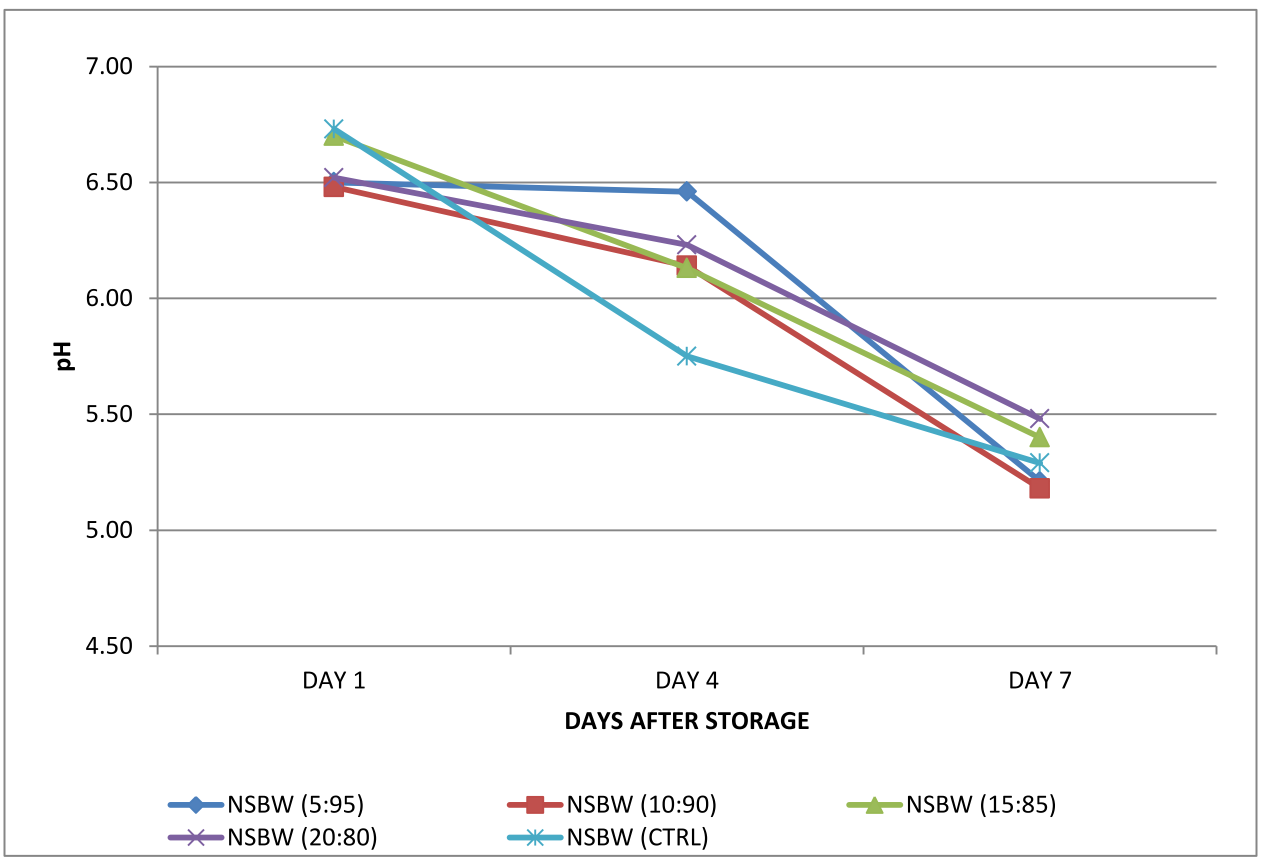


Figure 4: Changes in pH following NSBW treatment and days after storage

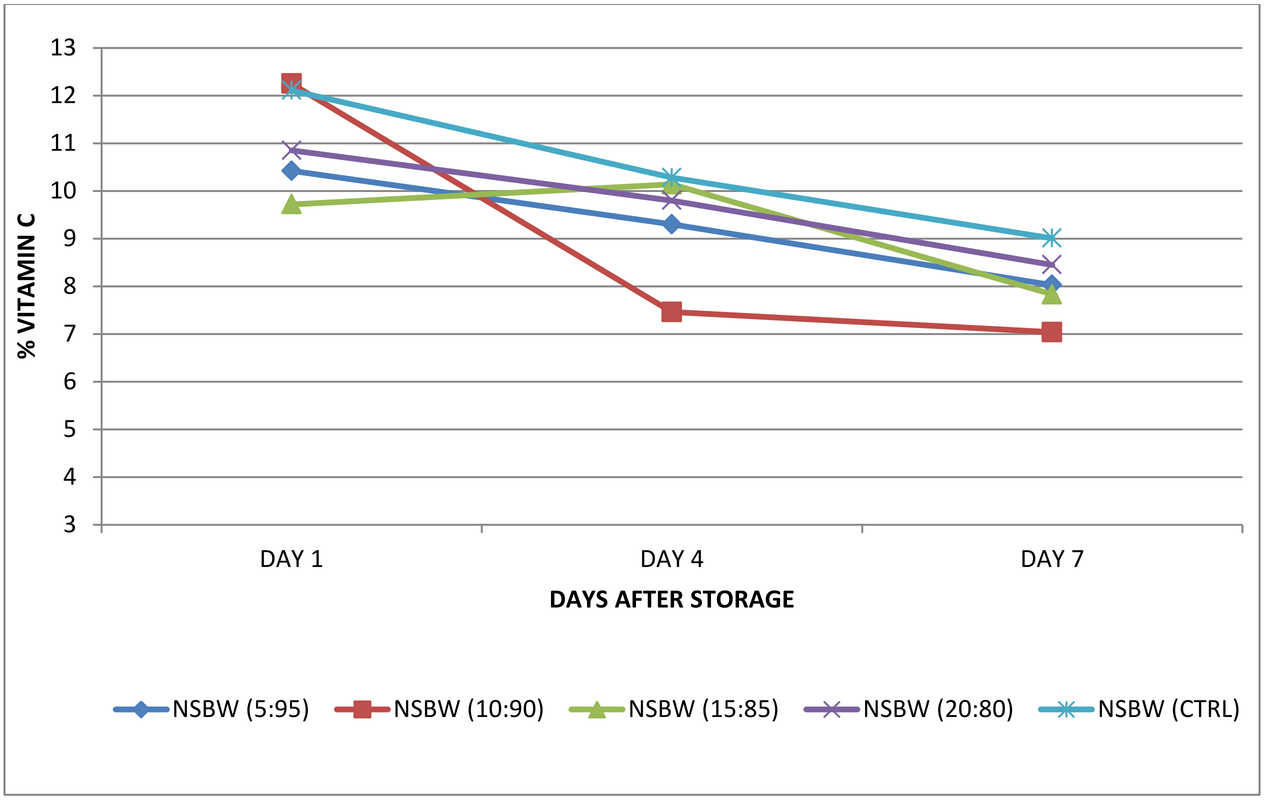


Figure 5: Changes in % Vitamin C following Neem oil/Shea-butter waxing and days of storage

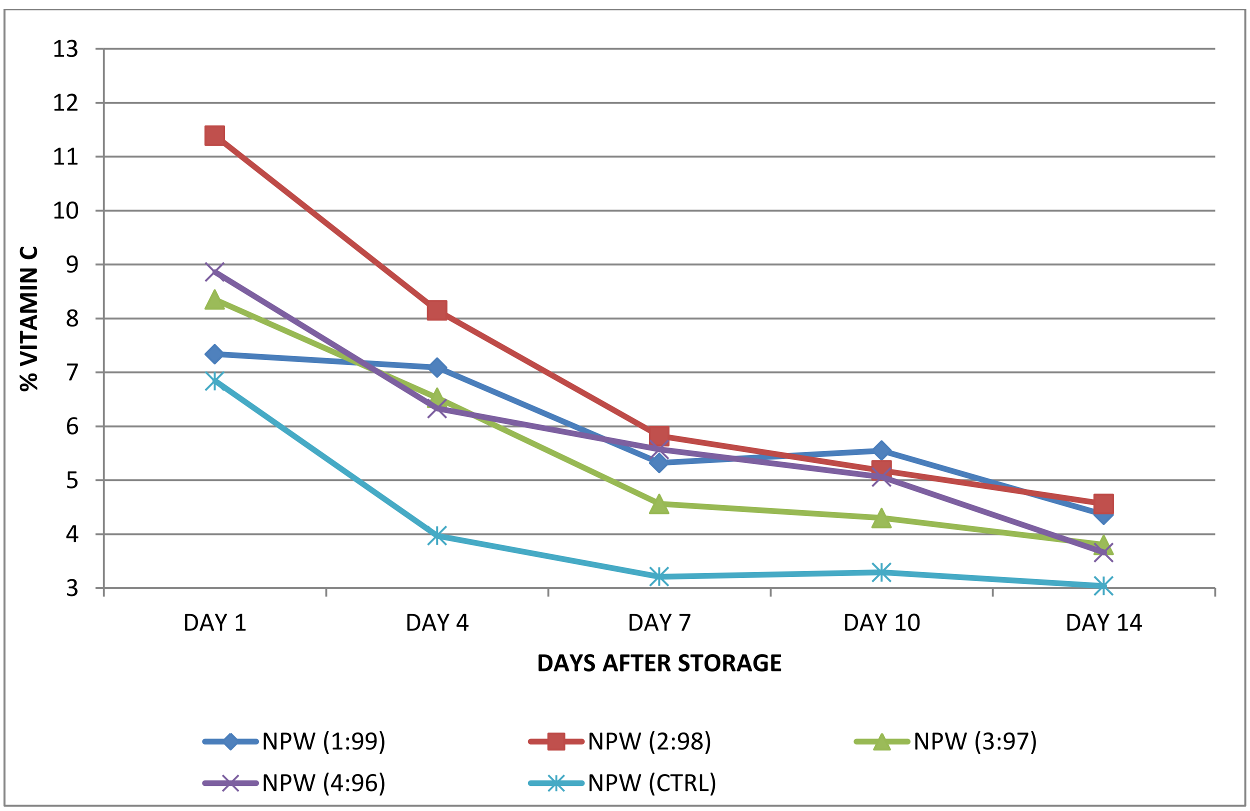


Figure 6: Changes in % Vitamin C following Neem oil/Palm oil waxing and days of storage

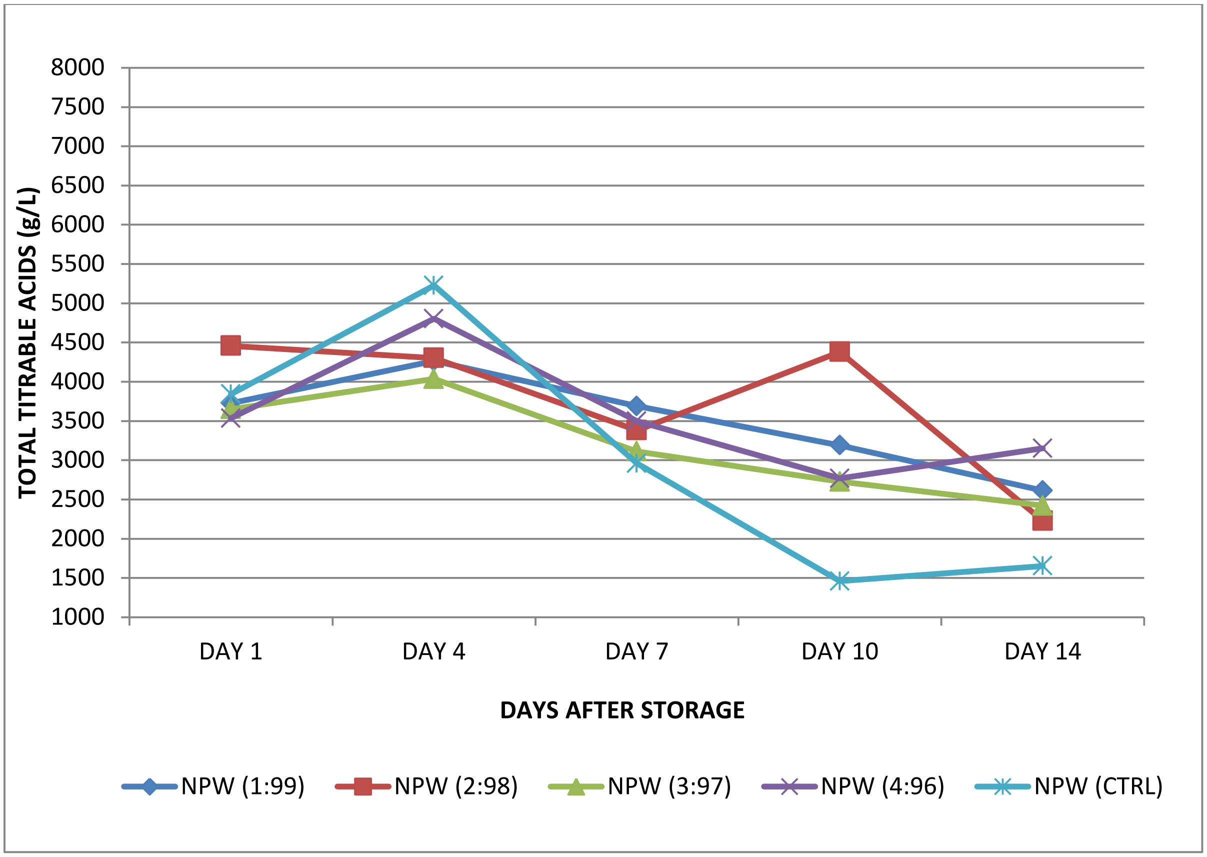


Figure 7: Changes in TTA (g/L) following NPW treatments and days of storage

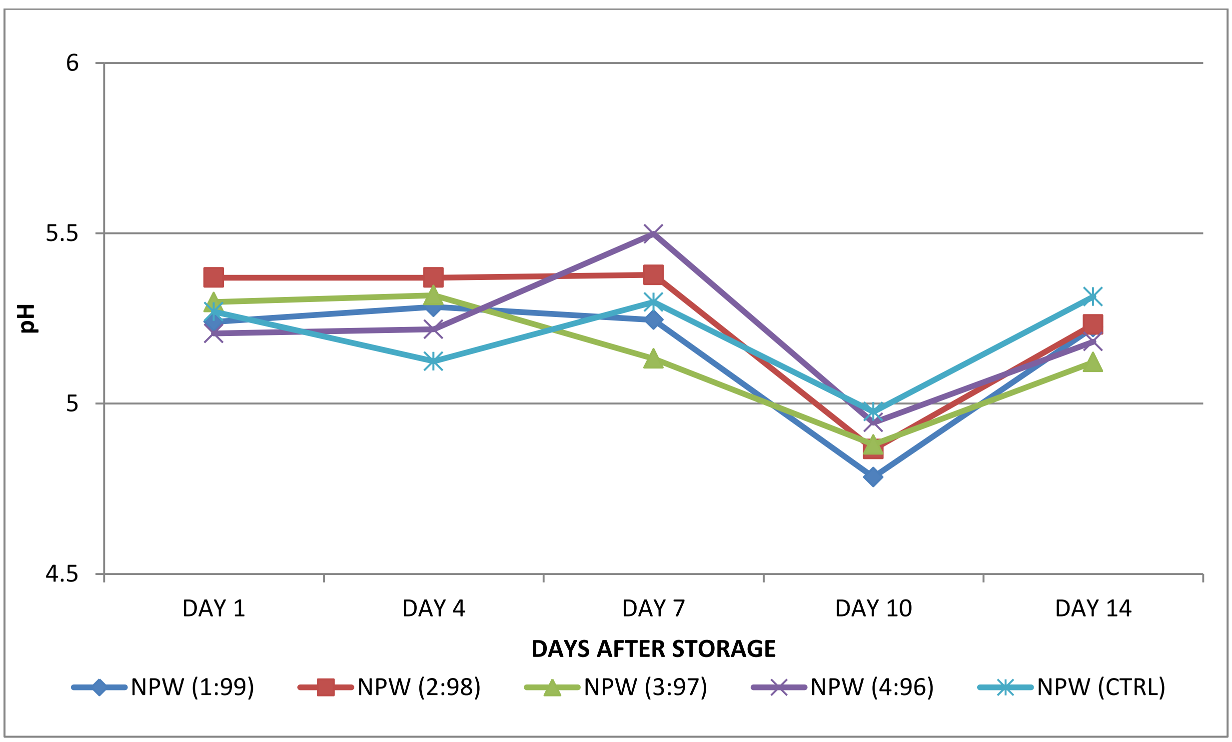


Figure 8: Changes in pH following Neem oil/Palm oil waxing and days of storage.

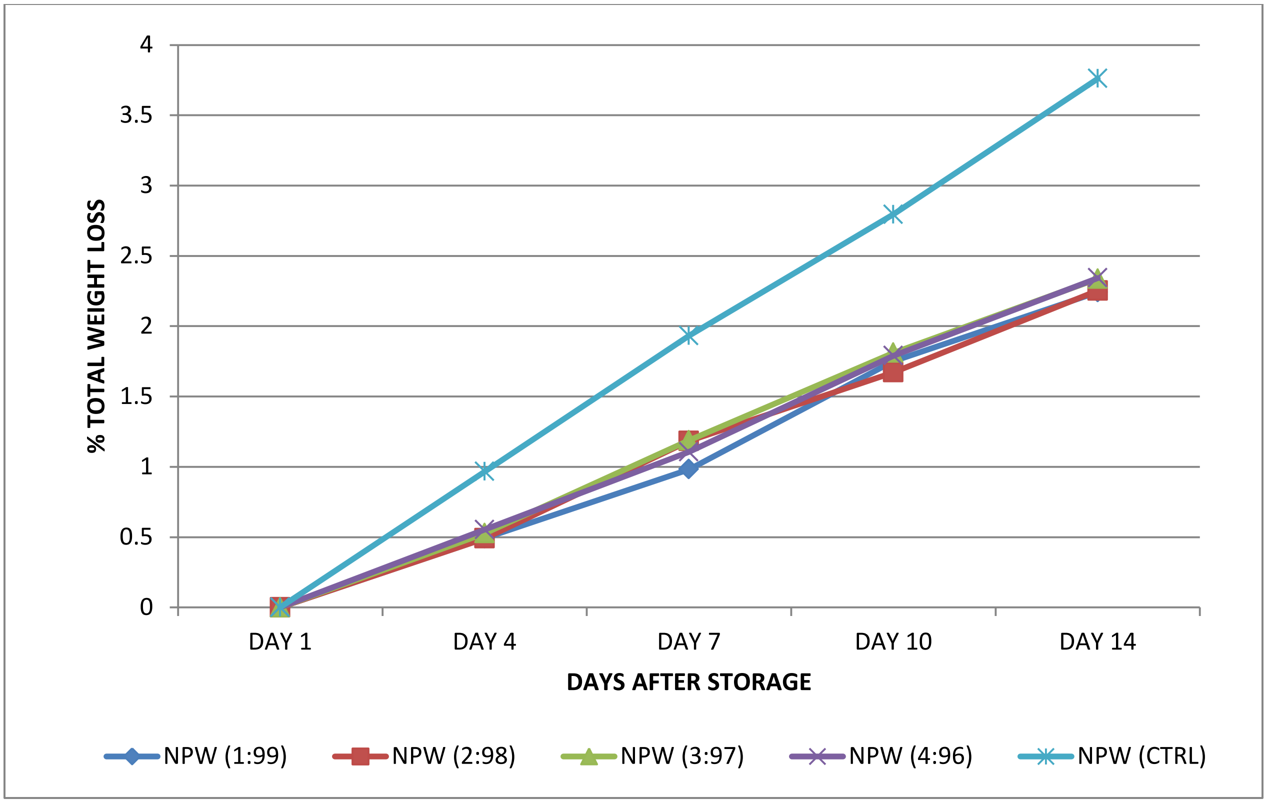


Figure 9: Changes in %TWL following Neem oil/Palm oil waxing and days of storage

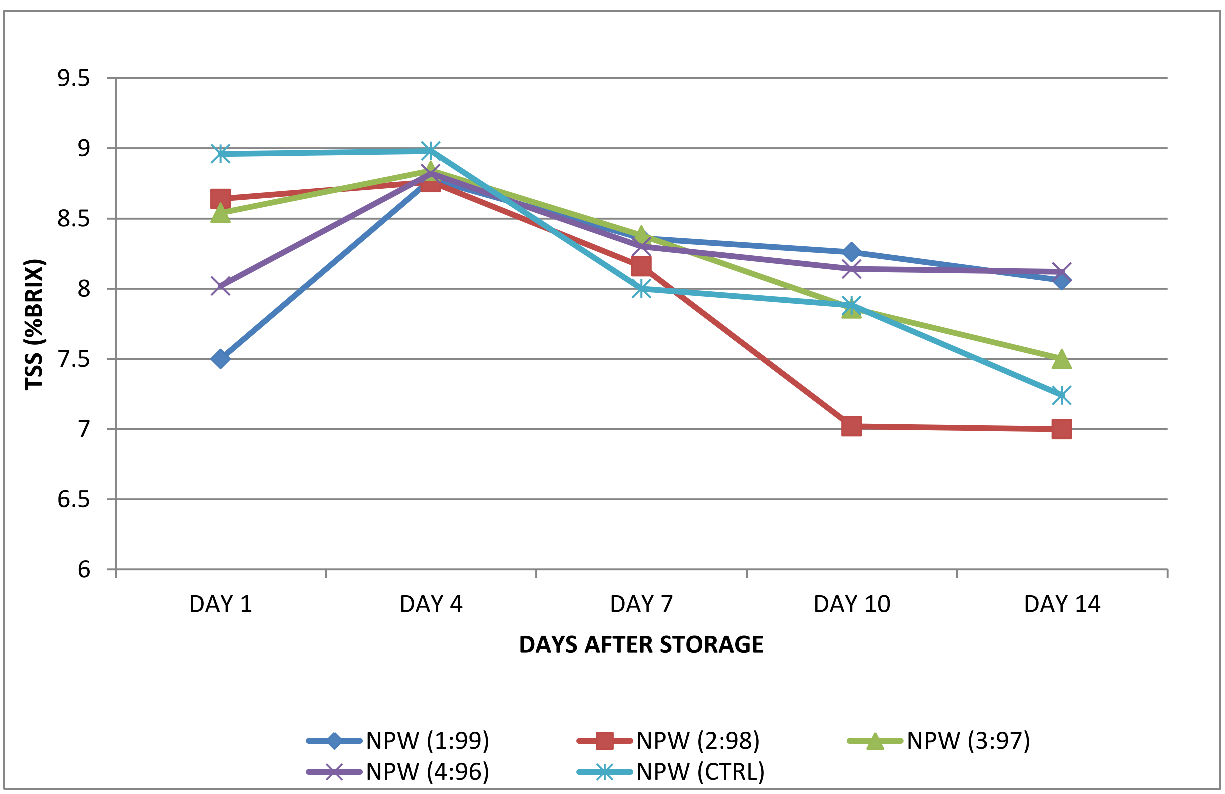


Figure 10: Changes in total soluble solids (% Brix) or TSS following Neem oil/Palm oil waxing and days of storage

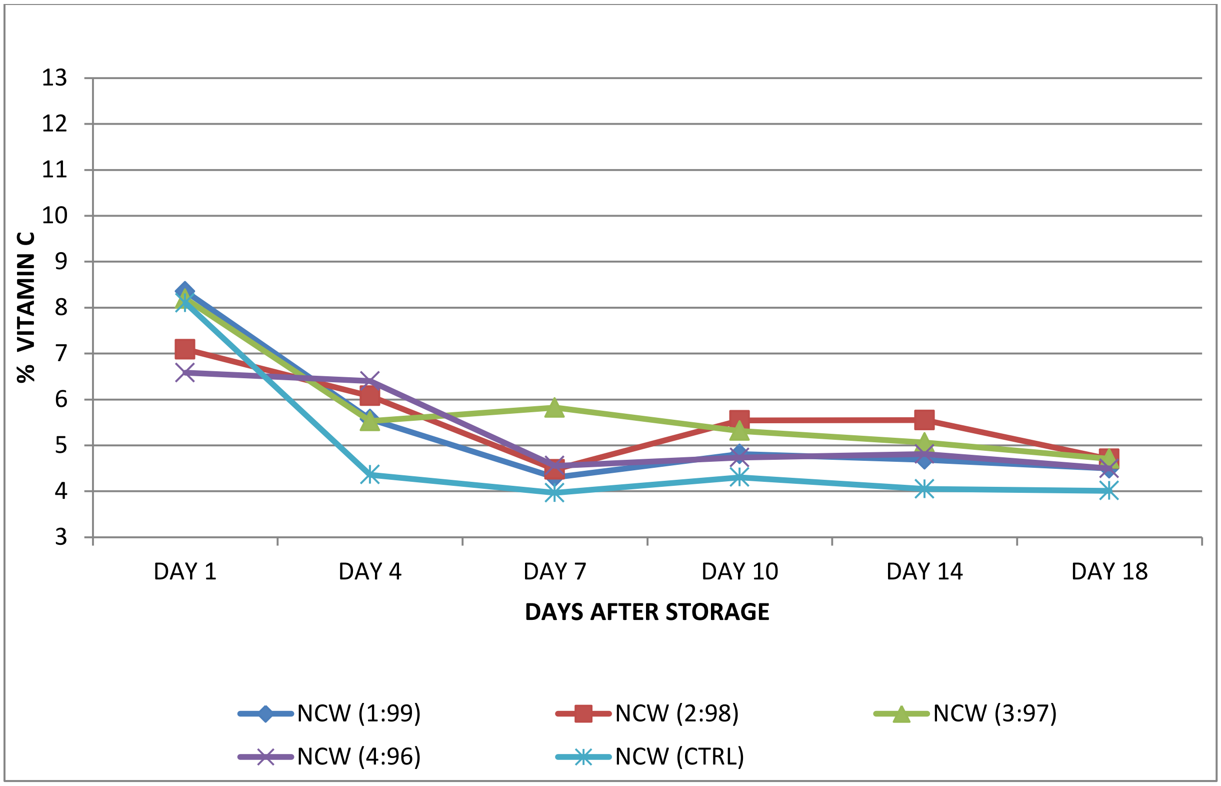


Figure 11: Storage life of watermelon following Neem oil/Palm oil waxing and days of storage

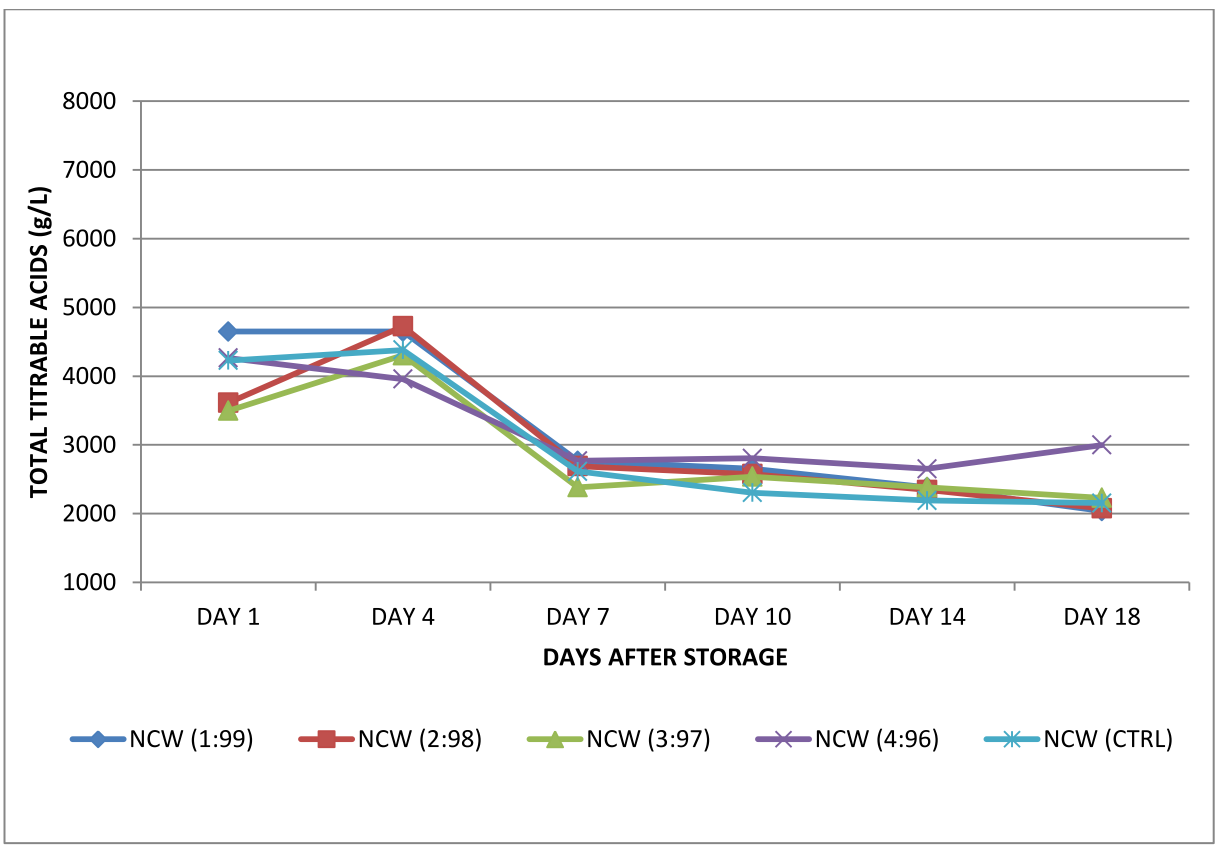


Figure 12: Changes in TTA following Neem oil/Coconut oil waxing and days after storage

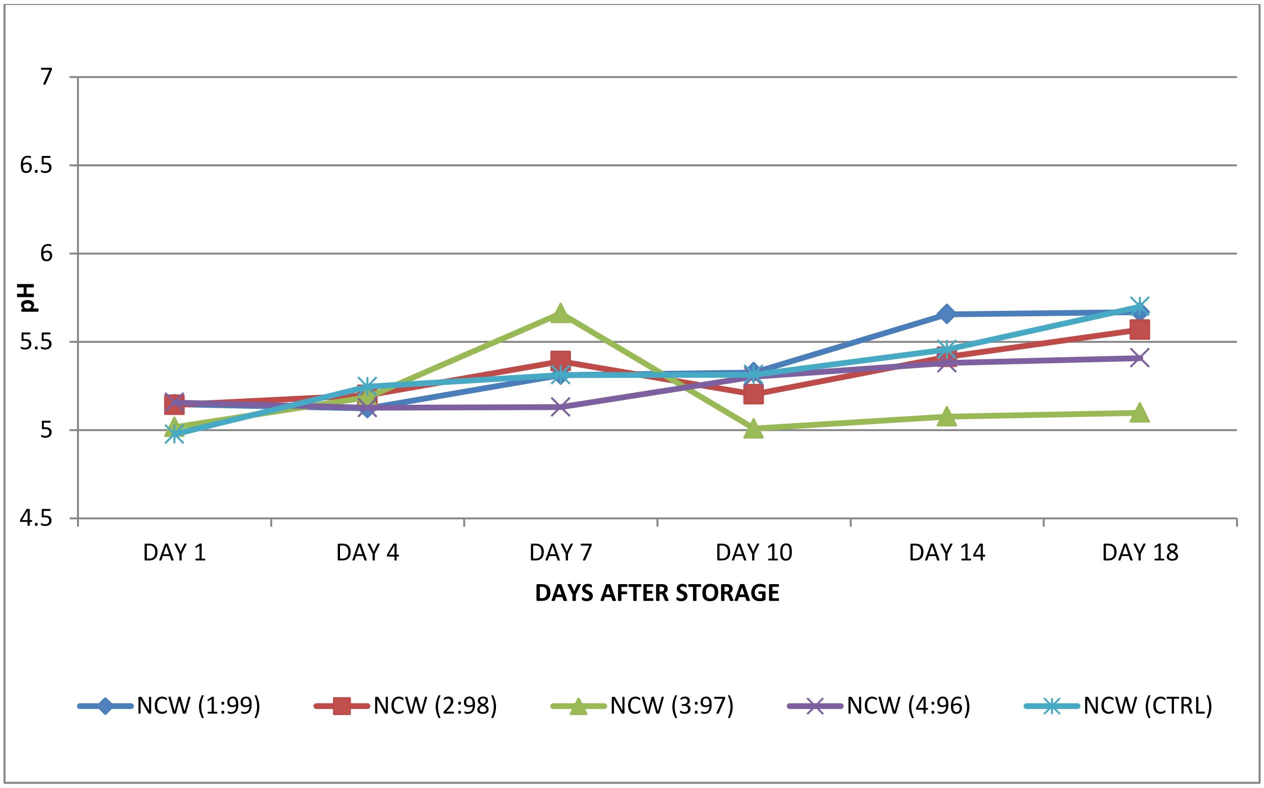


Figure 13: Changes in pH following Neem oil/Coconut oil waxing and days after storage

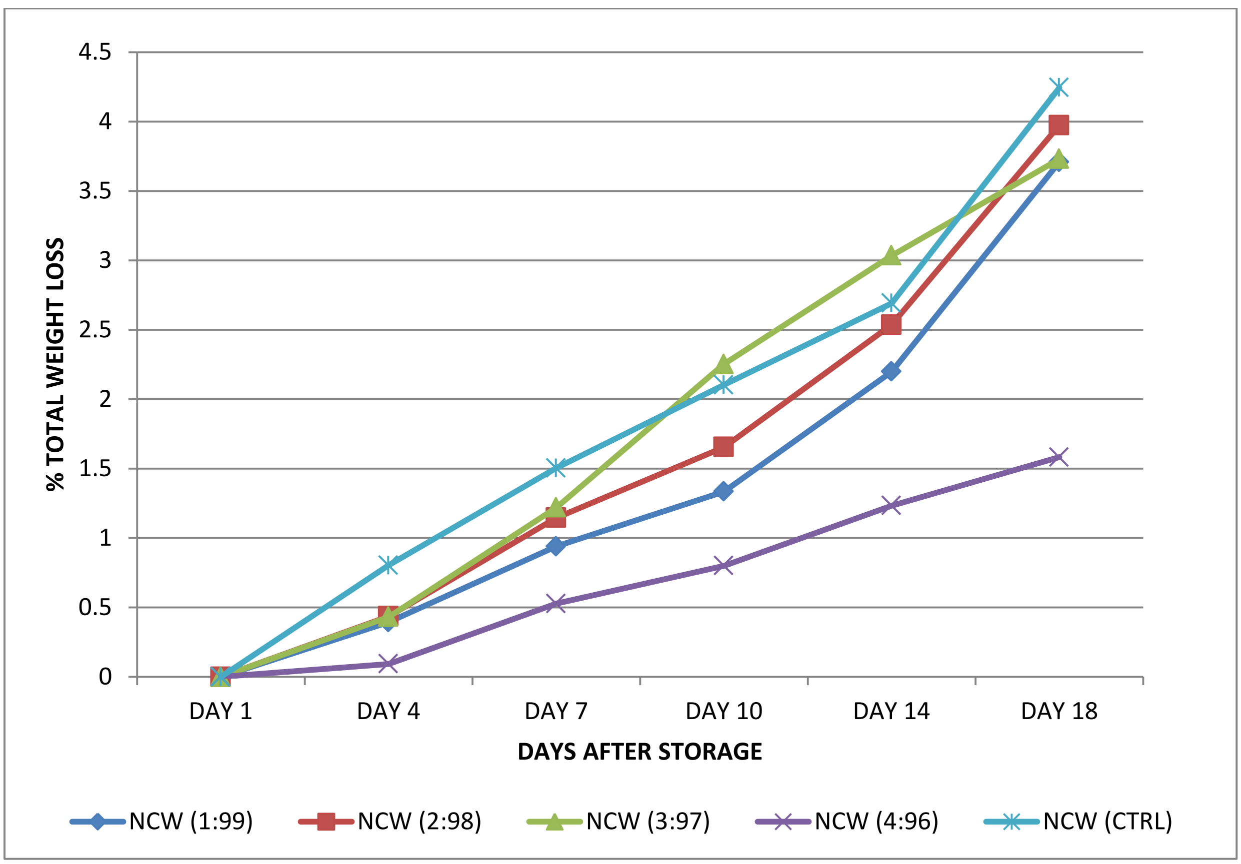


Figure 14: Changes in % TWL following Neem oil/Coconut oil waxing and days of storage

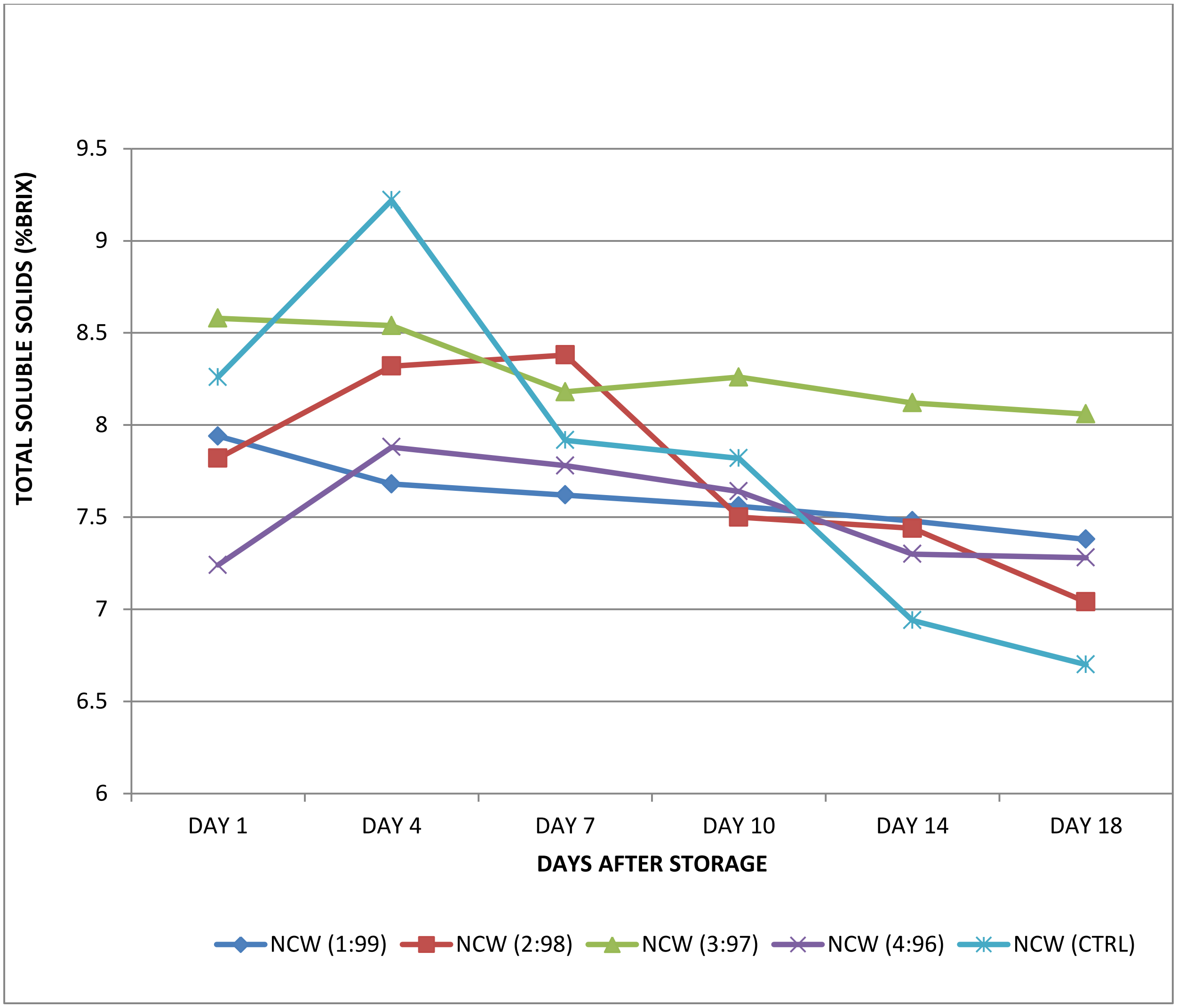


Figure 15: Changes in TSS following Neem oil/Coconut oil waxing and days of storage