STANDARDISATION OF WAX COATING IN CASSAVA (*Manihot esculenta* Crantz) TUBERS AND QUALITY EVALUATION

By

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THESIS

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DECLARATION

I, hereby declare that thesis entitled "Standardisation of wax coating in cassava (*Manihot esculenta* Crantz) tubers and quality evaluation" is a bonafide record of research work done by me during the course of research and that this thesis has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title of any other University or Society.

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Introduction

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is an annual tropical plant which can grow up to 3 metres. It forms large edible tubers with white flesh and brown fibrous skin. Cassava thrives in humid conditions and can tolerate extreme heat and drought. It is generally grown as a rainfed crop. Though it can grow in sub optimal soil nutrient conditions, it very well responds to good nutrient and water management resulting in higher yield. The starchy roots are the staple food for a large population in developing countries.

Cassava roots are rich in carbohydrates but deficient in protein, fat, minerals and vitamins. Typical mature roots have an average composition of 60 to 70 per cent water, 30 to 35 per cent carbohydrate, one to two per cent each fat, fibre and protein. About 64 to 72 per cent of the carbohydrate is starch mainly in the form of amylose and amylopectin. Sweet cassava cultivars contain about 14 per cent sucrose and small amounts of fructose and dextrose (Breuninger *et al.*, 2009). The tubers are toxic if eaten raw due to its cyanide content which varies among different varieties.

Fresh cassava tubers are highly perishable under ambient conditions and often becoming unmarketable after a few days to a week. This presents serious problems in the marketing and utilisation of the crop and often results in heavy losses. Mechanical damage has recently been emphasized as a major factor in post harvest loss of tubers leading to the most common post harvest physiological disorder in cassava called vascular discolouration or streaking. The rate of post harvest physiological deterioration is affected by environmental factors such as temperature, humidity and oxygen (Zidenga *et al.*, 2012).

Fresh roots can be stored up to 30 days with proper handling, permitting export by marine containers. The roots should be firm, turgid, fairly straight, and free from mechanical injury, decay and vascular streaking. The flesh of most common cultivars varies from white to light yellow. Extended storage can have two adverse effects on quality; starches are converted to sugars and roots become fibrous, lengthening cooking time (Booth *et al.*, 1976).

Cassava tubers can be preserved for a few days using traditional techniques such as reburial, placing under water and coating in mud or keeping in moistened saw dust.Sound tubers can be stored for four to five months at 2°C.Refrigerated storage may not be an economically viable method for extending the post harvest life of domestically marketed cassava, but is typically necessary for tubers intended for high value export markets.(Crentsil *et al.*, 1995).

Waxes are the esters formed from fatty acid and high molecular weightalcohol. At present, waxes have been used as an effective technology to increase the postharvest quality of fruits andvegetables (Tietel*et al.*, 2010). Studies have also indicated that waxing is an ideal method to extend shelf life of roots and tubers. It is helpful in controlling oxidation and respiration reactions and adds to texture and sensorycharacteristics and is environment friendly.

Various types of skin coating materials such as beewax, paraffin wax, carnauba wax and shellac have been used to restrict moisture loss from the surface of easily perishable crops through evaporation, transpiration and respiration (Ahmed *et al.*, 1997). It is an alternate method to extend the shelf life of cassava tubers which can reduce root moisture loss and extends market life for several days.Application of wax coating has immense scope from the export point of view and such studies have not yet been conducted in local varieties of Kerala. Hence, the present study is an attempt to explore the feasibility and the effect of wax application on the quality attributes of selected varieties of cassava tubers using different waxes such as paraffin wax, beewax and semperfresh with following objectives:

a) To standardise the percentage of wax coating to be applied on cassava tubers.

b) To evaluate various physico-chemical and nutritional attributes of wax coated cassava tubers.

Review of literature

2. REVIEW OF LITERATURE

The literature related to the study entitled "Standardisation of wax coating in cassava (*Manihot esculenta* Crantz) tubers and quality evaluation" is presented under the following heads.

2.1 Cassava and its importance

2.2 Changes in cassava during storage

2.3 Waxing and its role in storage of perishable foods

2.4 Chemical and nutritional qualities of cassava and waxed cassava

2.1 Cassava and its importance

Cassava (*Manihot esculenta* Crantz) is considered as an important source of food and dietary calories for a large population in tropical countries like Asia, Africa and Latin America. Though it has its origin in South America, cassava has become an indigenous crop in the tropics where it is widely grown and used (Enidiok *et al.*, 2008). According to Gleadow *et al.* (2009) and Burns *et al.* (2011), cassava is the most important source of dietary carbohydrates for 750 million people around the world.

Coursey (1973)has described cassava as a subsistence crop and its centre of origin as Tropical America. Rogers and Appan (1973) stated that the genus Manihot comprises 98 species spread throughout the Neotropics, seventeen of which are native to North America and the others to South America. Cassava otherwise known as tapioca is the fifth important staple food in the world (Philips, 1974). Toma and Tahekhia (1979) have reported cassava as the staple food of Nigerians. Chavarriaga *et al.* (1998) indicated that cassava ranks fourth among the major sources of carbohydrates in the tropics, where it is an important food for over 500 million people.

According to Soccol (1996), cassava is considered to have originated in Venezuela during 2700 B.C. It is known as tapioca in Asian countries, as aipin, castelinha and macaxeria in Africa. Kenneth and Barbara (1999) indicated that evolutionary and geographical origin of cassava is remaining unresolved and controversial. Cassava is a dicotyledonous annual woody shrub with an edible starchy root, belonging to the family Euphorbiaceae and it has many names, including cassava, bitter cassava, manioc, mandioca. The advantage of tapioca over other crops is related to its outstanding ecological adaptation, low labour requirement, ease of cultivation and high yields (Laurence *et al.*, 2012).

According to Charles *et al.* (2005), cassava is emerging as a dominant staple food of primary or secondary importance in many developing countries of the humid and sub-humid tropics. Enidiok *et al.* (2008) also suggested that cassava (*Manihot esculenta* Crantz) is one of the most important root crops in sub-saharan Africa and plays a vital role in the diet as a source of low cost carbohydrate especially for the grass root people.

Cassava has been changing its role from a traditional fresh human food to an efficient crop for animal feed and starch production (Kawano, 2000). According to Kolawole *et al.* (2010), cassava is a very important food crop that is capable of providing food security. Most of the cassava produced comes from peasant farmers who depend on manual tools for their field operations and these farmers have made Nigeria as the world's largest producer of this crop.

Cassava is a drought-tolerant, staple food crop grown in tropical and subtropical areas where many people are afflicted with undernutrition, making it a potentially valuable food source for developing countries (Montagnac *et al.*, 2009). Cassava is an annual, woody shrub that grows from about 1 m to about 3 m tall topped by palmate, dark green or purplish leaves (Salcedo and Siritunga, 2011).

The major cassava producers in Asia are Indonesia, China, India, Philippines, Thailand, and Vietnam. In India, Kerala and Tamil Nadu are the main cassava producers, with some additional production in the northeastern part of the country (Onwueme, 2002).

Cassava is one of the most important staple food with about 93 per cent of the production used for human consumption (Nweke *et al.*, 2002). The roots of cassava is an important carbohydrate source which are eaten both fresh as well as processed products (Westby, 2002).

Cassava has played vital roles in the diets of many African countries as a major source of low cost carbohydrate (Hair, 1990). The production of cassava for human consumption has been estimated to be 65 per cent while 25 per cent is for industrial purposesmostly as starch (6 per cent) and animal feed (19 per cent) and about 10 per cent is lost as waste (Maziya, 2007).

Cassava is becoming an important raw material in starch, brewing, pharmaceuticals, animal feed, textile and paper industries (El-Sharkawy, 2004). As a food crop, cassava storage roots can be eaten either raw, after boiling, or processing. In Africa, the most common on-farm processing involves sun drying followed by pounding or milling to flour (Were *et al.*, 2004). The processed cassava flour is used to develop a wide range of recipes like porridge, for local brewing and in combination with wheat flour and it is used to make baked products and feeding of livestock (Ceballos *et al.*, 2004).

The pattern of utilisation of cassava vary considerably in different parts of the world. In Africa the majority of cassava produced (88 per cent) is used as human food and over 50 per cent used in the form of processed products. In America, animal feed is far more important and human food represents only 42 per cent of production (Westby, 2002).

Processing of cassava is mainly done to improve its palatability and convert it into a storable form. Cassava based food products include cassava flakes, flour, macaroni, *fufu, gaplek, gari* and rice. Industrial food products from cassava include starch, alcohol, glucose, acetone, dextrins and single-cell protein (Aryee *et al.*, 2006; Chijindu and Boateng, 2008). All these foods have different pasting characteristics which are the characteristic of the cassava cultivars used and the processing methods involved (Taiwo *et al.*, 2010).

In India, 60 to 70 per cent of the total cassava production is used commercially to produce starch, sago, starch, dried chips, flour etc. Human consumption of cassava is common in Kerala and in Northeastern states like Assam and Meghalaya. It is used as raw or cooked tubers and as sago in Gujarat, Maharashtra and West Bengal states. Cassava is consumed as cooked or baked tubers in culinary preparations and in making pappads.Cassava fried chips is another form of utilisation observed in Tamil Nadu and Kerala at cottage industries level. Starch is used in textile industries as sizing agent, in pharmaceutical industries, making adhesives, dextrin manufacturing, paper industry, laundry and in many fast food preparations. Flour is made from driedcassava chips and this finds applications in gum industry, in making *Kumkum* (Vermillion) and in making colours applied to faces, during celebrations and festivals. *Thippi* (starch and sago industries fibrous waste) and Peel (waste from chip industries) are used as an ingredient in poultry and cattle feed preparations (Edison *et al.*, 2006).

Products such as cassava peels and sieviate (chaff that results from processing the root into "fufu") which constitute 25 per cent of the whole plant are used as poultry feeds. However, they are high in fibre (cellulose and hemicelluloses) which limits their utilisation due to the high water holding capacity (Aderemi and Nworgu, 2007). In Ghana, most cassava is consumed fresh as *fufu* although there are many small scale and a few medium to large-scale enterprises that process cassava into diversified food products and starch for industrial use (Baafi and Safo-Kantaka, 2007).

In Nigeria, *gari* (creamy-white partially gelatinised roasted free flowing granular flour) is the mostly consumed and traded food products from cassava. The wide consumption of *gari* is attributed to its relatively longer shelf life and ease of preparation as compared to other food products (Karim and Fasasi, 2009).

2.1.1 World production and trade

African continent is having a great share both in terms of area of cultivation as well as production, with 66.21 per cent of area under cultivation and shares 53.37 per cent of world production (Edison *et al.*, 2006). According to FAO (2013), the estimated total world cassava production in 2012 was 256 million tones, an increase of about 40 per cent since 2000.

Though cassava is grown in about 101 countries, India ranks first in the world for productivity of cassava with 27.92 t/ha as against the world average of 10.76 t/ha. However, India ranks fourth in Asia and 14^{th} in the world for area and third in Asia and 7^{th} in the world for the production of cassava roots (Edison *et al.*, 2006). Although cassava is cultivated in India in 13 states, major production is from the southern states of Kerala, Tamil Nadu and Andhra Pradesh.According to Kolawole *et al.* (2010), the world production of cassava root was estimated to be 184 million metric tonnes in 2002. The rapid adoption of Tropical Manioc Selection (TMS) for improved cassava varieties and the presence of the International Institute of Tropical Agriculture (IITA) in Ibadan has assisted in making Nigeria as a leader in cassava production. However, based on the statistics of the FAO, Thailand is the largest exporting country of dried Cassava, providing 77 per cent of world export in 2005.

Tumuhimbise *et al.* (2012) indicated that its production worldwide has increased from 1.8×10^8 t in 2000 to 2.3×10^8 t in 2010 and is expected to increase further due to its increasing demand as food as well as a valueable raw material for industrial products, particularly in Africa.

2.1.2.Varieties in cassava

Globally cassava is grown in an area of 18.51 m ha. producing 202.65 mt with a productivity of 10.95 t/ha. (FAO, 2013). It is reported to be grown in 102 countries of the world.

There are more than 10,000 varieties of cassava with each having its own distinctive plant form, genetic structure, and adaptability to different environment (Rogers and Appan, 1973).Several varieties of cassava have been identified in farming systems (Fregene *et al.*, 2003; Manu *et al.*, 2005), but they are often grouped into bitter and sweet varieties.

The different varieties of cassava are mentioned below (Edison *et al.*, 2006 and KAU, 2011):

H-97is a hybrid between a local variety 'Manjavella' and a Brazilian seedling selection. The plants are medium tall, branched with light brown emerging leaves. The tubers are conical shaped and stout, yielding 25-35 t/ha. The tuber flesh is white with 27-29 per cent starch content and matures in 10 months.

H-165is a hybrid between two indigenous cultivars viz.,'Chadayamangalam Vella and a clone similar to Kalikalan. The plants are predominantly unbranched with the mature leaves showing a drooping nature. The tubers are relatively short and conical, yielding 33-38 t/ha. The variety is comparatively early maturing in 8-9 months.

H-226is a hybrid between a local cultivar 'Etthhakka Karuppan" and the Malayan introduction M4. Plants are tall, occasionally branching and leaves with a characteristic green colour. The tuber yield is 30-35 t/ha and the crop duration is ten months. Both H-165 and H-226 are the predominant varieties cultivated in TamilNadu and Andhra Pradesh for their industrial potential.

Sree Visakham(H 1687)is a hybrid between an indigenous accession and a Madagascar variety S-2312. The female parent is unbranched with light yellow tuber flesh, while the male parent is a heavy yielder with good culinary qualities. Sree Visakham is predominantly a non-branching type and tall having compact tubers with yellow flesh due to high carotene content (466 IU/100 g). Tuber skin is brown and rind is cream in colour. The crop duration is ten months and the tuber yield is 35-38 t/ha with 25-27 per cent starch.

Sree Sahya (H 2304)is a hybrid involving five parents of which two are exotic and three indigenous.Plants are tall, generally non-branching with dark brown and a predominant spiny, stipular mark. The tubers are long necked with light brown skin, cream coloured rind and white flesh. Tuber yield is 35-40 t/ha.

Both Sree Visakham and Sree Sahya are improved varieties for table purpose having better palatability than the former three hybrids and are popular in southern Thiruvananthapuram and western Kanyakumari districts.

Sree Rekha (TCH 1): Top cross hybrid of cassava viz.TCH 1 was released for general cultivation in Kerala under the name 'Sree Rekha'. The average yield and starch content are 48.0 t/ha and 28 per cent respectively.Tubers cook well and give good yields both under upland and lowland conditions.

Sree Prabha (TCH 2): Top cross hybrid of cassava viz.TCH 2 was released for general cultivation in Kerala under the name 'Sree Prabha'. The average yield and starch content are 42.0 t/ha and 26 per cent respectively.Tubers cook well and give good yields both under upland and lowland conditions.

Sree Harsha: This is a triploid clone developed by crossing a diploid with an induced tetraploid clone of 'Sree Sahya'; plants are stout, erect and non-branching with tubers of good cooking quality and high starch content (38-41 per cent); yield 35-40 t/ha in 7-8 months.

Sree Prakashis a relatively short statured plant, generally non-branching with high leaf retention. The tubers are medium sized, necked and the tuber yield is 35-40 t/ha. The duration is 7-8 months. Tubers possess good culinary quality and give a starch content of 29-31 per cent.

Sree Jayais a medium tall variety and produces conical tubers and have white flesh. Its duration is 6 months and tuber yield is 26-30 t/ha. The cooking quality of the tuber is very good and on par with the popular local variety M4.

Sree Vijayais also medium tall and has conical tubers but yellow flesh. The tuber yield is 25-28 t/ha and duration is 6 months. It has average cooking quality

M-4: This is a non-branching variety with excellent cooking quality; susceptible to mites; yield 18-23 t/ha in 10 months

Nidhi: Yield (25.1 t/ha), tolerant to mosaic, short duration (5-6 months) grayish white stem, petiole white with red shade, skin light pink.

Kalpaka (KMC-1: Yield (28.4 t/ha), short duration (6 months), non branching stem, pink tuber rind.

Vellayani Hraswa: High yield (44.01 t/ha), short duration (5-6 months), pink tuber rind, excellent cooking quality.

Tamil Nadu Agricultural University also developed three varieties viz., CO-1, CO-2 and CO-3 (Edison, 2006).

CO-1:A clonal selection with tubers having whitish brown skin, creamy rind and 35 per cent starch,yield 30 t/ha in 8 to 9 months.

CO-2: A branching variety with tubers having brown skin, creamy white rind and 34.6 per cent starch, yield 35 t/ha in 8 to 9 months, suitable for consumption and industry.

CO-3 :A branching variety having tubers with brown skin and 35.6 per cent starch, yield 42.6 t/ha in 8 months.

2.2. Changes in cassava during storage

The short storage life of cassava roots is directly linked to an endogenous physiological process known as physiological post harvest deterioration (PPD), which is considered to be a complex procedure linked to enzymatic stress response to wounding (Beeching *et al.*, 2002).

A major limitation of cassava is the rapid post-harvest physiological deterioration which often begins within 24 hours of harvest followed by microbial deterioration within 5 to 7 days (Asaoka *et al.*, 1993and O'Brein *et al.*, 1995). Eka (1999) also reported that tubers deteriorate in air at ambient temperature within three to four days.

Booth *et al.* (1976) opinioned that fresh cassava roots are highly perishable under ambient conditions, becoming unmarketable within three days. He also pointed out that the principal causes for loss are vascular streaking and decay. Vascular streaking appears as blue or purple spots when the root is cut transeversly and is a result of an oxidative process in the vascular bundles. It typically develops at wound sites, such as the apical end where the root is cut at harvest or under breaks in the peel that can occur during careless handling. Development of vascular streaking is related to the oxidation of scopoletin, a phenolic compound (Wheatley and Schwabe, 1985).

Wenham (1995) reported that the major visual symptom of post harvest physiological deterioration of cassava is vascular streaking, resulting from occlusions in the vascular parenchyma by oxidized phenolics. According to Zidenga *et al.* (2012) , the rate of post harvest physiological deterioration is affected by environmental factors such as temperature, humidity and oxygen.

The PPD of Cassava root often begins rapidly at the wounded proximal terminal of the root which is a complex abiotic process that is still not fully understood (Aristizabal and Sanchez, 2007). The initial symptoms are blue or black vascular streaking, brownish occlusions and chemical deposits from wound sites along the root xylem strands, followed by discolouration of the storage parenchyma and accompanied by an unpleasant flavour and odour (Reilly *et al.*, 2007). According to Salcedo and Siritunga (2011), Physiological postharvest deterioration of cassava roots is an endogenous and complex process that restricts their storage potential to only a few days after harvest. This physiological phenomenon is one of the main constraints in cassava agriculture which has an enormous impact on the cassava market chain.

The initial visual symptoms of PPD are accompanied by a rapid accumulation of fluorescent compounds visible under UV light in the root parenchyma. These compounds have been identified as hydroxycoumarins such as scopolin, scopoletin and esculin. Scopoletin, which has been identified as the most fluorescent compound, is absent or has very low occurrence in fresh roots (Buschmann *et al.*, 2000).

Booth (1975) classified deterioration as primary deterioration and secondary deterioration. Primary deterioration is usually the initial cause of loss of acceptability of roots and is shown by fine blue-black streaks in the root vascular tissue, which later spread causing a brown discolouration. Secondary deterioration is due to pathogenic rots, fermentation and softening of the roots and generally occurs when the roots have already become unacceptable because of primary deterioration.

Ingram *et al.* (1972) reported that injuries can be avoided by harvesting the whole plant or by leaving a short piece of stalk on the root. According to Booth *et al.* (1976) during extended storage of cassava roots starches are converted to sugars making the roots fibrous thereby lengthening the cooking time. To maximize the storage life of cassava roots, they should not be injured or squashed during harvesting, transport and storage as injuries accelerate the physiological deterioration of the tissue. This deterioration is an active process distinct from the secondary deterioration caused by microbial infection.

Chavez *et al.* (2000) indicated that higher vitamin content was associated with decreased post-harvest physiological deterioration. PPD is initiated by mechanical damage, which typically occurs during harvesting and progresses from the proximal site of damage to the distal end, making the roots unpalatable within 72 hours (Wenham, 1995; Buschmann *et al.*, 2000; Iyer *et al.*, 2010).According to Jia *et al.*, (2013) the early accumulation of H_2O_2 as well as superoxide anion radicals in mitochondria of cassava roots leads to postharvest deterioration.

According to Apel and Hirt (2004) reactive oxygen species (ROS) production is one of the major cause for deterioration in plants. In plants, ROS are continuously produced as byproducts of aerobic respiration. In cassava roots, an oxidative burst occurs within 15 min of harvest (Reilly *et al.*, 2004).

Wenham (1995) reported that a decline in phospholipid content during PPD,is an indication of membrane degradation which is a known symptom of oxidative damage. Cassava cultivars that have high levels of β-carotene (which quenches ROS) are less susceptible to PPD (Sanchez *et al.*, 2005).

Zidenga *et al.*, (2012) reported that PPD is cyanide dependent, presumably resulting from a cyanide-dependent inhibition of respiration.

Reilly *et al.*, (2004) stated that PPD response is an enzymatically mediated oxidative process in which ROS appear to play a dual role as both a signaling molecule that induces programmed cell death as part of a more general wound response and in oxidizing phenolic compounds to produce the visible symptoms of PPD, with wound repair and antioxidant defenses being too late or inadequate to contain these effects.An increased activity of enzymes that modulate ROS levels, such as catalase, peroxidase and superoxide dismutase (Buschmann *et al.*, 2000, Reilly *et al.*, 2001 and Iyer *et al.,* 2010).

The PPD has become a major constraint (Janssen and Wheatley, 1985; Wenham,1995; Vlarr *et al.*, 2001) in processing cassava on a larger or industrial scale which demands the roots to be transported long distances to reach the industry and consumers (Balagopalan, 2002; Westby, 2002).

Buschmann *et al.*, (2000) and Aristizabal and Sanchez (2007) revealed a considerable variation in degree of development and severity of PPD among different cassava varieties and within the same variety .

2.3 Waxing and its role in storage of perishable foods

Films and coatings have received much attention in recent years because they extend shelf life and improve food quality by providing a barrier to mass transfer, carrying food ingredients and improving mechanical integrity or handling characteristics of a food (Krochta, 1997). Waxing is one of the coating technologies suitable for preservation of fruits and vegetables. By this method we can increase the shelf life of agro-produce by more than two weeks. This gives breathing time for marketing (Anonymous, 2004). Some of the benefits of waxing include improved appearance, less moisture loss, less economic loss, reduced postharvest decay, longer postharvest life and less susceptibility to chilling injury.

Some modern methods such as refrigeration, deep freezing, waxing, controlled atmosphere and chemical treatments have been suggested for the storage of fresh cassava. However freezing and waxing have been used primarily for export markets (Crentsil *et al.*, 1995). Sargent *et al.* (1995) studied the effect of post harvest coating in cassava tubers on vascular streaking and indicated that waxing and holding at 0 to 5°C extended shipping time to more than 30 days with minimal occurrence of vascular streaking. The authors also indicated that a water based carnauba wax maintained post harvest quality of cassava equivalent to paraffin wax.

According to Beyrer and Nindjin (2014), paraffin wax, classified as a chemical preservative which helps in prolonging the shelf life of cassava tubers. Dipping the roots in melted paraffin wax at 51.5°C to 52.5°C (125°F to 127°F) for one second adds a smooth thick surface coating to the root. This coating helps to reduce root moisture loss and extends market life up to two months (Anonymous, 2004). Cassava roots can be preserved by coating them in food grade wax which may or may not be supported with a fungicide (ARSO, 2012).

The effectiveness of an indigenous wax emulsion for the storage of mandarin orange and sweet potato was reported by Afolabi *et al.* (2003) and Afolabi and Oloyede (2006) respectively.

Zauberman *et al.* (1981) indicated a decrease in respiration and ethylene production in wax coated avocado fruit. Ladaniya (2001) indicated a reduction in the respiration rate in wax coated mosambi fruits. Silva *et al.* (2009) evaluated the shelf life of yellow passion fruit coated with four different substances like carnauba wax, rubber tree latex, solution of calcium chloride and cassava starch and indicated no change in the chemical constituents due to different coating materials. Supriya (2012) conducted a study on modified atmosphere packed waxed passion fruits indicated a maximum shelf life of thirty days at 7°C when they were coated with commercial wax emulsions.

Mollenhauer (1954) reported that passion fruit dipped in hot paraffin wax was in good condition after 2 to 3 months of storage, although the flavour had deteriorated. Dipping in hot paraffin wax apparently sterilised the skin preventing mold attacks and shriveling. He also suggested that it caused quick evaporation of volatiles from the fruit through the layer of wax, leading to poor flavour. Pruthi and Lal (1955) recommended that waxed fruit should be stored for only 4 to 5 weeks at 6.5°C. Huelin (1962) reported that dipping fruits in molten wax extended storage life of fruiits from 3 to 6 weeks.

According to Petracek *et al.*.(1998) internal O_2 concentrations in grape fruit should always be higher than 12 per cent. He reported that the use of carnauba or polythene waxes often results in less shine, but allows greater O_2 and CO_2 gas exchange than shellac wax. Candelilla wax has low shine, low melting point and low water vapour permeability. This wax is usually mixed with other waxes to maximize its coating effect on citrus fruit quality (Dou *et al.*, 1999).

Uthaibutra *et al.* (2014) reported that Long longan fruit coated with carnauba mixed wax for 30 seconds provides an alternative to maintain post harvest quality by lowering respiration rate and reducing weight loss without any severe pericarp browning or fruit decay during the first twenty days of storage.

The application of waxing on kinnow fruit surface decreased the weight loss in fruits to 1.5 per cent while in uncoated fruit the weight loss is about 33.23 per cent weight (Alam and Paul, 2001; Thakur *et al.*, 2002). Sharp increase in physiological loss in weight of fruit occurs at room temperature, while it is siginificantly lesser when fruit is waxed and stored in cold chamber (Shellhammer and Krochta, 1997). According to Thirupathi *et al.* (2006), wax coating prevents the evaporation of water from the commodity and increases its shelf life.

Ezeocha and Oti (2013) reported that *Dioscorea dumetorum* treated with bee wax, palm wax and paraffin wax retained the nutrients more than the unwaxed tubers. Palm wax performed better than the other waxing materials in terms of weight, nutrient and functional properties after storage.

2.4 Chemical and nutritional qualities of cassava and waxed cassava

Padmaja (1980) reported that cassava is used as a primary or secondary staple food by about one fifth of the world population of the low income group of the tropical countries. Ghosh (1984) reported cassava as poor man's food crop used as a partial substitute for cereals.Poulose *et al.* (1984) stated that the increase in population and decrease in production of rice have made cassava an important food *item* in Kerala.

Cassava roots are rich in carbohydrates but deficient in protein, fat, some minerals and vitamins. Typical mature roots have an average composition of 60 to 70 per cent water, 30 to 35 per cent carbohydrate, 1 to 2 per cent fat, 1 to 2 per cent fibre and 1 to 2 per centprotein . About 64 to 72 per cent of the carbohydrate is starch mainly in the form of amylose and amylopectin. Sweet cassava cultivars contain about 14 per cent sucrose and small amounts of fructose and dextrose. The amino acid content is very low particularly lysine, methionine and tryptophan. Cassava peels contain slightly more protein than the flesh inner part (Breuninger *et al.*, 2009).

Padonou *et al.* (2005) and Zvinavashe *et al.* (2011) indicated that moisture content of fresh cassava was in the range of 60.3 to 87.1 per cent. According to Udoro *et al.* (2008) cassava tubers are bulky with about 70 per cent moisture content which makes transportation of the tubers to urban markets difficult and expensive.

Cassava leaves are rich in proteins (14 to 40 per cent on dry matter basis depending on the cultivar), minerals, vitamins B_1, B_2, C and carotenes. The leaves are low in methionine, lysine and isoleucine content (Fasuyi, 2005). According toNdung'u *et al.* (2010) continued consumption of cassava leaves can lead to protein malnutrition.

The protein content of cassava was reported to be as low as 1.6 to 2.6 per cent (Anon, 1975). Meera (1985) has reported that cassava is nutritionally very much inferior to other cereals due to its low protein content. According to Balagopalan (2002) the crude protein content of whole cassava roots is around 3.5 per cent of the dry weight and 40 to 60 percent of the total nitrogen is non protein.

The lipid content in cassava roots ranges from 0.1 to 0.3 per cent on fresh weight basis (Charles *et al.* 2005) and 0.65 per cent on a dry matter basis (Padonou *et al.* 2005).

The starch content of cassava tubers ranged from 78.1 to 90.1 per cent on dry matter basis (Anon, 1975). Hoover (2001) indicated that the major carbohydrate of tubers and root crops is starch, which accounts for 16 to 24 per cent of their total weight. According to Aro (2008), cassava is a very cheap source of carbohydrate and forms the main carbohydrate source in the diet of the teeming population of the third world countries where it is largely grown.

Raw cassava root has more percentage of carbohydrate than potatoes and less carbohydrate than wheat, rice, yellow corn, and sorghum. Theroot physiologically reserves energy with a high carbohydrate content ranging from 32 to 35 per cent on a fresh weight (FW) basis, and from 80 to 90 per cent on dry matter (DM) basis (Montagnac, 2009 and Zvinavashe *et al.*, 2011).

Jacob (1985) in the study on nutritive value of tuber crops observed that cassava starch contains 20 per cent amylose and 80 per cent amylopectin and had a digestability of 48 per cent in the raw state and 78 per cent when cooked.

Ketiku and Ovenuga (1972) reported that the major portion of sugars in cassava is sucrose and it is above 69 per cent of the total sugars. According to Teles *et al.* (1979) the reducing and non reducing sugars in cassava ranged from2.62 to 5.07 and 7.13 to 16.48 mg/g respectively on fresh matter basis.They indicated that cassava tubers harvested in wet season had one to ten per cent higher moisture than those harvested in dry season. They also reported that there is a subsequent decrease in starch and total sugar content by 1.4 to 6.6 per cent and 0.5 to 10 per cent respectively. According to Anbuselvi and Balamurugan (2013), the reducing sugar in cassava was 6.6mg/100g.

Compared to other root crops cassava contains provitamin A carotenoids compared with other root crops and yellow tubers contain much more beta carotene than white tubers. The white tubers contain 0.1 to 3 mg/kg of beta carotene on fresh weight basis (Adewusi and Bradbury, 2005).

Enidiok *et al.*, (2008) reported that cassava contains significant amount of iron, phosphorous, calcium and is relatively rich in vitamin C.

According to Rickard (1985), the major factor that limits the use of cassava as food is the toxicity of hydrogen cyanide (HCN) which occurs as result of the hydrolysis of cyanogenic giucosides. The cyanide present in cassava may be considered to be of two types: bound cyanide present as cyanogenic glucoside and free cyanide present as the cyanohydrins, the known free hydrogen cyanide (Braudbury and Holloway, 1988).

The sweet cultivars had much lower HCN content than the bitter cultivars. The reports have shown that the concentration and occurrence of HCN in the various parts of cassava plants is influenced by the age, cultivar and environmental conditions (Charles *et al.*, 2005). The content of HCN in cassava ranges from less than 10 to more than 500 mg/kg on fresh weight basis (Nebiyu and Getachew, 2011).

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled "Standardisation of wax coating in cassava (*Manihot esculenta Crantz*) tubers and quality evaluation" was aimed to standardise the percentage of wax coating to be applied on cassava tubers and to evaluate various physico-chemical and nutritional attributes of wax coated cassava tubers. The materials used and the methods followed in this study are given under the following headings.

3.1. Selection of varieties

3.2. Selection of waxes

- 3.2.1. Paraffin wax, description and preparation
- 3.2.2. Bee wax, description and preparation
- 3.2.3. Commercial wax, description and preparation

3.3. Application of wax coating

3.4. Standardisation of wax coating

3.5. Quality evaluation of wax coated cassava tubers

- 3.5.1. Shelf life qualities
- 3.5.2. Physical qualities
- 3.5.3. Chemical and nutritional qualities
- 3.5.4. Sensory qualities

3.6. Cost analysis of wax application

3.7. Statistical analysis

3.1. Selection of varieties

Three varieties namely M-4, Sreevijaya and Vellayani Hraswa were selected for the study. Tubers were harvested at fully mature stage from the farm of Department of Agronomy, College of Horticulture, Vellanikkara, Central Tuber Crops Research Institute (CTCRI), Trivandrum and local farmers of Vellanikkara. Special care was taken at the time of harvest to avoid mechanical damage. All the tapioca tubers were harvested with 1.5 to 2 cm of stems attached to it.

3.2. Selection of waxes

Three types of waxes like paraffin wax, semperfresh (commercial wax) and bee wax were used for the study. Paraffin wax and bee wax were used for application after preparing wax oil emulsion. For this vegetable oil (rice bran oil) was used. In the case of semperfresh, wax water emulsion was used.

3.2.1. Paraffin wax, description and preparation

Paraffin wax, a petroleum-based wax is obtained from the distillation of crude oil. It is solid at room temperature and must be heated to about 52°C (125°F) for melting. Due to this solidification property rice bran oil was used as a base to prepare the wax emulsion.

3.2.2. Bee wax, description and preparation

Bee wax is a natural wax of animal origin. The melting point of bee wax is about 62 to 64°C. Bee wax formulation was also prepared as oil emulsion.

3.2.3. Commercial wax, description and preparation

The commercial wax used in the present investigation was semperfresh collected from M/s. Agri Coat Industries, UK. This was a powder formulation of sucrose ester, sodium carboxy methyl cellulose and a mixture of mono and diglycerides of fatty acids, all of which are derived from plant sources.

Commercial wax coatings create an invisible, edible protective film around the tubers. In addition, commercial wax coatings function by modifying the rate of respiration of the produce.

The commercial wax emulsion was prepared in boiling water and the resulting dispersion was kept for sometime and used for application.

3.3. Application of wax coating

The application of waxes on cassava tubers was done by manual rubbing. For this, the harvested tubers were first cleaned using a brush having firm bristles and wiped with a clean cotton cloth. The wax emulsion was applied on cassava tubers using a fine brush. A single coating was given. After application the tubers were left for air drying before packing.

3.4. Standardisation of wax coating

A preliminary study was conducted to find out the ideal percentage of wax coating to be applied in each of the selected varieties. For this, the specified varieties were collected and the three types of waxes were prepared at different concentrations of 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 4 and 5 per cent. The application of wax on cassava tubers was done as described in 3.3. The wax coated cassava tubers were kept for storage in paper cartons sized 45cm x28cm x75cm and arranged as three layers and studied the Physiological Loss in Weight (PLW) at two days interval. Waxes at concentration above 1.5 per cent were found to be inhibiting the metabolic processes and moisture accumulation was noticed in the inner flesh and the tubers were deteriorated within a week. In case of concentration below one percent, early appearance of vascular streaking (within 2-3 days), was observed in tubers applied with three different waxes and in control. Thus wax formulation at 1 per cent level was found to be ideal for application in all the three selected varieties and it was selected for the study. The quantity of oil and wax used for the preparation of paraffin and bee wax and the quantity of water and wax used for semperfresh wax is presented in Table 1. The treatments used for wax application are given in Table 2.

Table 1. Wax and oil/water used for the preparation of wax emulsion

Type of waxes	Oil (ml)	Water (ml)	Wax (g)
Paraffin wax	100	_	1
Beewax	100	_	1
Semperfresh	_	100	1

Table 2. Details of treatments used for wax application

Treatments	
T_1	Control- M-4 without wax coating
T_2	M-4 + paraffin wax
T_3	M-4 + bee wax formulation
T_4	M-4 + semperfresh
T_5	Control- Sreevijaya without wax coating
T_6	Sreevijaya + paraffin wax
T_7	Sreevijaya + bee wax formulation
T_8	Sreevijaya + semperfresh
T_9	Control- Vellayani Hraswa without wax coating
T_{10}	Vellayani Hraswa + paraffin wax
T_{11}	Vellayani Hraswa + bee wax formulation
T_{12}	Vellayani Hraswa + semperfresh

3.5. Quality evaluation of wax coated cassava tubers

Wax coated cassava tubers were stored after packing in ventilated paper cartons under ambient conditions till it showed the signs of deterioration. The shelf life, physical, chemical, nutritional and organoleptic qualities were evaluated. All the analysis was carried out in triplicate samples.

3.5.1. Shelf life qualities

The shelf life qualities of unwaxed and waxed cassava tubers were observed by measuring its respiration rate and physiological loss in weight (PLW) at two days interval. The respiration rate of the tubers were measured by water immersion method followed by measuring the level of O_2 consumed and CO_2 liberated using a gas analyser available at the Department of Post Harvest Technology and Agricultural Processing of KCAET, Tavanur.

The physiological loss in weight of cassava tubers was recorded at 2 days interval till the deterioration of tubers occur. The PLW was calculated by the following formula and expressed as percentage.

PLW(%) = A-B/A x 100 where, A – Original fruit weight (g)

B – Final weight (g) in the day of observation

3.5.2. Physical qualities

The physical qualities of unwaxed (control) and wax coated cassava tubers like appearance, colour and extent of vascular streaking were evaluated at two days interval in raw samples by visual observation after cutting the tubers transversely.

3.5.3. Chemical and nutritional qualities

The chemical and nutritional qualities of waxed and unwaxed cassava tubers were evaluated initially and at 14^{th} day of storage.

3.5.3.1. Moisture

Moisture content of cassava tuber was estimated by the method of A.O.A.C (1980). To determine the moisture content, five gram of the sample was taken in a petridish and dried at 60 to 70°C in a hot air oven, cooled in a desiccator and weighed. The process of heating and cooling was repeated till constant weight was achieved. The moisture content of the sample was calculated from the loss in weight during drying.

3.5.3.2. Protein

Protein was estimated by the method of A.O.A.C (1980). Sample (0.2g) was digested with six ml conc.H_2SO_4 after adding 0.4 g of $CuSO_4$ and 3.5g K_2SO_4 in a digestion flask until the colour of sample was converted to green. After digestion, it was diluted with water and 25ml of 40 percent NaoH was pumped. The distillate was collected in two percent boric acid containing mixed indicators and then titrated with 0.2 N HCl to determine the nitrogen content. The nitrogen content thus estimated was multiplied with a factor 6.25 to get the protein content.

3.5.3.3. Fat

The fat content of the cassava tubers was estimated using the method of A.O.A.C (1955). Two grams of the sample was taken in a thimble and plugged with cotton. The material was extracted with petroleum ether for six hours without interruption by gentle heating in a soxhlet apparatus. Extraction flask was then cooled and ether was removed by heating and weight was taken. The fat content was expressed in g per 100 g of the sample.

3.5.3.4. Fibre

The crude fibre content was estimated by acid alkali digestion method as suggested by Chopra and Kanwar (1978). Two grams of dried and powdered sample was boiled with 200 ml of 1.25 per cent sulphuric acid for 30 minutes. It was filtered through a muslin cloth and washed with boiling water. The residue was again boiled with 200 ml of 1.25 per cent sodium hydroxide for 30 minutes. Repeated the filtration through a muslin cloth and the residue was washed with 1.25 ml per cent sulphuric acid, water and alcohol. The residue was then ignited in a muffle furnace at 600°C for 30 minutes, cooled in a desiccators and reweighed. The crude fibre content of the sample was calculated from the loss in weight on ignition and expressed in percentage..

3.5.3.5. Total carbohydrate

The total carbohydrate content was analysed colourimetrically using anthrone reagent (Sadasivam and Manickam, 1992). Cassava powder (0.1 g) was hydrolysed with five ml of 2.5 N HCl and then cooled to room temperature. Later the residue was neutralised with solid sodium carbonate until the effervescence ceases and the volume was made upto to 100 ml and centrifuged. Pipetted 0.1 ml of supernatant and made up to one ml, added four ml anthrone reagent, heated for eight minutes, cooled rapidly and the intensity of green to dark green colour was read at 630 nm.

A standard graph was prepared using serial dilutions of standard glucose. From the standard graph the amount of total carbohydrate present in the sample was estimated and expressed in percentage.

3.5.3.6. Starch

The starch content was estimated colorimetrically using the anthrone reagent as suggested by Sadhasivam Manickam (1992). The sample (0.5 g) was extracted repeatedly with 80 per cent ethanol to remove sugars completely. The residue was dried over a water bath and 5 ml water and 6.5 ml 52 per cent perchloric acid were added and extracted at 0°C for 20 minutes. The sample was centrifuged and reextracted with fresh perchloric acid. The supernatant was pooled and made up to 100 ml. Pipetted out 0.2 ml of the supernatant and made up to one ml with water and 4 ml of anthrone reagent, heated for 8 minutes, cooled rapidly and read the OD at 630 nm.

A standard graph was prepared using serial dilution of standard glucose solution. From the graph, glucose content of the sample was computed and multiplied by a factor 0.9 to arrive at the starch content and expressed in percentage.

3.5.3.7. Amylose

Amylose content was determined by the method suggested by Sadasivam and Manickam (1992).To 100 mg of cassava sample, one ml of distilled ethanol and 10 ml of 1N NaOH were added and kept overnight and the volume was made up to 100 ml. The extract (2.5ml) was taken and added 20 ml of distilled water and three drops of phenolphthalein and neutralised with 0.1N HCl was added drop by drop until the pink colour disappears. To this, one ml of iodine reagent was added and the volume was made up to 50 ml. The intensity of the colour developed was read at 590 nm. The amylose present in the sample was estimated from standard graph prepared using serial dilution of standard amylose solution and expressed in percentage.

3.5.3.8. Amylopectin

Amylopectin content was calculated as described by Sadasivam and Manickam (1992). The amount of amylopectin was obtained by subtracting the amylose content from the starch content of cassava tubers.

3.5.3.9. Reducing sugar

Reducing sugar in the cassava tubers was estimated by adopting the method given by Lane and Eyon.(Ranganna, 1986). To 25 ml of cassava extract, 100 ml distilled water was added and then clarified with neutral lead acetate. The excess lead was removed by adding potassium oxalate. The volume was then made up to 250 ml. An aliquot of this solution was titrated against a mixture of fehlings solution A and B using methylene blue indicator. The reducing sugar was expressed as percentage on fresh weight basis.

3.5.3.10. Total sugar

The total sugar was determined using the method given by Lane and Eyon (Ranganna, 1986). From the clarified solution used for the estimation of reducing sugar, 50 ml was taken and boiled gently after adding citric acid and water. It was then neutralised with sodium hydroxide and the volume was made up to 250 ml. An aliquot of this solution was titrated against fehlings solution A and B. The total sugar content was expressed as percentage.

3.5.3.11. β Carotene

β–carotene content of the tubers was estimated using A.A.C.C. method (1995). Eight gram flour was taken in 150 ml glass stoppered Erlenmeyer flask and 40 ml water saturated butanol (WSB) was added. The contents of the flasks were mixed vigorously for 1 minute and kept overnight (16-18 h) at room temperature under dark for complete extraction of β-carotene. Next day, the contents were shaken again and filtered completely through the Whatman No. 1 filter paper. The optical density of the clear filtrate was measured at 440 nm. Pure WSB was used as blank. The β-carotene content was calculated from calibration curve from known amount of β-carotene .Calibration curve is made from known amounts of pure β-carotene from 0.25 μg/ml to 1.5 μg/ml which are prepared after suitable dilutions of original stock with WSB in calibrated 10 ml volumetric flasks.

3.5.3.12. Calcium

The calcium content of the sample was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Perkin-Elmer 1982). One gram of sample was predigested with 10 ml of 9:4 mixture of nitric acid and perchloric acid and made up to 100 ml and used directly in atomic absorption spectrophotometer for the estimation of calcium and expressed in mg per 100 g of sample.

3.5.3.13. HCN

The cyanide content was determined by the acid hydrolysis method suggested by Bradbury *et al.* (1991). To 2 ml of cassava extract prepared by filtration with 0.1 M Phosphoric acid, 2 ml of 4 M sulphuric acid was added and was heated in a boiling water bath for 50 min and cooled. To this cold solution, 5 ml of 3.6 M NaOH was added, filtered and allowed to stand for 5-10 min. From this, 1 ml of the solution was taken and added to two test tubes containing 7 ml of 0.2 M phosphate buffer. To one aliquot 2 ml of water was added and used as a blank. To the second test tube 0.4 ml of chloramine-T solution was added and cooled in ice for about 5 minutes and 1.6 ml of the pyridine/barbituric acid solution was added and kept for 60-90 minutes for the development of purple colour. The absorbance of the purple solution was measured at 583 nm against the blank solution.

A standard graph was prepared using potassium cyanide solution. From this graph, cyanide content present in the sample was estimated and expressed in mg per 100 g of the sample.

3.5.4. Sensory qualities

Organoleptic evaluation of cooked cassava tubers was conducted using score cards by selecting a panel of ten judges initially and on 14^{th} day of storage.

3.5.4.1. Selection of judges

A series of organoleptic trials were carried out using simple triangle test at laboratory level to select a panel of ten judges between the age group of 18 to 35 years as suggested by Jellinek (1985).

3.5.4.2. Preparation of score card

Score card containing six quality attributes such as appearance, colour, flavour, texture, taste and overall acceptability was prepared for organoleptic evaluation of tubers. Each of the above mentioned qualities were assessed by a nine point hedonic scale.

3.6. Cost analysis of wax application

Cost analysis of the wax application was done to assess the extent of expenses incurred for the application of wax coating on cassava tubers. Cost of production was worked out based on the market price of different waxes.

3.7. Statistical analysis

The observations were tabulated and analysed statistically as completely randomised design (CRD). The scores of organoleptic evaluation were assessed by Kendall's coefficient of concordance. The data on quality evaluation of cassava tubers during storage was analysed statistically using one way ANOVA and paired sample 't' test.

Result

4. RESULT

The result pertaining to the study entitled "Standardisation of wax coating in cassava *(Manihot esculenta* Crantz) tubers and quality evaluation" are presented under following headings.

4.1. Quality parameters of wax coated cassava tubers

- 4.1.1. Shelf life qualities
- 4.1.2. Physical qualities
- 4.1.3. Chemical and nutritional qualities
- 4.1.4. Organoleptic qualities

4.2. Cost analysis of wax application

4.1. Quality parameters of wax coated cassava tubers

The tubers of cassava varieties namely, M-4, Sreevijaya and Vellayani Hraswa were coated with three types of waxes namely paraffin wax, bee wax and semperfresh. Cassava tubers after application of waxes were stored after packing in ventilated paper cartons under ambient condition till it showed the signs of deterioration. Unwaxed cassava tubers were taken as the control. Various quality parameters like shelf life qualities, physical qualities, chemical and nutritional qualities and organoleptic qualities were evaluated and the results are as follows.

4.1.1. Shelf life qualities

The shelf life qualities of unwaxed and wax coated cassava tubers were observed by measuring its respiration rate and physiological loss in weight at two days interval.

4.1.1.1. Respiration rate

The rate of respiration in cassava tubers was determined by measuring the level of O_2consumed and CO_2liberated and the data is presented in terms of O_2consumed by the tubers. The respiration rate of waxed and unwaxed (control) cassava tubers were recorded from the initial day of storage and continued at two days interval till it showed the signs of deterioration. The data was statistically interpreted using one way ANOVA. Treatment comparison was made within varieties to identify the best treatments. The data are presented in Table 3.

The initial respiration rate of unwaxed (control) tubers of M-4, Sreevijaya and Vellayani Hraswa was 132.73, 124.38 and 128.9 ml of O_2/kg/h respectively. Compared to control significant variation was noticed in the respiration rate of wax coated cassava tubers.

In variety M-4, initially, the tubers treated with paraffin and beewax showed a higher respiration rate of 290.46 and 285.21 ml of O_2/kg/h respectively than noticed in unwaxed tubers. In tubers coated with semperfresh the respiration rate was lower than the control.

In unwaxed M-4 variety (control), a gradual decrease in respiration rate was recorded on storage upto 9th day. A slight increase was noticed from 11th to 15thday of storage and later it got deteriorated.

There was a gradual decrease in the respiration rate of tubers of M-4 treated with paraffin wax from the 1st day to 9th day of storage. A slight increase in respiration rate was noticed on 11th day but a decline in respiration rate was noticed on 13th day and the samples showed signs of deterioration. In the case of tubers treated with bee wax formulation, there was an increase in the respiration rate on 2nd day followed by a gradual decrease upto 9th day. On 11th day of storage, there occurred a slight increase in this treatment and a sudden decrease was noticed on the 13th day of storage followed by 15th day and got deteriorated by 17th day.

Table 3.Respiration rate (ml of O_2/kg/h) of wax coated cassava tubers in comparison with control

Treatments	1 st day	3rd day	5th day	7th day	9th day	11th day	13th day	15th day	17th day	19th day
Variety: M-4										
T_1-without wax coating (control)	132.73^b	122.61^b	117.59^b	107.59^b	92.14^b	105.24^b	133.7^b	140.56^b	-	-
T_2-Paraffin wax	290.46^a	287.85^a	280.28^a	261.72^a	258.49^a	264.83^a	240.97^a	-	-	-
T_3-Bee wax	285.21^a	296.64^a	294.69^a	265.16^a	260.40^a	262.40^a	235.80^a	230.23^a	-	-
T_4-Semperfresh	117.91^b	3.96^b	3.96^b	3.46^b	4.76^b	3.39^c	20.65^c	22.39^c	-	-
Variety: Sreevijaya										
T_5-without wax coating (control)	124.38^b	129.54^b	119.99^b	118.61^b	106.8^b	104.2^b	103.67^b	101.12^b	100.03^b	-
T_6-Paraffin wax	130.68^d	120.21^d	120.15^d	120.60^d	146.95^d	-	-	-	-	-
T_7-Bee wax	163.28^a	149.61^a	137.08^a	138.61^a	142.54^a	-	-	-	-	-
T_8-Semperfresh	106.04^c	103.84^c	99.60^c	100.49^c	97.28^c	95.3^c	95.7^c	92.33^c	90.11^c	-
Variety: Vellayani Hraswa										
T_9-without wax coating (control)	128.9^b	124.43^b	125.37^b	122.8^b	137.45^a	116.27^b	133.79^b	132.03^b	115.80^b	-
T_{10}-Paraffin wax	120.6^b	114.98^b	116.20^b	118.16^b	110.12^b	111.41^b	112.02^b	114.15^b	112.63^b	-
T_{11}-Bee wax	167.55^a	164.82^a	168.66^a	164.39^a	168.69^a	160.55^a	164.41^a	163.90^a	161.42^a	-
T_{12}-Semperfresh	45.26^c	42.17^c	44.58^c	44.40^c	47.59^c	46.80^c	50.28^c	49.37^c	49.85^c	-

DMRT-Coloumn wise comparison
Values with same superscript do not differ significantly

The tubers of M-4 treated with semperfresh exhibited a sudden fall in respiration rate from the initial level. On 13th and 15th day a raise in the respiration rate was observed and got deteriorated after 15 days of storage.

In variety M-4, statistically the respiration rate of unwaxed and semperfresh coated tubers was similar upto 9th day of storage and significant variation in respiration rate was noticed from 11th to 15th day of storage. Among the tubers coated with paraffin and beewax, significant variation in respiration rate was not observed throughout the study. But they differed significantly from T_1 and T_4.

In variety Sreevijaya, lower respiration rate than control was noticed in semperfresh coated tubers (106.04 ml of O_2/kg/h). In control, a gradual increase in respiration rate was noticed on 3rd day of storage followed by a decline in respiration rate upto 9th day of storage.

There was a noticeable decrease in respiration rate of wax coated tubers of Sreevijaya from 1st to 5th day except in control. Later a raise in respiration rate was noticed in beewax and semperfresh coated tubers on 7th day. In semperfresh coated tubers a decline was noticed in respiration rate on 9th day whereas an increase was noticed in paraffin coated tubers. From 11th day onwards a gradual decrease in respiration rate was noticed in control and semperfresh coated tubers of Sreevijaya. But the paraffin and beewax coated tubers showed the signs of deterioration by 11th day.

Based on DMRT, significant variation in the respiration rate was noticed between the treatments of Sreevijaya variety throughout the storage period.

In Vellayani Hraswa, the tubers treated with beewax exhibited a higher respiration rate (167.55 ml of O_2/kg/h) than control whereas, the tubers treated with semperfresh and paraffin waxed showed a lower respiration rate than control in terms of O_2consumed.

Upto 3rd day of storage, all the four treatments of variety Vellayani Hraswa recorded a gradual decrease in respiration rate from the 1st day observation. But a slight increase in respiration rate was observed on 5th day in all the treated and untreated samples. Wide fluctuation in respiration rate was noticed in all the treatments upto 17th day of storage.

Significant variation in respiration rate was noticed between all the treatments of Vellayani Hraswa throughout the storage period.

4.1.1.2. Physiological loss in weight (PLW)

The PLW of cassava tubers occurs due to the reduction in moisture content. This leads to the formation of vascular streaking on the periphery of tubers and eventually increases the rate of shrinkage. The PLW increased consistently as a function of storage. The results regarding the effect of different wax coating on PLW (%) of different varieties of cassava tubers have presented in the Table 4.

From the table 4, it is clear that, in variety M-4, comparatively lower PLW was noticed in wax coated tubers than the control upto the 7th day of storage. On succeeding days the rate of PLW of wax coated tubers was found to be higher than the unwaxed ones. Maximum PLW was noticed in M-4 coated with paraffin wax (T_2– 6.08%) followed by bee wax (T_3-5.84%) and minimum in semperfresh coated tubers (T_4- 6.76%) on 15th day of storage. By 15th day of storage, the beewax coated tubers of M-4 showed signs of deterioration.

In variety Sreevijaya, on 3rd day of storage, PLW was noticed only in paraffin coated tubers (T_6– 4.29%). In semperfresh coated tubers PLW was noticed from 7th day onwards. Compared to unwaxed tubers (control) the rate of PLW was lower in Semperfresh coated tubers throughout the study. After 9 days, paraffin and beewax coated tubers deteriorated. The storage of unwaxed and semperfresh extended upto 17 days. On 17th day of storage the maximum PLW was noticed in unwaxed tubers (T_5- 7.79%) and minimum in semperfresh coated ones (T_8 – 1.44%).

Table 4. Physiological loss in weight (%) of wax coated cassava tubers in comparison with control

Treatments	1st day	3rd day	5th day	7th day	9th day	11th day	13th day	15th day	17th day	19th day
Variety: M-4										
T_1-without wax coating(Control)	0	2.23	3.21	3.93	3.93	4.44	5.18	5.94	-	-
T_2-Paraffin wax	0	0.63	1.52	2.68	4.03	5.01	6.08	-	-	-
T_3-Bee wax	0	1.39	2.69	3.50	4.16	5.15	5.84	6.84	-	-
T_4-Semperfresh	0	0.16	2.30	2.30	3.68	5.23	5.38	6.76	-	-
Variety: Sreevijaya										
T_5-without wax coating (Control)	0	0	1.06	3.47	4.01	4.75	5.29	6.95	7.79	-
T_6-Paraffin wax	0	4.29	6.87	8.46	11.84	-	-	-	-	-
T_7-Bee wax	0	0	1.43	3.13	3.16	-	-	-	-	-
T_8-Semperfresh	0	0	0	0.36	0.58	0.58	0.8	1.16	1.44	-
Variety: Vellayani Hraswa										
T_9-without wax coating (Control)	0	1.07	3.96	5.01	5.01	5.94	5.94	6.86	7.73	-
T_{10}-Paraffin wax	0	1.77	1.54	2.21	4.55	7.86	10.07	13.16	17.53	-
T_{11}-Bee wax	0	1.22	3.21	4.02	5.83	5.42	6.12	10.97	15.2	-
T_{12}-Semperfresh	0	1.30	3.07	3.54	7.87	9.65	9.65	10.58	11.34	-

In variety Vellayani Hraswa, compared to unwaxed tubers the PLW was more in waxed tubers on 3rd day itself. The PLW increased with advancement in days of storage in waxed as well as unwaxed tubers. Tubers coated with beewax formulation (T_{11}) showed higher rate of PLW and had maximum weight loss percentage (15.2%) on 15th day of storage. Among wax coated tubers minimum PLW on 17th day of storage was noticed in tubers coated with the commercial wax, semperfresh (T_{12}).

4.1.2. Physical qualities of wax coated cassava tubers

The internal appearance of the cassava tubers, its colour and the extent of vascular streaking in the peripheral tissues are the three most important parameters which determines the acceptability of tubers during storage. The details on internal colour and vascular streaking in tubers are presented in Table 5 and 6 respectively.

The three varieties of cassava tubers differed in their external appearance (plate 1). M-4 was a medium sized tuber encased in a hard rind and the outer skin was light brown in colour. The individual tubers were 25 cm in length and weighed 200 to 300 g. The tubers of Sreevijaya was long and tapered with a soft rind which is brown in colour. It was about 20 to 30 cm in length and individual tubers had a weight of 100 to 250 g. Vellayani Hraswa is a medium sized tuber with a hard brown rind. It had about 20 to 27 cm length and individual tubers weighed around 250 to 450 g. The internal appearance of the selected cassava tubers during storage is shown in plate 2 to 5.

The colour of edible portion of three varieties of cassava varied from white in vellayani Hraswa and M-4, to creamy white in Sreevijaya.

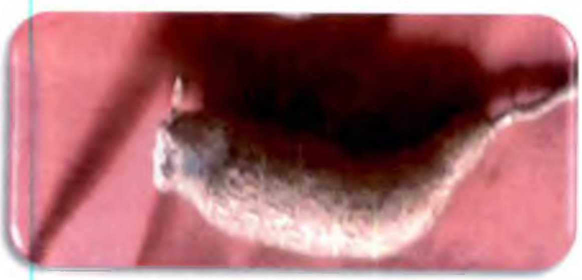
In M-4, upto 13 days, the flesh of tubers remained white except in paraffin coated tubers in which development of slight bluish colour was observed on 11th day and in other treatments development of bluish colour was noticed by 15th day of storage. Later the tubers became inedible.

Unwaxed tubers

Waxed cassava tubers

M-4

Sreevijaya



Vellayani

Hraswa

Plate 1. External appearance of unwaxed and waxed cassava tubers

Plate 2. Internal appearance of cassava tubers (Initial)

Plate 3. Internal appearance of cassava tubers during storage (M-4)

Plate 4. Internal appearance of cassava tubers during storage (Sreevijaya)

Plate 5. Internal appearance of cassava tubers during storage (Vellayani Hraswa)

Table 5. Internal colour of waxed and unwaxed tubers of three cassava varieties

Variety	Treatments	1st day	3rd day	5th day	7th day	9th day	11th day	13th day	15th day	17th day	19th day	21st day
M-4	T_1-without wax (control)	White	White	White	White	White	White	White	Slight bluish	D	D	D
	T_2-Paraffin wax	White	White	White	White	White	Slight bluish		D	D	D	D
	T_3-Beewax	White	White	White	White	White	White	White	Slight bluish	D	D	D
	T_4-Semperfresh	White	White	White	White	White	White	White	Slight bluish	D	D	D
Sreevijaya	T_5-without wax (control)	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Slight bluish	D
	T_6-Paraffin wax	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Slight bluish	D	D	D	D	D
	T_7-Beewax	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Slight bluish	D	D	D	D	D
	T_8-Semperfresh	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Creamy white	Slight bluish	D
Vellayani Hraswa	T_9-without wax (control)	White	White	White	White	White	White	White	White	White	Slight bluish	D
	T_{10}-Paraffin wax	White	White	White	White	White	White	White	White	White	Sluish bluish	D
	T_{11}-Beewax	White	White	White	White	White	White	White	White	White	Slight bluish	D
	T_{12}-Semperfresh	White	White	White	White	White	White	White	White	White	Slight bluish	D

Table 6. Vascular streaking in waxed and unwaxed cassava tubers of three varieties

Treatments	1st day	3rd day	5th day	7th day	9th day	11th day	13th day	15th day	17th day	19th day	21st day
Variety: M-4											
T_1-without wax coating	ND	ND	ND	ND	ND	ND	ND	VS	D	-	-
T_2- Paraffin wax	ND	ND	ND	ND	ND	VS	VS	D	-	-	-
T_3-Beewax	ND	ND	ND	ND	ND	ND	ND	VS	D	-	-
T_4- Semperfresh	ND	ND	ND	ND	ND	ND	ND	VS	D	-	-
Variety: Sreevijaya											
T_5-without wax coating	ND	ND	ND	ND	ND	ND	ND	ND	ND	VS	D
T_6-Paraffin wax	ND	ND	ND	ND	ND	VS	D	-	-	-	-
T_7-Beewax	ND	ND	ND	ND	ND	VS	D	-	-	-	-
T_8-Semperfresh	ND	ND	ND	ND	ND	ND	ND	ND	ND	VS	D
Variety: Vellayani Hraswa											
T_9-without wax coating	ND	ND	ND	ND	ND	ND	ND	ND	ND	VS	D
T_{10}-Paraffin wax	ND	ND	ND	ND	ND	ND	ND	ND	ND	VS	D
T_{11}-Beewax	ND	ND	ND	ND	ND	ND	ND	ND	ND	VS	D
T_{12}-Semperfresh	ND	ND	ND	ND	ND	ND	ND	ND	ND	VS	D

ND- not detected, VS-vascular streaking, D-Deteriorated

Among Sreevijaya, the unwaxed tubers (control) and the semperfresh coated tubers were found to be creamy white for 17 days. But after 9 days paraffin and beewax coated tubers started developing blue colour and complete deterioration was noticed by 13th day of storage.

The waxed and unwaxed tubers of Vellayani Hraswa was found to be white in colour upto 17 days. After that it showed development of blue colour and became inedible by 19th day of storage.

Vascular streaking was not observed in both the waxed and unwaxed tubers of M-4 variety upto 11 days of storage except in paraffin coated tubers. The signs of vascular streaking was seen in the periphery of the paraffin coated tubers and slowly it spreaded to the internal part and it became inedible and in other treatments it was observed by 15th day of storage.

In Sreevijaya, vascular streaking was not noticed in unwaxed and semperfresh coated tubers upto 17 days. But in paraffin and beewaxed tubers, this was observed from 11th day and then the tubers got deteriorated.

Among Vellayani Hraswa, no vascular streaking was observed upto 17 days in all treatments. The cut surface of tubers with vascular streaking is presented in plate 6.

4.1.3. Chemical and nutritional qualities

The chemical constituents such as moisture, protein, fat, fibre, total carbohydrate, starch, amylose, amylopectin, total sugars, reducing sugars, β-carotene, calcium and HCN contents of wax coated cassava tubers were estimated initially and on 14th day of storage. Since tubers of M-4 coated with paraffin and Sreevijaya coated with paraffin and beewax were deteriorated by 11th day of storage, their chemical and nutritional constituents could not be evaluated on 14th day of storage. The data on chemical and nutritional attributes were statistically interpreted using paired sample 'T' test and the results are as follows.

M-4

(Paraffin coated tubers after eleven days)

Sreevijaya

(Paraffin and beewax coated tubers after nine days)

Vellayani Hraswa

(After seventeen days)

Plate 6.Vascular streaking of cassava tubers during storage

4.1.3.1. Moisture

Initially, the moisture content of unwaxed tubers of M-4, Sreevijaya and Vellayani Hraswa was 54.86 per cent (T_1), 63.93 per cent (T_5) and 60 per cent (T_9) respectively. The moisture content of unwaxed tubers was 47.16 per cent, 55.25 per cent and 46.84 per cent respectively on 14[th] day of storage.

Table 7. Moisture content (%) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14[th] day	% variation
M-4	T_1 – Control	54.86	47.16**	14.03
	T_2– Paraffin		-	-
	T_3- Bee wax		45.03**	17.91
	T_4-Semperfresh		45.14**	17.71
Sreevijaya	T_5- Control	63.93	55.25**	13.57
	T_6- Paraffin		-	-
	T_7- Bee wax		-	-
	T_8-Semperfresh		62.77**	1.81
Vellayani Hraswa	T_9- Control	60	47.51**	20.81
	T_{10}- Paraffin		46.2**	23
	T_{11}-Bee wax		41.96**	30.06
	T_{12}-Semperfresh		46.84**	21.93

**-1% significant level

In M-4 coated with beewax and semperfresh, the moisture content on 14[th] day of storage was 45.03 and 45.14 per cent respectively. Among waxed cassava tubers of M-4, the percentage of moisture loss in 14 days of storage was minimum in tubers coated with semperfresh (T_4- 17.71 per cent). The moisture loss in waxed tubers was found to be more than unwaxed tubers.

In tubers of Sreevijaya coated with semperfresh the percentage loss in moisture was 1.81 per cent during 14 days of storage and it was found to be lower than the control (13.57 per cent)

In the case of Vellayani Hraswa, the moisture content in waxed tubers varied from 41.96 (T_1-bee wax) to 46.84 (T_{12}-semperfresh) per cent. Among waxed tubers, the percentage loss in moisture content during 14 days of storage was found to be minimum in semperfresh coated tubers (21.93 per cent). The moisture loss in waxed tubers was found to be higher than the control. Maximum moisture loss in waxed tubers was noticed in tubers coated with beewax (30.06 per cent).

The variation noticed in moisture content of all the treatments on 14^{th} day of storage was statistically significant in all the treatments.

4.1.3.2. Protein

The effect of application of different waxes on the protein content of cassava tubers is furnished in Table 8.The protein content in unwaxed tubers of three varieties varied from 0.28 (Sreevijaya) to 1.08 per cent (Vellayani Hraswa) initially. Maximum protein content was noticed in Vellayani Hraswa and minimum in Sreevijaya.

The protein content of waxed and unwaxed tubers of M-4 slightly decreased during 14 days of storage and it varied from 0.52 (T_3-bee wax) to 0.72 (T_1-control) per cent. The percentage decrease in protein content was maximum in bee wax coated tubers (T_3- 38.22 per cent). The reduction in protein content of waxed tubers was found to be more than the unwaxed tubers (Control).

In Sreevijaya, the protein content of unwaxed tuber was 0.22 per cent and in tuber coated with semperfresh was 0.25. The percentage decrease in protein content in semperfresh coated tubers (10.71 per cent) was found to be lower than the control (21.42 per cent).

In Vellayani Hraswa, the protein content decreased in waxed and unwaxed tubers and it varied from from 0.89 (T_{10}- paraffin) to 1.07 (T_9- control) per cent. The percentage decrease in protein content was maximum in bee waxed tubers (17.59 per cent) and minimum was noticed in control (0.92 per cent).

Table 8. Protein content (%) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14th day	% variation
M-4	T_1– Control	0.85	0.72**	15.29
	T_2– Paraffin		-	-
	T_3- Bee wax		0.52**	38.82
	T_4- Semperfresh		0.66**	22.35
Sreevijaya	T_5- Control	0.28	0.22NS	21.42
	T_6- Paraffin		-	-
	T_7- Bee wax		-	-
	T_8- Semperfresh		0.25NS	10.71
Vellayani Hraswa	T_9- Control	1.08	1.07NS	0.92
	T_{10}- Paraffin		0.95NS	12.03
	T_{11}-Bee wax		0.89NS	17.59
	T_{12}-Semperfresh		1.02NS	5.55

**-1% significant level, NS- not significant

The decrease in protein content was statistically significant in waxed and unwaxed tubers of M-4 (T_1, T_3, T_4). In all other treatments the decrease in protein content during two weeks of storage was insignificant.

4.1.3.3. Fat

The fat content of cassava tubers during storage is given in Table 9. Initially the fat content of unwaxed cassava tubers of M-4, Sreevijaya and Vellayani Hraswa was 0.22 per cent. The fat content of unwaxed tubers increased as 0.24 per cent, 0.23 per cent and 0.28 per cent respectively during 14 days of storage.

Among waxed cassava tubers of M-4, the percentage increase in fat content after two weeks of storage was maximum in tubers coated with semperfresh (T_4 – 13.6 per cent) and the fat content was 0.25 per cent on 14th day of storage.

Table 9. Fat content (%) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14th day	% variation
M-4	T_1 – Control	0.22	0.24^{NS}	9.09
	T_2 – Paraffin		-	-
	T_3- Bee wax		0.23^{NS}	4.54
	T_4-Semperfresh		0.25^{NS}	13.6
Sreevijaya	T_5- Control	0.22	0.23^{NS}	4.54
	T_6- Paraffin		-	-
	T_7- Bee wax		-	-
	T_8-Semperfresh		0.25^{NS}	13.6
Vellayani Hraswa	T_9- Control	0.22	0.29^{NS}	31.81
	T_{10}- Paraffin		0.28^{NS}	27.27
	T_{11}-Bee wax		0.25^{NS}	13.6
	T_{12}-Semperfresh		0.26^{NS}	18.18

NS-not significant

In tubers of Sreevijaya coated with semperfresh the percentage increase in fat content was higher than the control during 14 days of storage. The fat content in T_5 and T_8 were 0.23 and 0.25 per cent respectively.

In the case of Vellayani Hraswa, the highest fat content on 14th day of storage was noticed in control (T_9-0.29 per cent). The percentage increase in fat content was upto 31.81 per cent. Among waxed tubers, the percentage increase in fat content was maximum for paraffin coated tubers (T_{10}-27.27 per cent) and minimum was noticed in bee wax coated tubers (13.6 per cent).

The increase in fat content during two weeks of storage was found to be statistically insignificant in all treatments.

4.1.3.4. Fibre

The fibre content of waxed and unwaxed cassava tubers is given in Table 10. The fibre content in unwaxed tubers of three varieties varied from 0.55 to 0.76 per cent. Highest fibre content was noticed Sreevijaya and lowest in M-4 initially.

The fibre content of waxed and unwaxed tubers slightly increased during 14 days of storage. In variety M-4, the fibre content of unwaxed tubers was 0.63 per cent (T_1). In waxed tubers the fibre content in T_3 and T_4 was 0.62 to 0.59 per cent respectively and the percentage increase in fibre content during 14 days of storage was 12.7 and 7.2 per cent respectively.

The fibre content in unwaxed and semperfresh coated tubers of Sreevijaya variety was 0.92 and 0.79 per cent respectively on 14th day of storage. The rate of increase in fibre content was found to be high in the unwaxed tubers (21.05 per cent).

In Vellayani Hraswa, the fibre content on 14th day of storage varied from 0.73 (T_{12}-semperfresh) to 0.81 (T_9-control). Compared to control, the percentage increase in fibre content of waxed tubers was found to be lower on 14 days of storage. The lowest percentage increase was noticed in semperfresh coated tubers and it was only 2.82 per cent.

The variation in fibre content was noticed during 14 days of storage and it was found to be statistically significant in unwaxed tubers of M-4, Sreevijaya and

Vellayani Hraswa. In the case of waxed tubers, the increament was significant in beewax coated tubers of M-4 (T_3) and Vellayani Hraswa (T_{11}) and in all others it was found to be insignificant.

Table 10. Fibre content (%) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14th day	% variation
M-4	T_1– Control	0.55	0.63**	14.5
	T_2– Paraffin		-	-
	T_3- Bee wax		0.62**	12.7
	T_4-Semperfresh		0.59^{NS}	7.2
Sreevijaya	T_5- Control	0.76	0.92**	21.05
	T_6- Paraffin		-	-
	T_7- Bee wax		-	-
	T_8-Semperfresh		0.79^{NS}	3.9
Vellayani Hraswa	T_9- Control	0.71	0.81**	14.08
	T_{10}- Paraffin		0.76^{NS}	7.04
	T_{11}-Bee wax		0.80**	12.68
	T_{12}-Semperfresh		0.73^{NS}	2.82

**-1% significant level, NS-not significant

4.1.3.5. Total carbohydrate

The total carbohydrate content among the three varieties of cassava during storage is given in the Table 11. Initially, the carbohydrate content of unwaxed tubers of M-4, Sreevijaya and Vellayani Hraswa was 38.22 per cent (T_1) 29.47 per cent (T_5) and 31.77 per cent (T_9) respectively. The carbohydrate content of unwaxed tubers was noticed as 37.32 per cent, 25.43 per cent and 25.86 per cent respectively on 14th day of storage. A decrease in total carbohydrate content was noticed during 14 days of storage.

Table 11. Total carbohydrate content (%) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14^{th} day	% variation
M-4	T_1- Control	38.22	37.32^{NS}	2.34
	T_2- Paraffin		-	-
	T_3- Beewax		37.03^{NS}	3.11
	T_4-Semperfresh		37.47*	1.96
Sreevijaya	T_5- Control	29.47	25.43*	13.71
	T_6- Paraffin		-	-
	T_7- Beewax		-	-
	T_8-Semperfresh		28.49*	3.33
Vellayani Hraswa	T_9- Control	31.77	25.86**	18.60
	T_{10}- Paraffin		27.73*	12.72
	T_{11}-Beewax		30.51^{NS}	3.96
	T_{12}-Semperfresh		30.87^{NS}	2.83

**-1 % significant level, *-5% significant level, NS- not significant.

Among waxed cassava tubers of M-4, compared to control the loss in carbohydrate content during storage was minimum in tubers coated with semperfresh (T_4) and the percentage loss was only 1.96 per cent. But in beewax coated tubers it was higher than control (T_3-3.11 per cent). The total carbohydrate content in T_3 and T_4 on 14^{th} day of storage was 37.03 per cent and 37.47 per cent respectively.

In tubers of Sreevijaya coated with semperfresh the total carbohydrate was 28.49 per cent on 14th day of storage. Compared to control (T_5), the percentage loss was lower in semperfresh (T_3-3.33 per cent) coated tubers.

In the case of Vellayani Hraswa, tubers coated with semperfresh showed comparatively minimum carbohydrate loss (2.83 per cent) during two weeks of storage. The loss in carbohydrate in waxed tubers was lower than the control. Maximum carbohydrate loss among waxed tubers was noticed in tubers coated with paraffin (T_{10}-12.72 per cent). The total carbohydrate content in T_{10}, T_{11} and T_{12} after second week of storage was 27.73, 30.51 and 30.87 per cent respectively.

The variation noticed in carbohydrate content in all the treatments on 14th day of storage was statistically significant except in case of T_1, T_3, T_{11} and T_{12}.

4.1.3.6. Starch

The observation regarding the starch content of waxed and unwaxed cassava tubers is furnished in Table 12. The starch content in unwaxed tubers of three varieties varied from 23.11 to 28.56 per cent initially. Maximum starch content was noticed in Vellayani Hraswa and minimum in Sreevijaya.

The starch content of waxed and unwaxed tubers decreased during 14th day of storage. In M-4 variety, the starch content in beewax and semperfresh coated tubers was 22.12 and 25.36 respectively. The percentage decrease in starch content during 14th day of storage was found to be maximum in beewax coated tubers ie, 17.89 per cent.

Semperfresh coated tubers of Sreevijaya variety had a moisture content of 22.85 per cent after two weeks of storage. Compared to control, the percentage decrease in starch content was minimum in semperfresh coated tubers (1.13 per cent).

In Vellayani Hraswa, the percentage decrease in starch content during storage varied from 2.35 to 17.78 per cent. The maximum decrease in starch content was noticed in tubers coated with beewax (17.78 per cent) and the minimum was showed by semperfresh coated tubers (2.35 per cent). The starch content in tubers coated with three different waxes during 14 days was 23.48 to 27.89 per cent.

Table 12. Starch content (%) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14th day	% variation
M-4	T_1- Control	26.94	24.07**	10.65
	T_2- Paraffin		-	-
	T_3- Beewax		22.12**	17.89
	T_4-Semperfresh		25.36*	5.86
Sreevijaya	T_5- Control	23.11	21.75**	5.88
	T_6- Paraffin		-	-
	T_7- Beewax		-	-
	T_8-Semperfresh		22.85*	1.13
Vellayani Hraswa	T_9- Control	28.56	27.16*	4.90
	T_{10}- Paraffin		25.26**	11.55
	T_{11}-Beewax		23.48**	17.78
	T_{12}-Semperfresh		27.89*	2.35

**-1 % significant level, *-5% significant level

The variation noticed in starch content during two weeks of storage was statistically significant in all the treatments.

4.1.3.7. Amylose

The amylose content in cassava tubers during storage is given in Table 13. Initially, the amylose content of unwaxed tubers of M-4, Sreevijaya and Vellayani Hraswa was 12.73 per cent (T_1), 9.93 per cent (T_5) and 12.07 per cent (T_9) respectively. The unwaxed tubers recorded an amylose content of 11.11 per cent, 9.15 per cent and 10.79 per cent respectively on 14th day of storage. A decrease in amylose content was noticed during 14th day of storage in waxed and unwaxed tubers.

Among waxed cassava tubers of M-4, the percentage loss in amylose noticed on 14th day of storage was minimum in tubers coated with semperfresh (T_4-2.59 per cent). The percentage loss in amylose content was 18.15 per cent in bee wax coated tubers and it was found to be higher than the loss noticed in control (12.73 per cent). The percentage reduction in amylose content was more than the control.

In waxed and unwaxed tubers of Sreevijaya the amylose content insignificantly decreased during storage and in tubers coated with semperfresh the percentage loss in amylose content was slightly more than the control on 14th day of storage and the amylose content was 9.04 per cent (T_8).

In the case of Vellayani Hraswa, tubers coated with semperfresh showed comparatively lower per cent of loss in amylose during two weeks of storage. The percentage loss in amylose content in tubers waxed with paraffin and bee wax was higher than control. The decrease in amylose content during storage in waxed tubers was maximum in tubers coated with bee wax (16.57 per cent).

The variation noticed in amylose content during two weeks of storage was statistically significant in all the treatment of M-4 and Vellayani Hraswa except in Vellayani Hraswa tubers treated with semperfresh.

Table 13. Amylose content (%) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14^{th} day	% variation
M-4	T_1- Control	12.73	11.11**	12.73
	T_2- Paraffin		-	-
	T_3- Beewax		10.42**	18.15
	T_4-Semperfresh		12.4*	2.59
Sreevijaya	T_5- Control	9.93	9.15^{NS}	7.85
	T_6- Paraffin		-	-
	T_7- Beewax		-	-
	T_8-Semperfresh		9.04^{NS}	8.96
Vellayani Hraswa	T_9- Control	12.07	10.79**	10.61
	T_{10}- Paraffin		10.11**	16.24
	T_{11}-Beewax		10.07**	16.57
	T_{12}-Semperfresh		11.73^{NS}	2.82

**-1% significant, *-5% significant, NS- not significant

4.1.3.8. Amylopectin

The effect of application of different waxes on the amylopectin content of cassava tubers is furnished in Table 14. The amylopectin content in unwaxed tubers of three varieties varied from 14.21 to 16.49 per cent initially. Maximum amylopectin content was noticed in Vellayani Hraswa and minimum in Sreevijaya.

The amylopectin content of waxed and unwaxed tubers decreased during 14 days of storage. In M-4 variety, the percentage decrease in amylopectin content on 14^{th} day of storage was significant and maximum was noticed in bee wax coated tubers (T_3- 17.66 per cent) and the content was 11.7 per cent.

In variety Sreevijaya, an insignificant decrease in amylopectin content was noticed in semperfresh coated tubers. But a significant decrease in amylopectin was noticed in control on 14 days of storage.

Table 14. Amylopectin content (%) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14^{th} day	% variation
M-4	T_1- Control	14.21	12.6*	8.86
	T_2- Paraffin		-	-
	T_3- Beewax		11.7**	17.66
	T_4-Semperfresh		12.96*	8.79
Sreevijaya	T_5- Control	13.18	10.59*	19.65
	T_6- Paraffin		-	-
	T_7- Beewax		-	-
	T_8-Semperfresh		13.81^{NS}	4.77
Vellayani Hraswa	T_9- Control	16.49	16.16^{NS}	2.00
	T_{10}- Paraffin		15.15*	8.13
	T_{11}-Beewax		12.69**	23.04
	T_{12}-Semperfresh		16.46^{NS}	0.18

**-1 % significant, *-5% significant, NS-not significant

In Vellayani Hraswa, the amylopectin content in wax coated tubers after two weeks of storage varied from 12.69 to 16.46 per cent. The waxed tubers showed a higher rate of reduction in amylopectin content than the unwaxed tubers except in semperfresh coated tubers. The maximum percentage decrease in amylopectin content was noticed in tubers coated with bee wax (23.04 per cent) and minimum in semperfresh coated tubers (0.18 per cent).

The decrease in amylopectin content was statistically significant in waxed and unwaxed tubers of M-4 and Vellayani Hraswa except in T_9 and T_{12}.

4.1.3.9. Total sugar

The total sugar content in different varieties of cassava tubers is furnished in Table 15. Initially, the total sugar content of unwaxed tubers of M-4, Sreevijaya and VellayaniHraswa was 5.01 per cent (T_1), 5.52 per cent (T_5) and 8.58 per cent (T_9) respectively. The total sugar content of unwaxed tubers was noticed as 6.59 per cent, 6.23 per cent and 9.69 per cent respectively on 14^{th} day of storage.

Among waxed cassava tubers of M-4, the percentage increase in total sugar on 14^{th} day of storage was maximum in tubers coated with bee wax (T_3 – 35.13 per cent) and minimum in semperfresh coated tubers (T_3-24.75 per cent).

In tubers of Sreevijaya coated with semperfresh the percentage increase in total sugar was lower than the control in two weeks of storage and the content of total sugar was 5.98 per cent.

In the case of Vellayani Hraswa, tubers coated with bee wax showed comparatively maximum increase in total sugar content during 14 days of storage. The percentage increase in total sugar in waxed tubers was higher than control except in semperfresh coated tubers. The percentage increase in toatal sugar content among waxed tubers was maximum in tubers coated with beewax (12.94 per cent). The content of total sugar among waxed tubers after two weeks varied from 8.69 to 9.12 per cent.

Table 15. Total sugar content (%) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14^{th} day	% variation
M-4	T_1- Control	5.01	6.59**	31.53
	T_2- Paraffin		-	-
	T_3- Beewax		6.77**	35.13
	T_4-Semperfresh		6.25**	24.75
Sreevijaya	T_5- Control	5.52	6.23**	12.86
	T_6- Paraffin		-	-
	T_7- Beewax		-	-
	T_8-Semperfresh		5.98**	8.33
Vellayani Hraswa	T_9- Control	8.58	8.88*	3.49
	T_{10}-Paraffin		9.12**	6.29
	T_{11}-Beewax		9.69*	12.94
	T_{12}-Semperfresh		8.69^NS	1.28

**-1% significant, *-5% significant, NS-not significant

The variation noticed in total sugar content on 14^{th} day of storage was statistically significant in all the treatment except in semperfresh coated tubers of Vellayani Hraswa (T_{12}).

4.1.3.10. Reducing sugar

The reducing sugar content of waxed and unwaxed cassava tubers during storage is furnished in Table 16. The reducing sugar content in unwaxed tubers of three varieties varied from 1.43 to 2.54 per cent initially. Maximum reducing sugar content was noticed in Vellayani Hraswa and minimum in M-4. On 14^{th} day of storage the reducing sugar content in unwaxed tubers was 1.53, 2.05 and 2.58 per cent respectively.

Table 16. Reducing sugar content (%) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14^{th} day	% variation
M-4	T_1- Control	1.43	1.53*	6.99
	T_2- Paraffin		-	-
	T_3- Beewax		1.65**	15.38
	T_4-Semperfresh		1.51*	5.59
Sreevijaya	T_5- Control	1.98	2.05^{NS}	3.53
	T_6- Paraffin		-	-
	T_7- Beewax		-	-
	T_8-Semperfresh		2.00^{NS}	1.01
Vellayani Hraswa	T_9- Control	2.54	2.58^{NS}	1.57
	T_{10}- Paraffin		2.73**	7.48
	T_{11}-Beewax		2.87**	12.99
	T_{12}-Semperfresh		2.55^{NS}	0.39

*-1 % significant, *-5% significant, NS-not significant

The percentage of reducing sugar content of waxed and unwaxed tubers of M-4 significantly increased during 14 days of storage. The percentage increase in reducing sugar content on 14^{th} day of storage was maximum in bee wax coated tubers (T_3- 15.38 per cent). In unwaxed tubers and semperfresh coated tubers the reducing sugar content on 14^{th} day of storage was 1.53 and 1.51 respectively.

In variety Sreevijaya too, the reducing sugar content of semperfresh coated tubers increased insignificantly during two weeks of storage and the content was 2 per cent. The percentage increase was found to be lower than the control.

In Vellayani Hraswa, the reducing sugar content in wax coated tubers on 14th day of storage varied from 2.55 to 2.87 per cent. In all treatments a slight increase in reducing sugar content was noticed during storage. The percentage increase in reducing sugar content varied from 0.39 to 12.99 per cent respectively. The maximum increase in reducing sugar content was noticed in tubers coated with bee wax (12.99 per cent) and the minimum was shown by semperfresh coated tubers (0.39 per cent). The increase in reducing sugar content in waxed tubers was higher than the control except in semperfresh coated tubers. The increase in reducing sugar content during storage was statistically significant in T_{10} and T_{11}.

4.1.3.11. β-carotene

The β-carotene content in cassava tubers is furnished in Table 17. The β-carotene content was not detected in Vellayani Hraswa and M-4 in all periods of storage.

Table 17.β-carotene (μg 100g^{-1}) content of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14th day	% variation
M-4	T_1- Control	ND	ND	–
	T_2- Paraffin			
	T_3- Beewax			
	T_4-Semperfresh			
Sreevijaya	T_5- Control	0.44	0.34**	22.72
	T_6- Paraffin		-	-
	T_7- Beewax		-	-
	T_8-Semperfresh		0.35**	20.45
Vellayani Hraswa	T_9- Control	ND	ND	–
	T_{10}- Paraffin			
	T_{11}-Beewax			
	T_{12}-Semperfresh			

**-5 % significant level

Presence of β-carotene was observed in Sreevijaya and was found to be 0.44 μg 100 g^{-1} initially. The β-carotene content of unwaxed tubers of Sreevijaya was noticed as 0.34 μg 100 g^{-1} on 14^{th} day of storage. In tubers of Sreevijaya coated with semperfresh the percentage decrease during storage in β-carotene content was lower than the control on 14^{th} day of storage and the content was 0.35 μg 100 g^{-1}. The variation noticed in β-carotene content on 14^{th} day of storage was statistically significant in variety Sreevijaya.

4.1.3.12. Calcium

The calcium content in cassava tubers is furnished in Table 18. The calcium content in unwaxed tubers of three varieties varied from 23.53 to 38.07 mg 100 g^{-1}initially. Maximum calcium content was noticed in Vellayani Hraswa and minimum in M-4. The calcium content slightly increased during 14 days of storage in unwaxed tubers and was 23.80, 37.86 and 38.63 mg 100 g^{-1} respectively. The percentage increase in calcium content during storage varied from 5.63 to 7.35 per cent in different varieties. In M-4 variety, the tubers coated with bee wax and semperfresh had a calcium content of 23.58 and 23.66 on 14^{th} day of storage. The percentage increase in calcium content in waxed tubers varied from 0.21 (T_3) to 2.02 (T_{12}) on 14^{th} day of storage among different varieties.

In Sreevijaya, lower calcium content than control was noticed in semperfresh coated tubers on 14^{th} day of storage. The percentage increase in calcium content was 5.63 per cent.

In Vellayani Hraswa too, the calcium content slightly increased during 14 days of storage and it varied from 38.32 to 38.84 in wax coated tubers. The highest and lowest calcium content was noticed as 38.84 and 38.32 mg 100g^{-1}in semperfresh coated and bee wax coated tubers respectively. The percentage increase in calcium content during storage varied from 0.65 to 2.02.

Table 18. Calcium content (mg 100 g^{-1}) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14^{th} day	% variation
M-4	T_1- Control	23.53	23.80^{NS}	7.35
	T_2- Paraffin		-	-
	T_3- Beewax		23.58^{NS}	0.21
	T_4-Semperfresh		23.66^{NS}	0.55
Sreevijaya	T_5- Control	35.82	37.86^{NS}	5.69
	T_6- Paraffin		-	-
	T_7- Beewax		-	-
	T_8-Semperfresh		37.84^{NS}	5.63
Vellayani Hraswa	T_9- Control	38.07	38.63*	1.47
	T_{10}- Paraffin		38.74*	1.75
	T_{11}-Beewax		38.32**	0.65
	T_{12}-Semperfresh		38.84**	2.02

**-1 % significant level, *-5% significant level, NS-not significant

The variation noticed in calcium content of cassava tubers on 14^{th} day of storage was insignificant throughout the storage period.

4.1.3.13. Hydrocyanic acid (HCN)

The HCN content in cassava tubers is furnished in Table 19. Initially, the cyanide content of unwaxed tubers of M-4, Sreevijaya and VellayaniHraswa was 59.63 per cent (T_1), 52.16 per cent (T_5) and 32.26 per cent (T_9) respectively. The HCN content of unwaxed tubers decreased to 55, 50.86 and 28.73 mg kg^{-1}respectively by 14^{th} day of storage.

Among waxed cassava tubers of M-4, Sreevijaya and Vellayani Hraswa reduction in HCN content during two weeks of storage was noticed. The percentage reduction was found to be maximum in semperfresh coated tubers of all the three varieties. The content of HCN in semperfresh coated tubers of M-4, Sreevijaya and Vellayani Hraswa were 52.2, 48.73 and 26.5 respectively after two weeks of storage. In M-4, the beewax coated tubers had a HCN content of 54.53 mg/kg. The paraffin and beewax coated Vellayani Hraswa tubers had a HCN content of 31.1 and 30.46 mg/kg respectively during storage.

Table 19. HCN content (mg/kg) of waxed cassava tubers in comparison with control during storage

Varieties	Treatments	Initial	14^{th} day	% variation
M-4	T_1- Control	59.63	55**	7.76
	T_2- Paraffin		-	-
	T_3- Beewax		54.53**	8.55
	T_4-Semperfresh		52.2**	12.46
Sreevijaya	T_5- Control	52.16	50.86**	2.49
	T_6- Paraffin		-	-
	T_7- Beewax		-	-
	T_8-Semperfresh		48.73**	6.57
Vellayani Hraswa	T_9- Control	32.26	28.73**	10.94
	T_{10}- Paraffin		31.1**	3.55
	T_{11}-Beewax		30.46**	5.57
	T_{12}-Semperfresh		26.5**	17.85

**-1% significant level

4.1.4. Organoleptic qualities

Organoleptic qualities of cooked samples of unwaxed and waxed cassava tubers of three varieties were evaluated for various quality attributes like appearance, colour, flavour, texture, taste and overall acceptability, initially and after on 14 days of storage using a score card having nine point hedonic scale (Plate 7 & 8). The mean scores and the mean rank scores for different quality attributes of cooked samples of

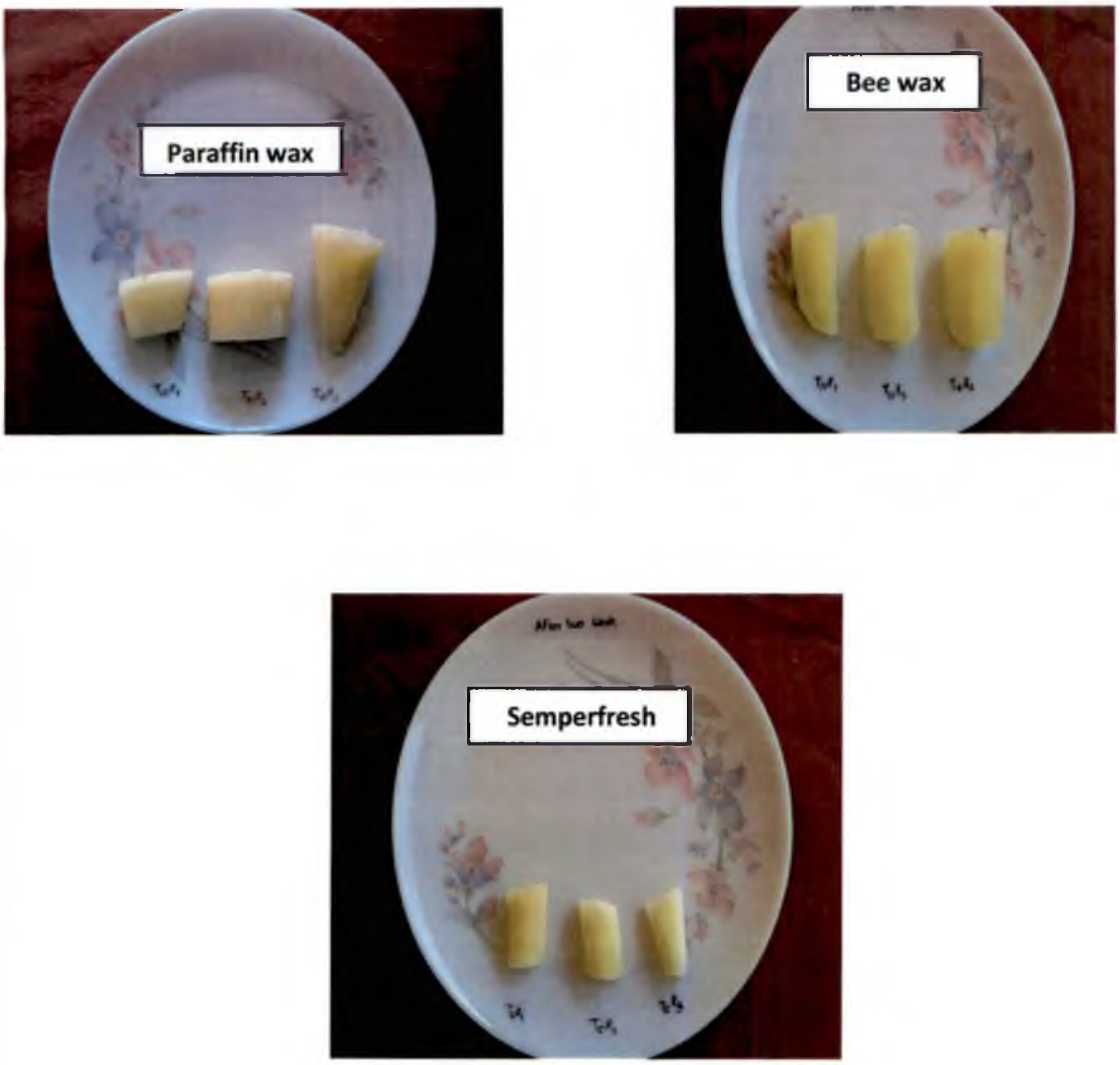
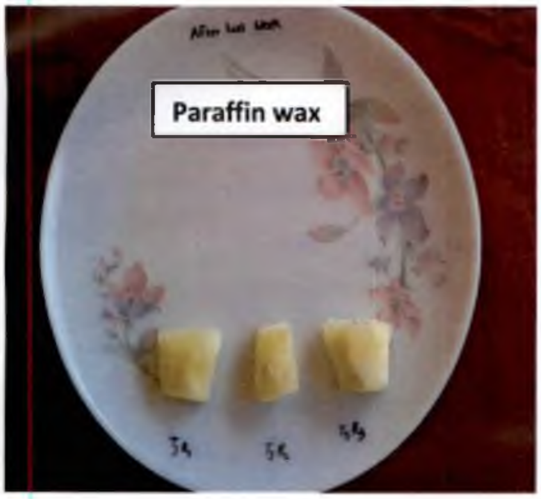


Plate 7. Cooked cassava tubers (Initial)



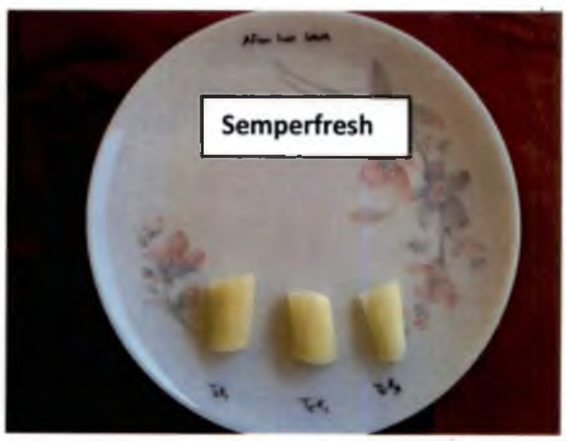


Plate 8.Cooked cassava tubers (14th day)

cassava are presented in Table 20, 21 and 22. The data on organoleptic qualities were statistically interpreted using Kendall's Coefficient of Concordance.

The mean scores for the different organoleptic qualities of waxed and unwaxed tubers of M-4 during storage is shown in Table 20. Initially the mean score for different organoleptic attributes of unwaxed tubers like appearance, colour, flavour, texture, taste and overall acceptability was 8.62, 8.59, 8.71, 8.55, 8.82 and 8.82 respectively. During two weeks of storage, the mean score for appearance, colour and flavour of waxed as well as unwaxed tubers decreased whereas an increase was noticed in mean score for texture, taste and overall acceptability of unwaxed tubers on 14^{th} day of storage. In waxed tubers the mean score for these parameters showed decreased during storage. The maximum mean score for different quality attributes was noticed in unwaxed tubers followed by semperfresh coated tubers. The mean scores for appearance, colour, flavour, texture, taste and overall acceptability of control (T_1) on 14^{th} day of storage was 8.59 (3.85), 8.36 (2.70), 8.58 (3.95), 8.58 (3.95), 8.96 (4.00) and 8.93 (4.00) and in semperfresh coated tubers it was 8.52 (2.70), 8.52 (3.40), 7.76 (2.95), 8.04 (2.90), 7.80 (3.00) and 7.91 (2.90) respectively.

Based on Kendall's value significant agreement among judges was noticed in evaluating different quality attributes of waxed and unwaxed tubers during storage.

The mean scores for various quality attributes of unwaxed tubers of Sreevijaya (Table 21) was 8.6 for appearance, 8.53 for colour, 8.49 for flavour, 8.29 for texture, 8.23 for taste and 8.71 for overall acceptability initially. After two weeks of storage, the mean score for appearance (8.62), flavour (8.51), texture (8.44) and taste (8.64) of unwaxed tubers increased slightly while the mean score for colour (8.38) and overall acceptability was lower than the initial value. Better mean score for different quality attributes was noticed in unwaxed tubers than waxed ones during storage. The mean score for different quality attributes of unwaxed tubers varied from 8.62 (3.90) for appearance, 8.38 (3.90) for colour, 8.51 (3.75) for flavour, 8.44 (3.90) for texture, 8.64 (3.95) for taste and 8.6 (3.25) for overall acceptability. In semperfresh coated tubers the mean scores was between 7.94 (appearance) to 8.13 (taste).

Table 20. Mean scores for the organoleptic qualities of waxed and unwaxed cassava tubers of M-4 during storage

Treatments	Appearance		Colour		Flavour		Texture		Taste		Overall acceptability	
	Initial	2nd week	Initial	2nd week	Initial	2nd week	Initial	2nd week	Initial	2nd week	Initial	2nd week
T_1-Control	8.62	8.59 (3.85)	8.59	8.36 (2.70)	8.71	8.58 (3.95)	8.55	8.58 (3.95)	8.82	8.96 (4.00)	8.82	8.93 (4.00)
T_2-Paraffin wax		–		–		–		–		–		–
T_3-Beewax		8.47 (2.45)		8.37 (2.90)		7.15 (2.10)		7.35 (2.15)		6.86 (2.00)		7.27 (2.10)
T_4-Semperfresh		8.52 (2.45)		8.52 (3.40)		7.76 (2.95)		8.04 (2.90)		7.80 (3.00)		7.91 (2.90)
Kendall's (W) value	–	0.885**	–	0.724**	–	0.972**	–	0.966**	–	1.00**	–	0.964**

Figures in parenthesis are mean rank scores
**-1% significant level

Table 21. Mean scores for the organoleptic qualities of waxed and unwaxed cassava tubers of Sreevijaya during storage

Treatments	Appearance		Colour		Flavour		Texture		Taste		Overall acceptability	
	Initial	2nd week	Initial	2nd week	Initial	2nd week	Initial	2nd week	Initial	2nd week	Initial	2nd week
T_1-Control	8.6	8.62 (3.90)	8.53	8.38 (3.90)	8.49	8.51 (3.75)	8.29	8.44 (3.90)	8.23	8.64 (3.95)	8.71	8.6 (3.25)
T_2-Paraffin wax		–		–		–		–		–		–
T_3-Beewax		–		–		–		–		–		–
T_4-Semperfresh		7.94 (3.10)		7.68 (3.10)		7.99 (3.25)		7.98 (3.10)		8.13 (3.05)		7.95 (3.75)
Kendall's (W) value	–	0.960**	–	0.960**	–	0.927**	–	0.960**	–	0.990**	–	0.971**

Figures in parenthesis are mean rank scores

**-1% significant level

Table 22. Mean scores for the organoleptic qualities of waxed and unwaxed cassava tubers of Vellayani Hraswa during storage

Treatments	Appearance		Colour		Flavour		Texture		Taste		Overall acceptability	
	Initial	2nd week	Initial	2nd week	Initial	2nd week	Initial	2nd week	Initial	2nd week	Initial	2nd week
T1-Control	8.96	9.00 (4.00)	8.66	8.96 (4.00)	8.84	8.86 (3.75)	8.73	8.92 (3.95)	9.00	8.89 (3.85)	9.00	8.89 (3.90)
T2-Paraffin wax		8.09 (1.80)		7.72 (1.65)		7.79 (1.50)		7.82 (1.30)		7.44 (1.20)		7.54 (1.30)
T3-Beewax		8.15 (1.95)		7.82 (1.70)		8.27 (2.20)		8.10 (2.15)		8.12 (2.55)		8.03 (2.45)
T4-Semperfresh		8.21 (2.25)		8.02 (2.65)		8.30 (2.55)		8.34 (2.60)		8.14 (2.40)		8.06 (2.45)
Kendall's (W) value	–	0.739**	–	0.826**	–	0.557**	–	0.817**	–	0.783**	–	0.825**

Figures in parenthesis are mean rank scores
**-1% significant level

Based on Kendall's value significant agreement among judges was noticed in the evaluation of different quality attributes of waxed and unwaxed tubers of Sreevijaya.

Mean scores for the organoleptic qualities of waxed and unwaxed tubers of Vellayani Hraswa during storage is given in Table 22. The mean scores for appearance, colour, flavour, texture, taste and overall acceptability of unwaxed tubers was initially 8.96, 8.66, 8.84, 8.73, 9.00 and 9.00 respectively. The highest mean score for different quality attributes among waxed and unwaxed tubers after two weeks of storage was noticed in unwaxed tubers itself and the mean scores were 9.00 (4.00) for appearance, 8.96 (4.00) for colour, 8.86 (3.75) for flavour, 8.92 (3.95) for texture, 8.89 (3.85) for taste and 8.89 (3.90) for overall acceptability. Among waxed tubers the maximum mean score for different quality attributes was noticed in semperfresh coated cassava tubers after two weeks of storage and the mean scores were 8.21 (2.25) for appearance, 8.02 (2.65) for colour, 8.30 (2.55) for flavour, 8.34 (2.60) for texture, 8.14 (2.40) for taste and 8.06 (2.45) for overall acceptability.

Based on Kendall's value significant agreement among judges was noticed in the evaluation of different quality attributes of unwaxed and waxed tubers of Vellayani Hraswa during storage.

4.2. Cost analysis of wax application

The application of wax on cassava tubers was done by using three waxes such as paraffin wax, beewax and semperfresh. The cost incurred for application of waxes on different varieties was Rs. 7.96 for paraffin wax, 6.71 for bee wax and Rs.10 for semperfresh and application per kg of tubers.

Discussion

5. DISCUSSION

The results of the study entitled "Standardisation of wax coating in cassava (*Manihot esculenta* Crantz) tubers and quality evaluation" are discussed under following headings.

5.1. Quality attributes of wax coated cassava tubers

5.1.1. Shelf life qualities

5.1.2. Physical qualities

5.1.3. Chemical and nutritional qualities

5.1.4. Organoleptic qualities

5.2. Cost analysis of wax application

5.1. Quality attributes of wax coated cassava tubers

Three varieties namely, M-4, Sreevijaya and Vellayani Hraswa were selected for the study. Tubers harvested at fully mature stage without any mechanical damage were treated with three different waxes like Paraffin wax, bee wax and Semperfresh (commercial wax). The wax formulation at one percent level which prolonged the days of storage with minimum weight loss was selected for the study. The wax coated cassava tubers were stored after packing in ventilated paper cartons under ambient conditions till it showed the signs of deterioration. Various quality parameters like shelf life qualities, chemical and nutritional qualities and organoleptic qualities were evaluated.

5.1. 1. Shelf life qualities

Respiration rate and physiological loss in weight of both waxed and unwaxed cassava tubers of three varieties were determined at two days interval.

The rate of respiration in cassava tubers was presented in terms of O_2 consumed by the tubers. The initial respiration rate of unwaxed (control) tubers of M-4, Sreevijaya and Vellayani Hraswa was 132.73, 124.38 and 128.9 ml/kg/h respectively (Fig.1 to 3). Compared to control significant variation was noticed in the respiration rate of wax coated cassava tubers. Only in semperfresh coated tubers, the respiration rate showed a lower rate than control throughout the storage period. In semperfresh coated tubers, a steady decrease in respiration rate was noticed up to 7th day in varieties M-4 and Vellayani Hraswa. There after an increase was observed. But in Semperfresh coated tubers of Sreevijaya gradual decrease was noticed up to 17th day of storage. In paraffin coated tubers, a decrease in respiration rate up to 7 to 9days was noticed in all the varieties, there after an increase was noticed. In bee wax coated tubers wide variation in respiration rate as intermittent increase and decrease was noticed especially in variety Vellayani Hraswa.

Hirose (1986) observed the respiratory changes in stored cassava and indicated that the intact roots reached their highest respiration rates on the second day of storage. In this study, only in unwaxed tubers of sreevijaya showed the peak respiration rate on second day and there after a gradual reduction was noticed. According to him, the respiration rates then decreased gradually until the fourth day, later the rates began to increase again, reaching their maximum approximately on the fifth day. These two peaks of increased respiratory rates are thought to be due biochemical changes induced by the development of PPD. The second respiration rate peak on day 5 to 6 days coincide with the occurrence of rapid development of PPD. Eight days after harvest the respiratory rate decreased to levels similar to the time of harvest. Here, in unwaxed tubers of M-4 and Vellayani Hraswa, the second peak in respiration rate was noticed on 11th and 9th day respectively. As suggested by the author, the respiration rate become almost nearer to the initial value when the tubers started showing the onset of deterioration. According to Hirose *et al.* (1984) the differences in respiratory rates in roots under PPD, particularly at one day after harvest, were found to be cultivar dependent.

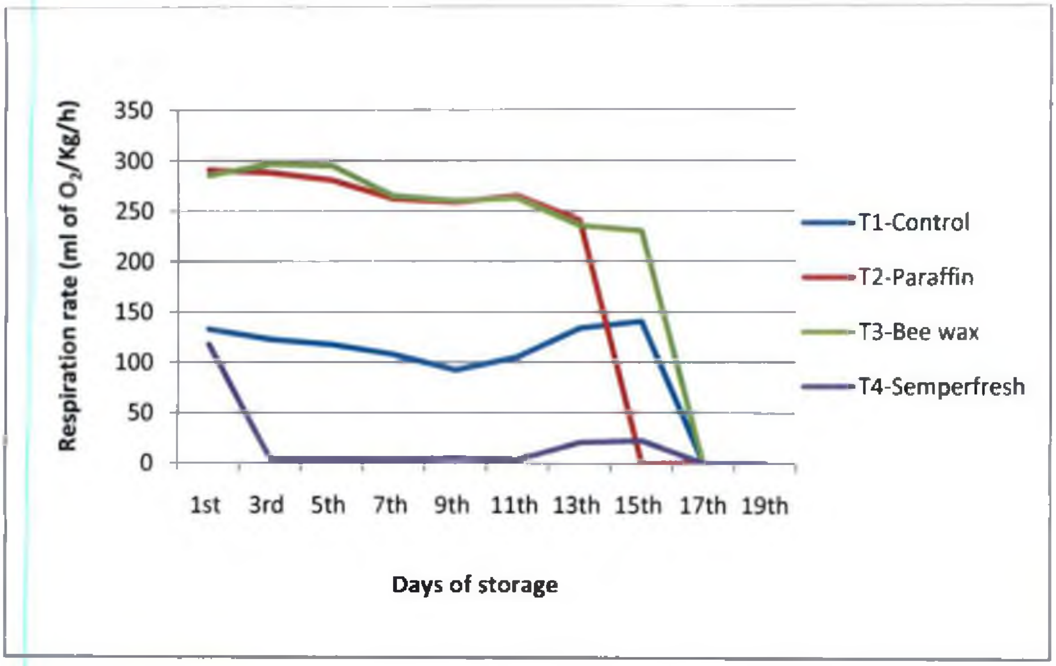


Fig.1. Effect of wax coating on cassava tubers during storage (M-4)

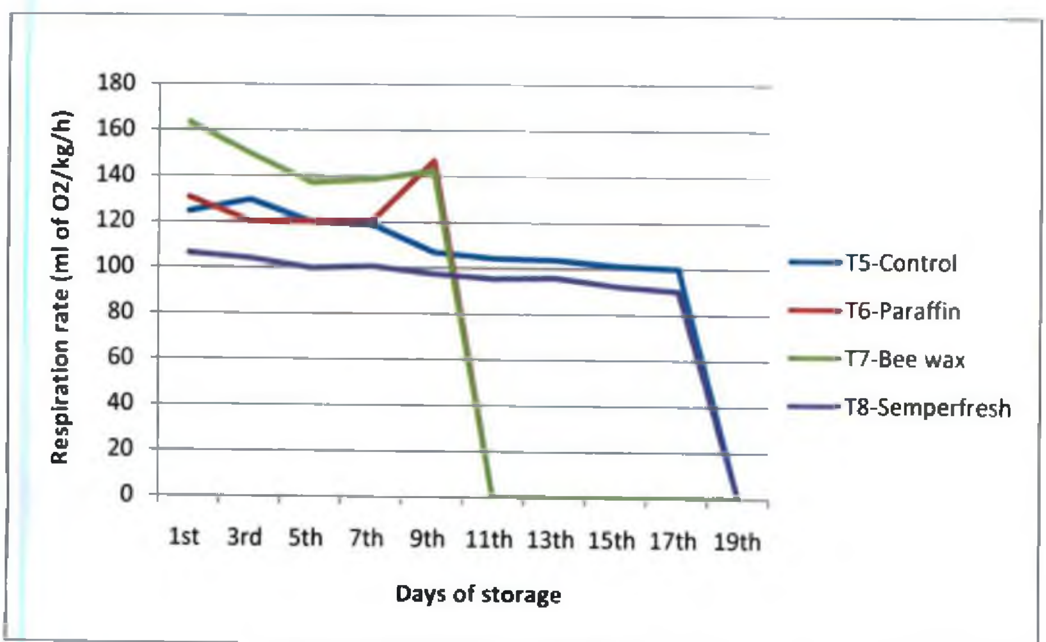


Fig.2. Effect of wax coating on cassava tubers during storage (Sreevijaya)

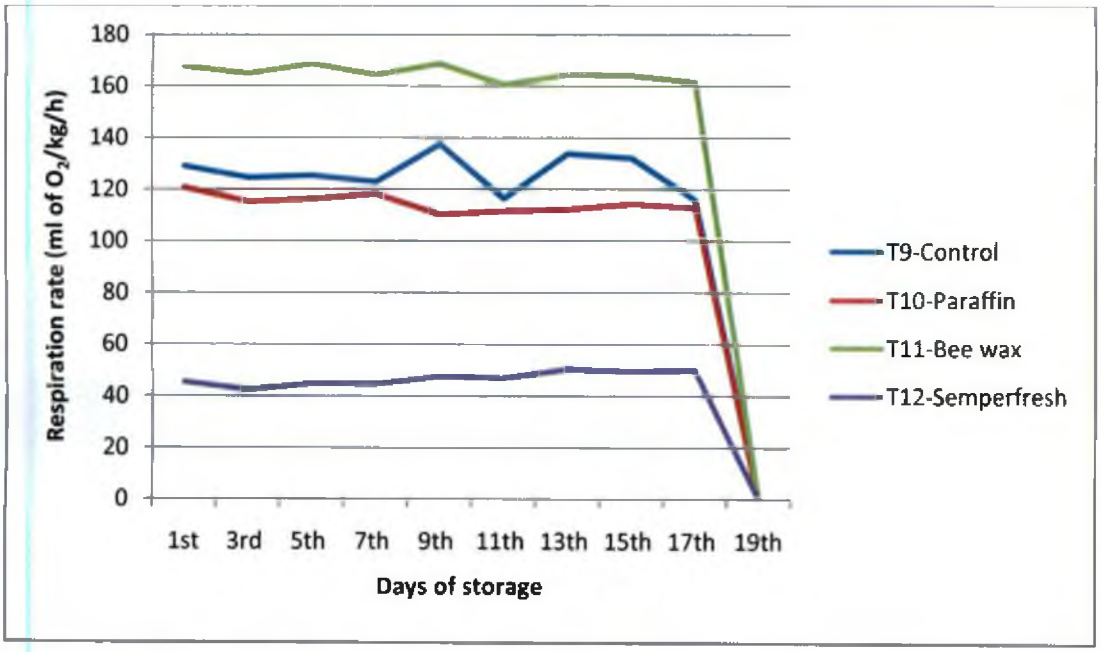


Fig.3. Effect of wax coating on cassava tubers during storage (VellayaniHraswa)

According to Ravi *et al.* (1996), fresh tubers have a very high respiration rate and the resultant heat production soften the tissues leading to damage.The normal atmospheric concentration of 20per cent oxygen is optimal for respiratory processes. However, when this level drops, the respiration rate may be slowed and this trend was noticed in all treatments.

Waxes have been used as an effective technology to increase the post harvest quality of fruits and vegetables (Quipping and Wenshui, 2007; Fan *et al.*, 2009; Tzoumaki *et al.*, 2009; Tietel *et al.*, 2010). The reasons for their use are, they extend product shelf life (Park *et al.*, 1994), control oxidation and respiration reactions (Mc Hugh and Krochta, 1994), and add to texture and sensory characteristics (Guilbert *et al.*, 1996). Waxing creates a modified atmosphere inside the product in which the oxygen content is decreased and the carbon dioxide content is increased. This results in a reduction in the product's respiration rate and an increase in postharvest life (Anonymous, 2004). In the present study, due to waxing suppression in oxygen levels than control was noticed only in semperfresh coated tubers.Semperfresh is a water based formulation and it may have helped to decrease the oxygen uptake by tubers. In the case of paraffin and bee wax, they were oil based emulsions and the oil may have negatively influenced the respiration of tubers, causing early perishability in case of M-4 and Sreevijaya. But in Vellayani Hraswa, except bee wax the other waxes were found to be effective in controlling respiration rate.

Among different waxes tried for the storage of cassava tubers, Semperfresh had an acceptable effect on the cassava tubers in extending its shelf life by reducing its respiration rate. The wax coating (Semperfresh) may have acted as a barrier against respiration, thus controlling the respiration rate (Dou, 1999). Kaynas & Ozelkok (1999) have investigated the effect of 0.8 and 1.0 per cent levels of Semperfresh coating on post harvest quality of two cucumber varieties. Their results showed that Semperfresh application at 1.0 per cent level reduced respiration rate more effectively. In the present study, semperfresh at one percent level was used for application.

According to Aracena (1993), the cassava tubers stored for 4 days with 98 per cent relative humidity had an internal CO_2 production of 8 and 11 µl/ kg/h , While O_2 levels were 9 and 11.5 µl/kg/h for unwaxed and waxed roots, respectively. But their results are contradictory to the values of cassava tubers waxed with paraffin wax in the present study in which the respiration rate were 116.20, 280.28 and 186.84 ml/kg/h in M-4, Sreevijaya and Vellayani Hraswa. Among the three varieties, the tubers treated with paraffin wax showed an increase in respiration rate which resulted in deterioration of tubers by 15^{th} to 17^{th} day of storage. The increase in respiration rate could be due to water stress (Kader, 1987).

Normally wax application should bring down the respiration rate. But in the present study it was not happened in case of paraffin and bee wax application. It may have happened due to the insufficient wax level in the oil emulsion and the excess oil content may have caused an anaerobic condition with in the tuber as suggested by Mathur & Srivastava (1955) resulting in fruit injury. The variation in respiration rate and in turn the metabolic processes was evident in the total carbohydrate and protein levels of tubers during storage. In all the varieties, semperfresh coated tubers retained maximum protein and carbohydrates in tubers.

Weight loss is mainly associated with respiration and moisture evaporation through the skin. Coatings act as barriers, thereby restricting water transfer and protecting peel from mechanical injuries as well as sealing small wounds and thus delaying dehydration (Hernandezmunoz *et al.*, 2008).

In variety M-4, comparatively lower PLW was noticed in wax coated tubers than the control upto the 7^{th} day of storage. On succeeding days the rate of PLW of wax coated tubers was found to be higher than the unwaxed ones. Maximum PLW was noticed in M-4 coated with paraffin wax followed by beewax and minimum in Semperfresh coated tubers on 15^{th} day of storage.

In variety Sreevijaya, on 3rd day of storage, PLW was noticed only in paraffin coated tubers. In Semperfresh coated tubers PLW was noticed from 7th day onwards. Compared to unwaxed tubers (control) the rate of PLW was lower in Semperfresh coated tubers throughout the study. The storage life of unwaxed and semperfresh coated tubers extended upto 17 days.

In variety Vellayani Hraswa, compared to unwaxed tubers the PLW was more in waxed tubers on 3rd day itself. The PLW increased with advancement in days of storage in waxed as well as unwaxed tubers. Tubers coated with beewax formulation showed higher rate of PLW and minimum PLW on 17th day of storage was noticed in tubers coated with the commercial wax, Semperfresh.

After 9 days, paraffin and beewax coated tubers of Sreevijaya deteriorated. By 15th day of storage, the beewax coated tubers of M-4 showed signs of deterioration.

In general, the maximum physiological loss in weight was observed in paraffin waxed tubers followed by beewax treated tubers. The minimum physiological loss was noticed in unwaxed tubers followed by Semperfresh treated tubers. This is in contradictory with the finding of Ezeocha and Oti (2013) in trifoliate yam in which the PLW was highest in the unwaxed tubers. An increase in PLW was noticed among all the treatments with advancement in days of storage. Eventhough the minimum PLW was noticed in control, Semperfresh is also found to be equally good in controlling PLW compared to other waxes used for the study. The moisture content of the tubers also decreased during storage in accordance with the PLW. According to Banks *et al.* (1997) weight can be reduced up to 50 per cent depending upon the type and concentration of wax coating and extend of storage period.

5.1.2. Physical qualities

The three varieties had variation in appearance, colour and extent of vascular streaking. The tubers of M-4 and Vellayani Hraswa were white in colour and the tubers of Sreevijaya were creamy white in colour.

In the case of Vellayani Hraswa, there was no change in internal colour of tubers for two weeks. In bee wax coated cassava tubers (T_3 and T_7) the signs of vascular streaking was noticed on 11th day itself. According to Sargent *et al.* (1995) waxing and holding the cassava tubers at 0 to 5°C extended shipping time to more than 30 days with minimal occurrence of vascular streaking. This was contradictory to the results of present study and in this study the tubers were stored under ambient conditions.

According to Asaoka *et al.* (1993) rapid post-harvest physiological deterioration of cassava tubers begin within 24 h of harvest. The shelf life of fresh cassava is limited because they are highly perishable (Udoro *et al.*, 2008). When semperfresh coated tubers of M4, Sreevijaya and Vellayani Hraswa were evaluated, vascular streaking was noticed only by 17th day of storage. Physiological post harvest deterioration or vascular streaking among different cassava varieties and within the same variety has revealed a considerable variation in the degree of development and PPD response is under genetic control and is also influenced by environmental factors (Plumbley and Richard, 1991, Aristizabal and Sanchez, 2007 and Buschmann *et al.*, 2000).

There are many kinds of metabolism that are activated during PPD in cassava. It has been found that sugar contents increased and the amount of starch decreased during the process, while amylase activity was found to be present following the discoloration in cassava tuberous roots (Maini and Balagopal, 1978). It has also been shown that there are many changes in protein level which are not only caused by degradation and synthesis of existing proteins but also by *de novo* production of novel proteins (Beeching, *et al.* 1994, Wenham, 1995, Uritani, 1998 and 1999). It was also reported that the amount and composition of membrane lipids were changing following the deterioration in cassava tuberous roots, which was hypothesized to be due to membrane disorganization or membrane degradation during the deterioration process in cassava tuberous roots (Tanaka, *et al.*,1983, Lalaguna and Agudo, 1989).The above mentioned changes were also observed in the present study.

The major symptom of vascular streaking such as blue or black vascular streaking, brownish occlusions accompanied by an unpleasant flavour and odour (Reilly *et al.*, 2007) were observed in Vellayani Hraswa and M-4 after two weeks. But, in the case of Sreevijaya, the tubers treated with paraffin wax and beewax it was observed within 9 days.

5.1.3. Chemical and nutritional qualities

The three varieties of cassava tubers were waxed in single layer and stored after packing in ventilated paper cartons under ambient conditions till it showed the signs of deterioration. The chemical and nutritional qualities were evaluated initially and after second week of storage. Since tubers of M-4 and Sreevijaya coated with paraffin and beewax were deteriorated by 12 to 13th day of storage, their chemical and nutritional constituents could not be evaluated on 14th day of storage.

The moisture content among the three varieties of cassava tubers was in the range of 54.86 to 63.93 per cent initially (Fig. 4). The moisture content noticed in the present study was found to be less than the reported value of 70 per cent by Hahn *et al.* (1987) and almost similar to the content of 59.4 per cent reported by Gopalan *et al.* (2012). Padonou *et al.* (2005) and Zvinavashe *et al.* (2011) had given a wide range of 60.3 to 87.1 per cent moisture content in cassava tubers. A decrease in moisture content of cassava tubers was noticed during two week of storage. Both the waxed and unwaxed tubers showed a decrease in moisture content. The moisture content in waxed as well as unwaxed cassava tubers was in the range of 41.96 to 62.77 per cent after two week of storage. The moisture content after two weeks of storage substantiates the PLW noticed in the tubers during storage.

The reduction in moisture during storage of cassava tubers can be attributed to various physiological processes. Afoakwa and Sefa-Dedeh (2001) has related this high moisture loss observed in yams to the hardening phenomenon. He suggested that the rapid water removal in the tubers may cause the cell wall polysaccharides to shrink

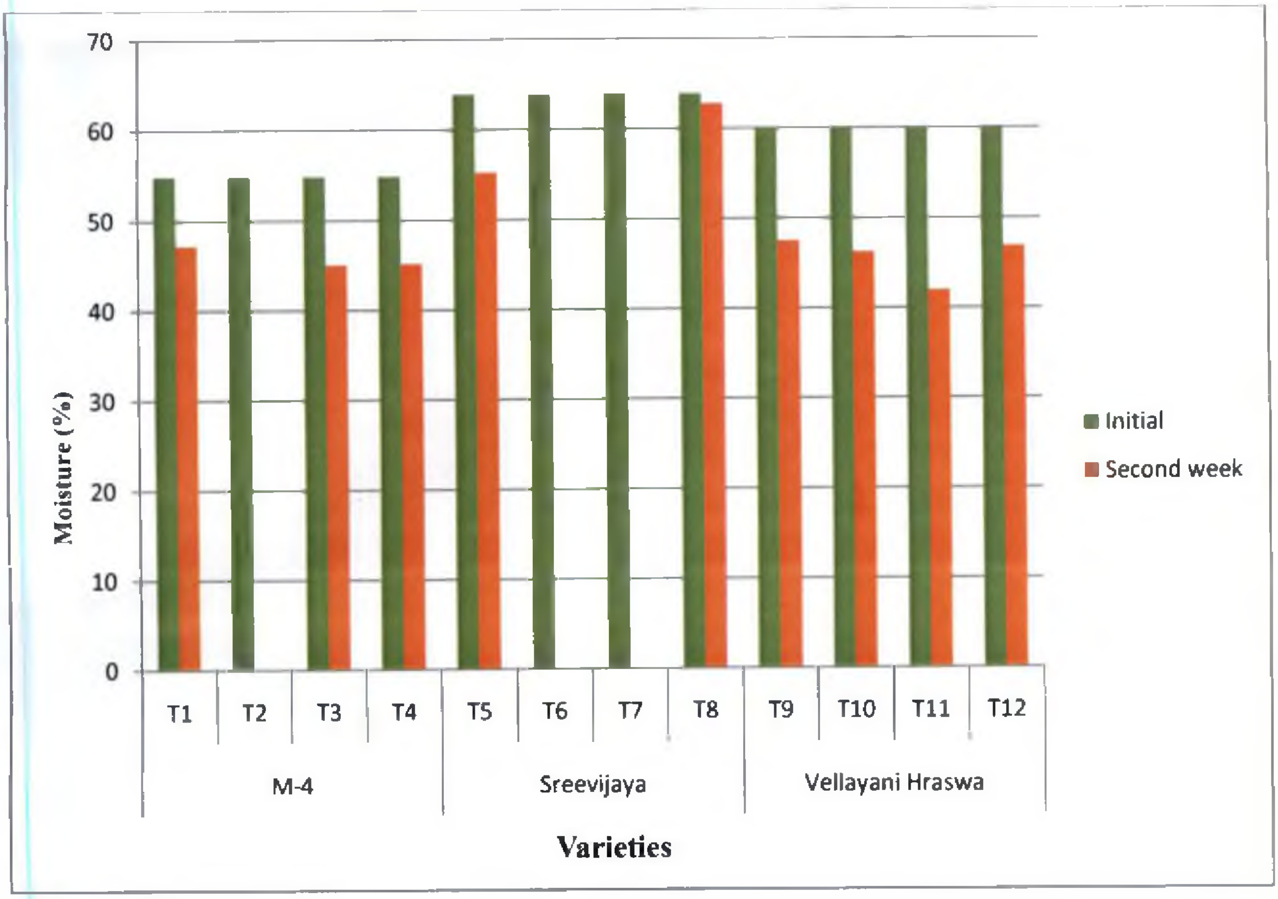


Fig.4. Moisture content (%) of waxed cassava tubers in comparison with control during storage

permitting greater interactions by means of hydrogen bonding and Van der waals forces, resulting in increased cell rigidity during storage.

Waxing significantly reduced the rate of moisture loss in case of semperfresh coated tubers of variety Sreevijaya alone.In other varieties, the percentage moisture loss was higher than control especially for bee wax and paraffin wax. The same trend was seen in the evaluation of PLW. In the preliminary trials when the waxes were tried at different concentration, one per cent concentration of the three waxes was very effective in preventing moisture loss in all the three varieties. But when the actual work was done highly fluctuating results were obtained and the paraffin and bee wax could not preserve the tubers for upto14 days. From this, it can be concluded that harvesting maturity of tubers is very important for while selecting tubers for waxing.

Afoakwa and Sefa-Dedeh, (2001) evaluated the effect of different waxes on moisture loss of tubers. They reported that bee waxed tubers had the highest moisture retention on 2^{nd} , 4^{th} and 6^{th} week of storage however on the 8th week of storage the moisture content reduced with palm wax having the highest retention. This was found to be contradictory with the results of present study in which bee wax was not effective in controlling moisture loss. A study conducted by Ezeocha and Oti (2013) in trifoliate yam also reported reduction in moisture content with increase in storage period.

Among all the treatments, the tubers treated with semperfresh were found to be more effective in preventing moisture loss. The possible reason may be that commercial wax served as a semi permeable membrane around the fruit surface which resulted in reduction of transpiration and rate of respiration, thereby reducing the moisture loss and hence the PLW (Kaushal and Thakur, 1996). Those treated with paraffin and beewax except in the case of Vellayani Hraswa, were susceptible to damage at early days of storage. The oil in the wax emulsion may have negatively influenced the gas exchange and water loss or retention. Further studies are required to find out the exact mechanism which led to the early perishability of tuberswaxed with paraffin and bee wax.

Among the three varieties, Vellayani Hraswa is having maximum amount of protein content (1.08 g/100 g) compared to other varieties (Fig 5). Cassava is not a good source of protein and reported a protein content of 1 to 3 per cent on a dry matter basis and between 0.4 and 1.5 g/100 g on fresh weight basis (Bradbury and Holloway, 1988). The content of some essential amino acids, such as methionine, cysteine, and tryptophan, is very low in cassava. However, the roots contain an abundance of arginine, glutamic acid, and aspartic acid (Gil and Buitrago, 2002). About 50 per cent of the crude protein in the roots consists of whole protein and the other 50per cent as free amino acids (predominantly glutamic and aspartic acids) and non protein components such as nitrite, nitrate, and cyanogenic compounds.

According to Balagopalan *et al.* (1990), the crude protein content of whole cassava roots is around 3.5 per cent on dry weight basis and 40 to 60 per cent of the total nitrogen is non protein nitrogen.

Crude protein content decreased significantly during storage (0.92 to 38.82 %). A similar observation was made by Otegbayo *et al.* (2011) in two varieties of yam. The decrease in crude protein content of the tubers with increase in storage period may have been a result of the breakdown of protein in the tubers by endogenous proteases (Osuji and Umezurike, 1985).

The fat content in cassava tubers was found to be 0.2g in all the three varieties (Fig.6). According to Charles *et al.* (2005) and Montagnac *et al.* (2009), the lipid content in cassava roots ranged from 0.1 to 0.3 per cent on a fresh weight basis. Padonou *et al.* (2005) had given the fat content in cassava as 0.65 per cent on a dry weight basis. After two week, the fat content present in waxed and unwaxed tubers was in the range of 0.23 to 0.29 per cent. A slight increase in fat content was noticed during two weeks of storage of tubers. The insignificant increase in fat content can be attributed to the moisture loss during storage of tubers. It was also reported that the amount and composition of membrane lipidswere changing following the deterioration in cassava tubers, which washypothesised to be due to membrane disorganisation or

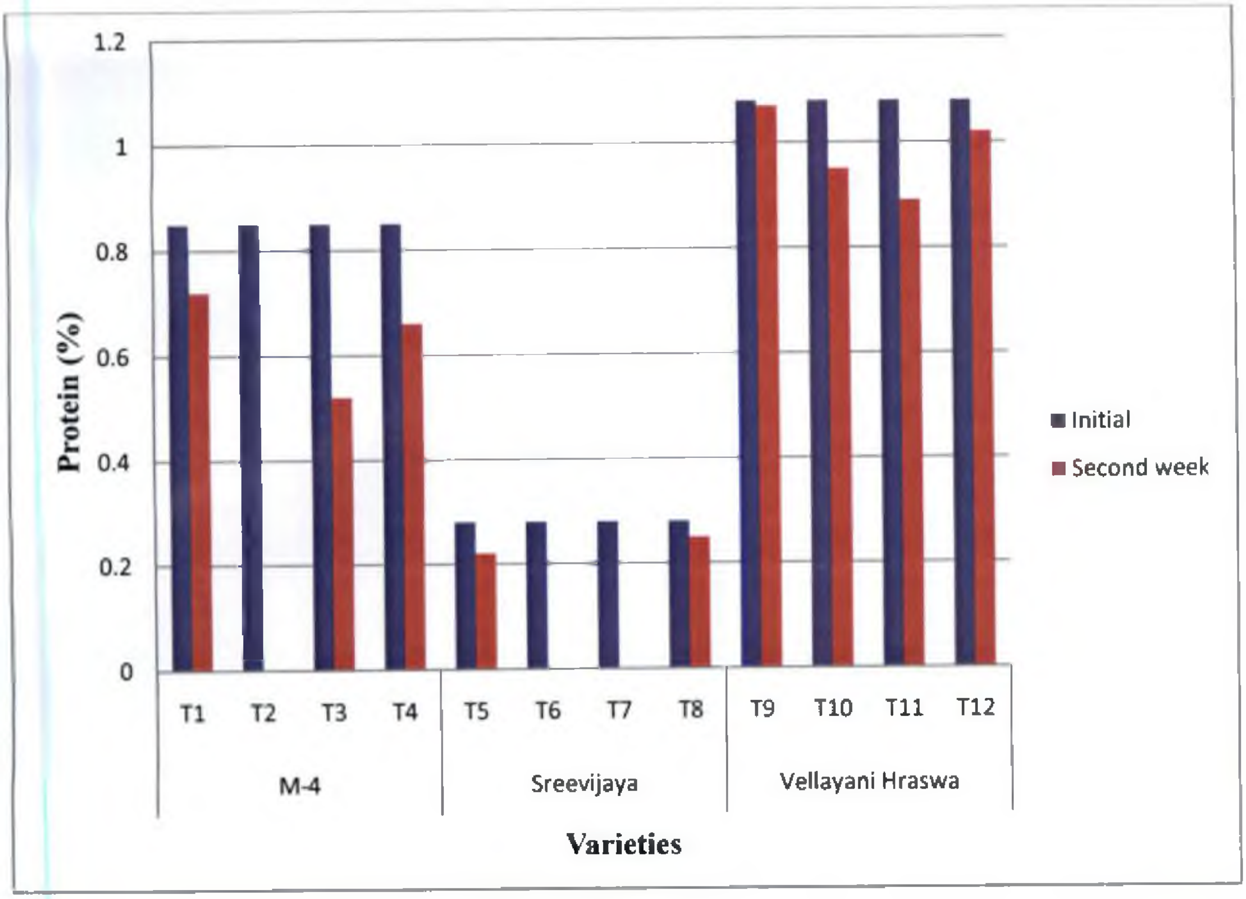


Fig.5. Protein content (%) of waxed cassava tubers in comparison with control during storage

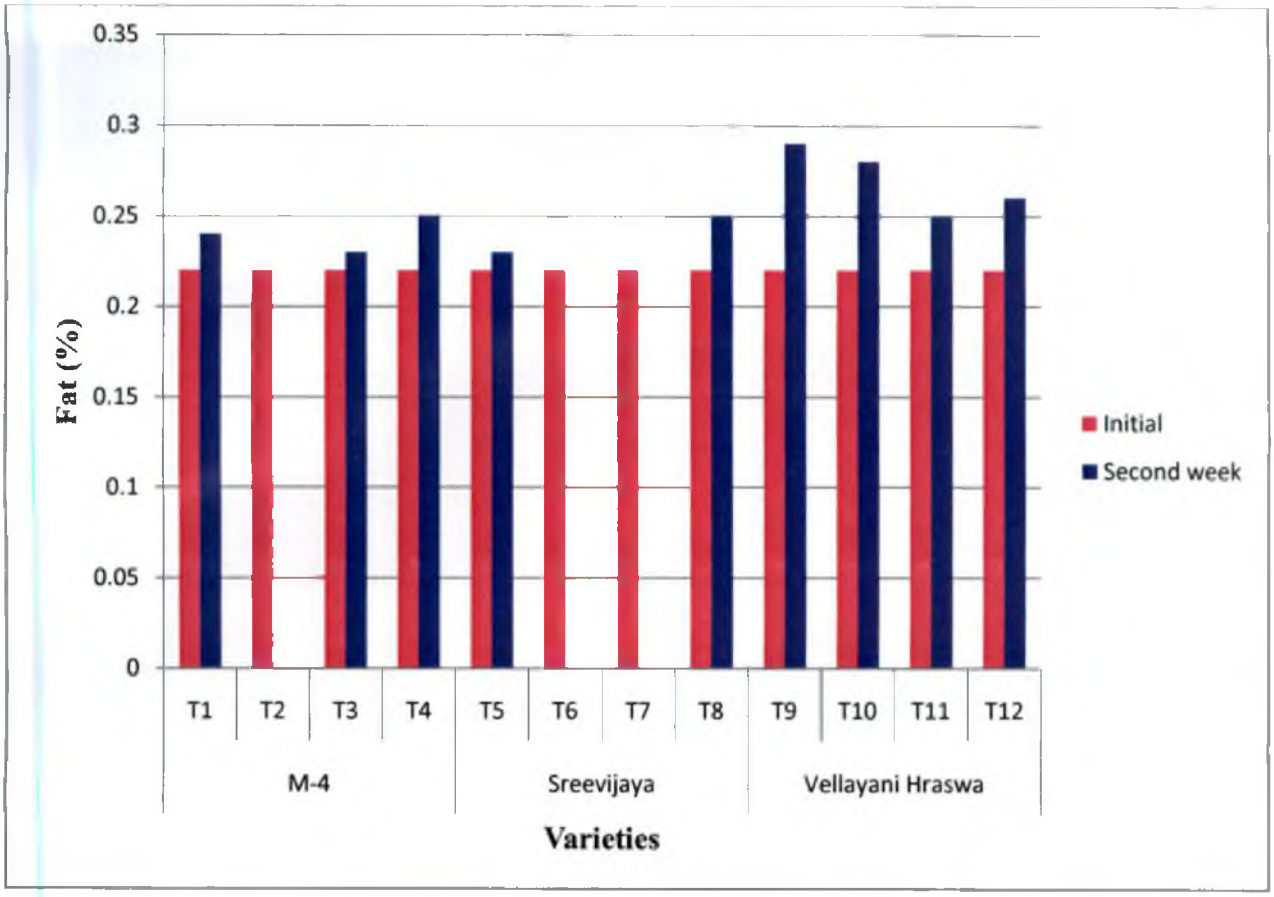


Fig.6. Fat content (%) of waxed cassava tubers in comparison with control during storage

membrane degradation duringthe deterioration process in cassava tuberous roots (Tanaka, *et al.,* 1983, Lalaguna andAgudo, 1989).

The fibre content of waxed and unwaxed cassava tubers was in the range of 0.55 to 0.76 percent (Fig.7). The maximum fibre content was noticed in T_5 (0.92/100 g) and minimum in T_4 (0.59 g/100 g) during storage. The fibre content in cassava roots depends on the variety and the age of the root. Usually its content does not exceed 1.5 per cent in fresh cassava roots (Gil and Buitrago, 2002).

In all the varieties an increase in fibre content was noticed during storage and the percentage increase was minimum in semperfresh coated tubers. According to Ezeocha and Oti (2013), the crude fibre content of the tubers (which is composed of lignin, pectin, acid detergent fibre and cellulose) increased significantly with increase in storage period. A similar observation was made by Brillouet *et al*, (1981); Treche and Agbor-Egbe, (1996); Sefa-Dedeh and Afoakwa (2002) and Otegbayo *et al*, (2011) in *D. rotundata, D. alata and D. dumetorum*. The increase in crude fibre content during storage may be due to hardening phenomenon which usually develops few days after storage as suggested by Ezeocha and Oti (2013).

Carbohydrate content in fresh tubers varied from 29.47 to 38.22 per cent and the starch content was23.11 to 28.56 percent. After two weeks of storage the total carbohydrate and starch content varied from 25.43 to 37.47 per cent and 21.75 to 27.89 per cent in different treatments (Fig.8). According to Westby (2002), most of the carbohydratein cassava is present as starch (31 per cent of fresh weight). The starch content of mature cassava roots can be ranged from 15 to 33 per cent depending on the climate and the harvesting time (Breuninger *et al.,* 2009).Cassava produces higher amounts and better quality of starch compared to other tuber and cereal crops(Nuwamanya *et al.*, 2010).

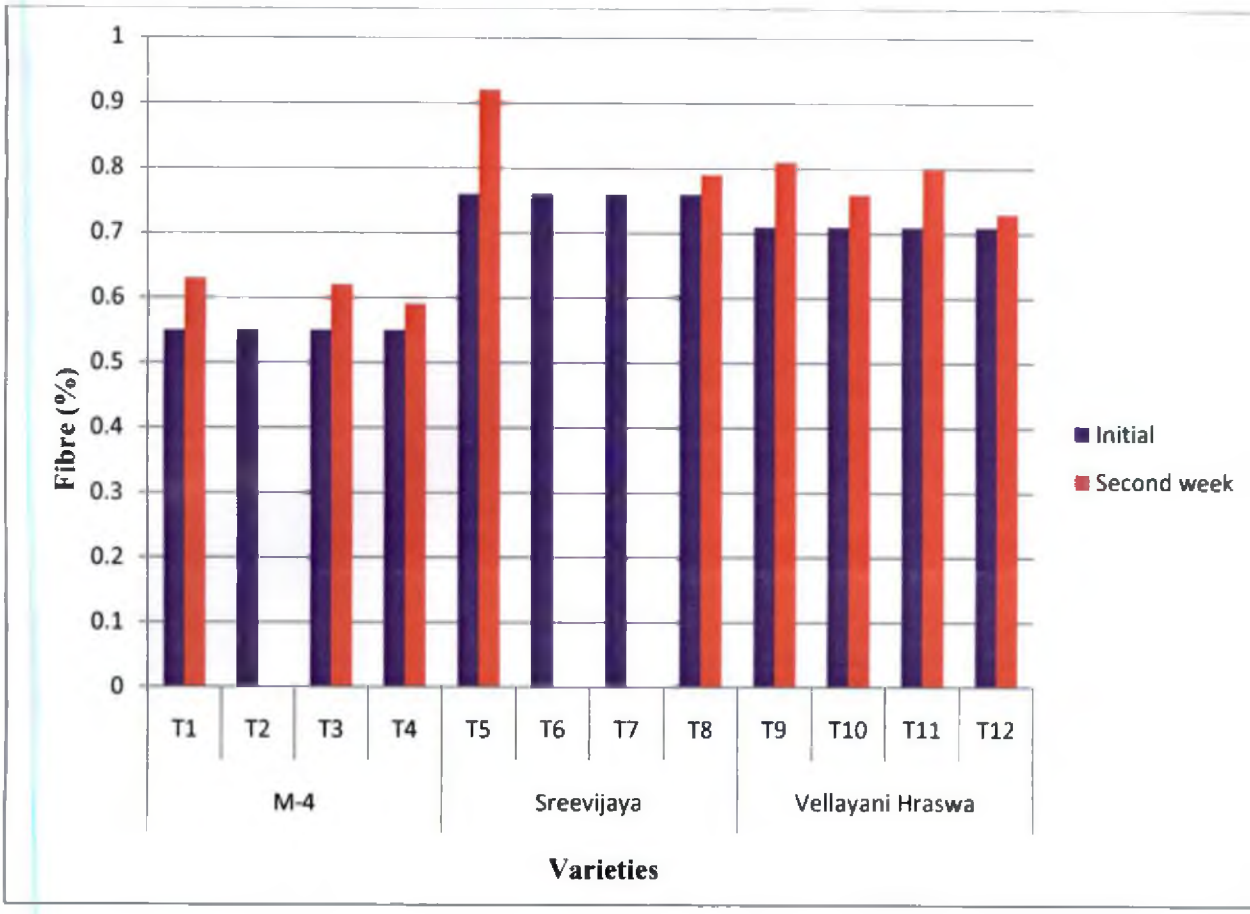


Fig.7. Fibre content (%) of waxed cassava tubers in comparison with control during storage

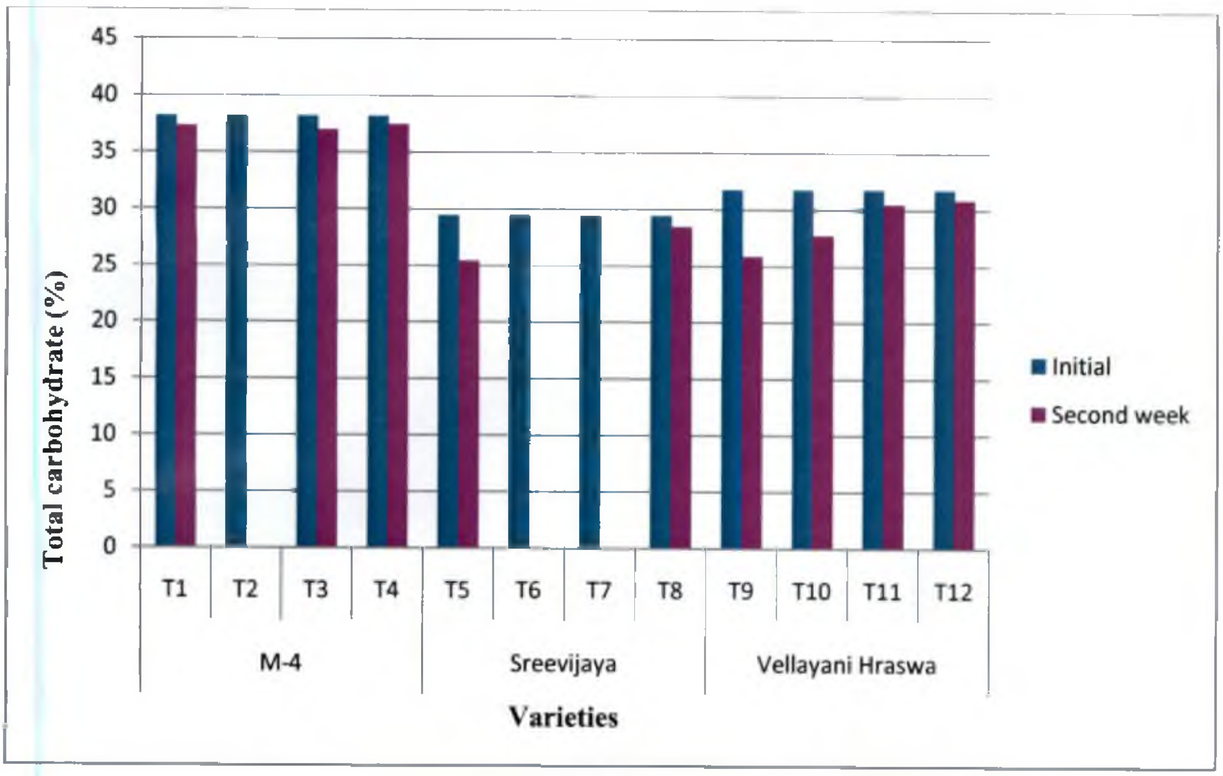


Fig.8. Total carbohydrate (%) content of waxed cassava tubers in comparison with control during storage

A decrease in carbohydrate content was noticed in majority of the treatments after two weeks. This decrease is due to difference in starch yield between cassava varieties as suggested by Apea-Bah *et al.* (2011). The composition changes slightly with increasing age as the roots become more fibrous and the starch content declines.

The starch content in unwaxed tubers of three varieties varied from 23.11 to 28.56 per cent initially (Fig 9). Maximum starch content was noticed in Vellayani Hraswa and minimum in Sreevijaya. The maximum decrease in starch content was noticed in tubers coated with beewax (17.78 per cent) and the minimum was showed by semperfresh coated tubers (2.35 per cent).The decrease in the starch yield of tubers during storage period may have been as a result of the conversion of starch to sugars by endogenous α-amylase during metabolic activities (Otegbayo *et al*, 2011).

Cassava starch granules are mainly composed of two polysaccharides, amylose (20%) and amylopectin (80%) (Sandoval, 2008).About 64 to 72 per cent of the carbohydrate is starch mainly in the form of amylose and amylopectin. Initially the amylose content varied from 9.93 to 12.73 per cent and the amylopectin content in the range of 13.18 to 16 per cent (Fig. 10 & 11). In two week of storage a decrease in both amylose and amylopectin was noticed in all treatments. Hydrolytic degradation may have resulted in changes in the content of amylose and amylopectin.

An increase in total and reducing sugar was noticed during second week from the initial content (Fig 12 & 13). According to (Booth *et al.,* 1976; Osunsami *et al.*, 1989; Akingbala *et al.,* 2005;Lin *et al.*, 2011:), total sugar content increased consistently throughout the storage period. This was supported by Chellammal (1995) who reported that the conversion of starch to sugar during storage as the reason for the increase in sugar content of stored products. Usually the content of soluble sugars (hexose and sucrose) increased during storage. Sucrose, which is the major form of translocatable carbohydrate, and the most abundant of the sugars, increased much more than the hexose (Huang *et al.*, 2001).

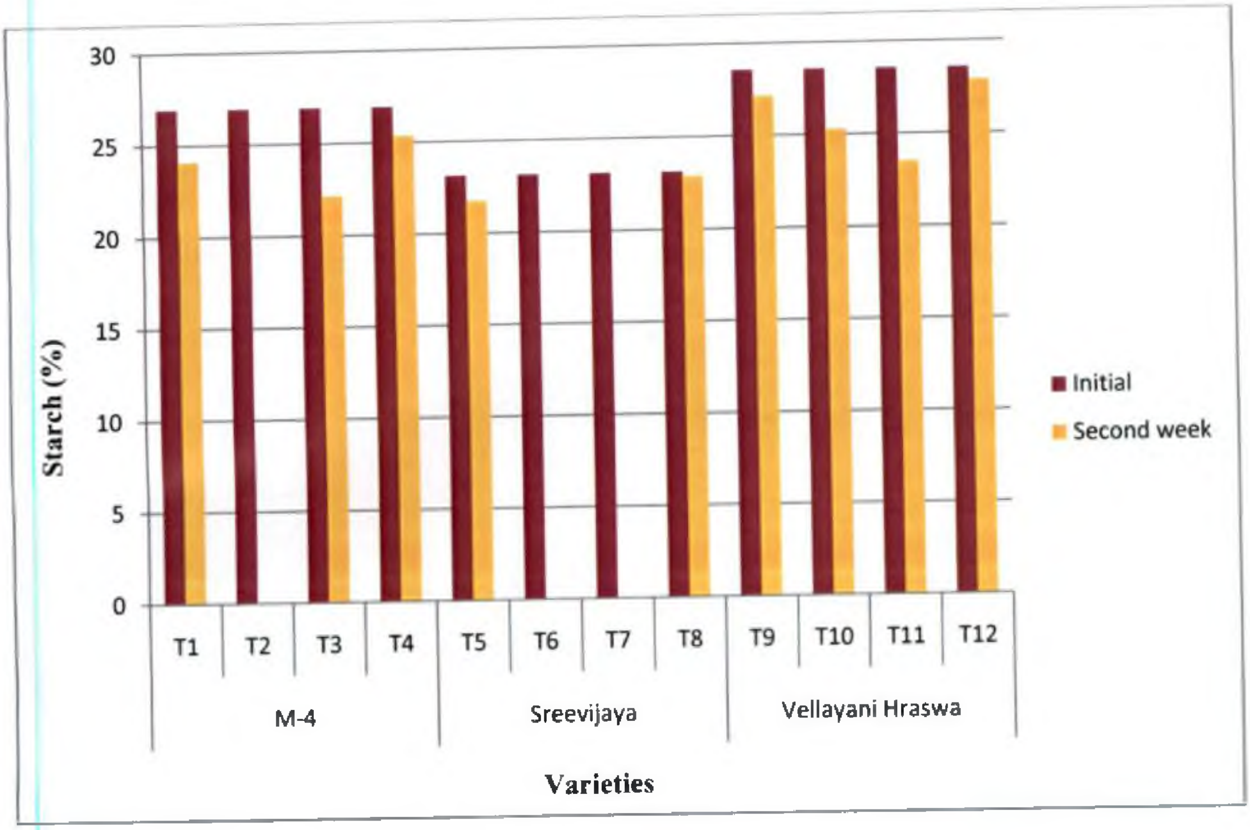


Fig.9. Starch content (%) of waxed cassava tubers in comparison with control during storage

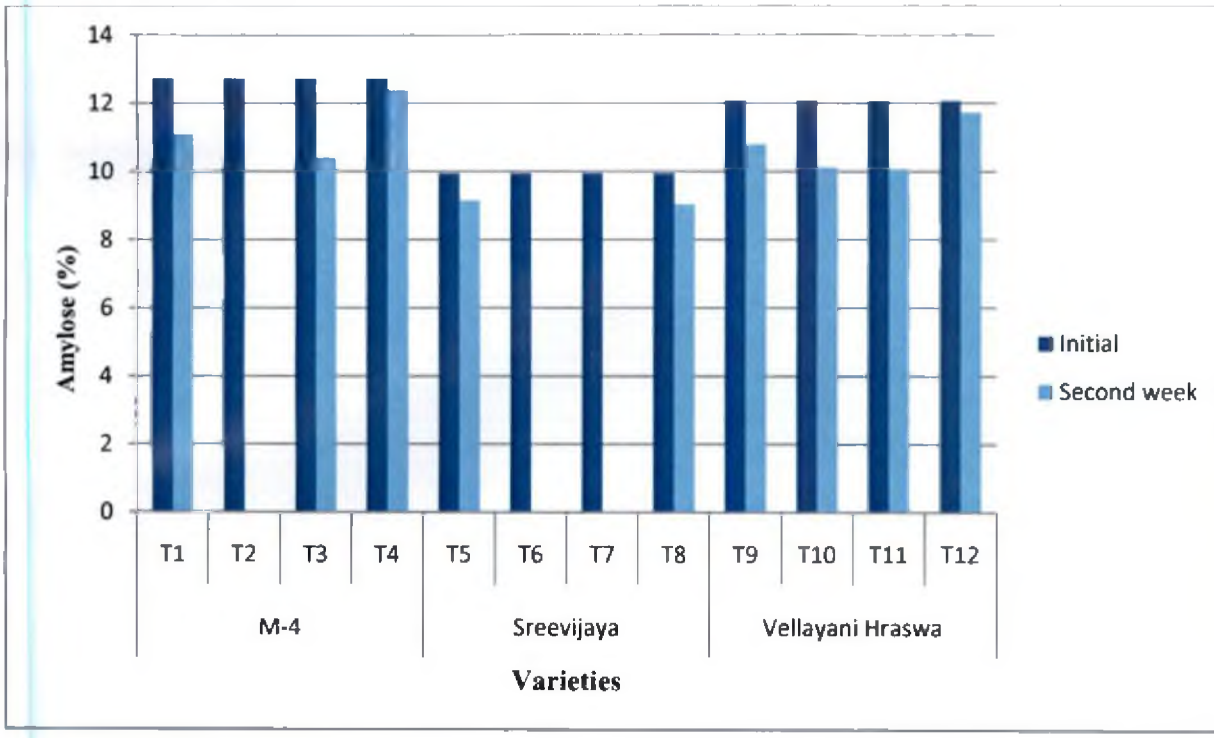


Fig.10. Amylose content (%) of waxed cassava tubers in comparison with control during storage

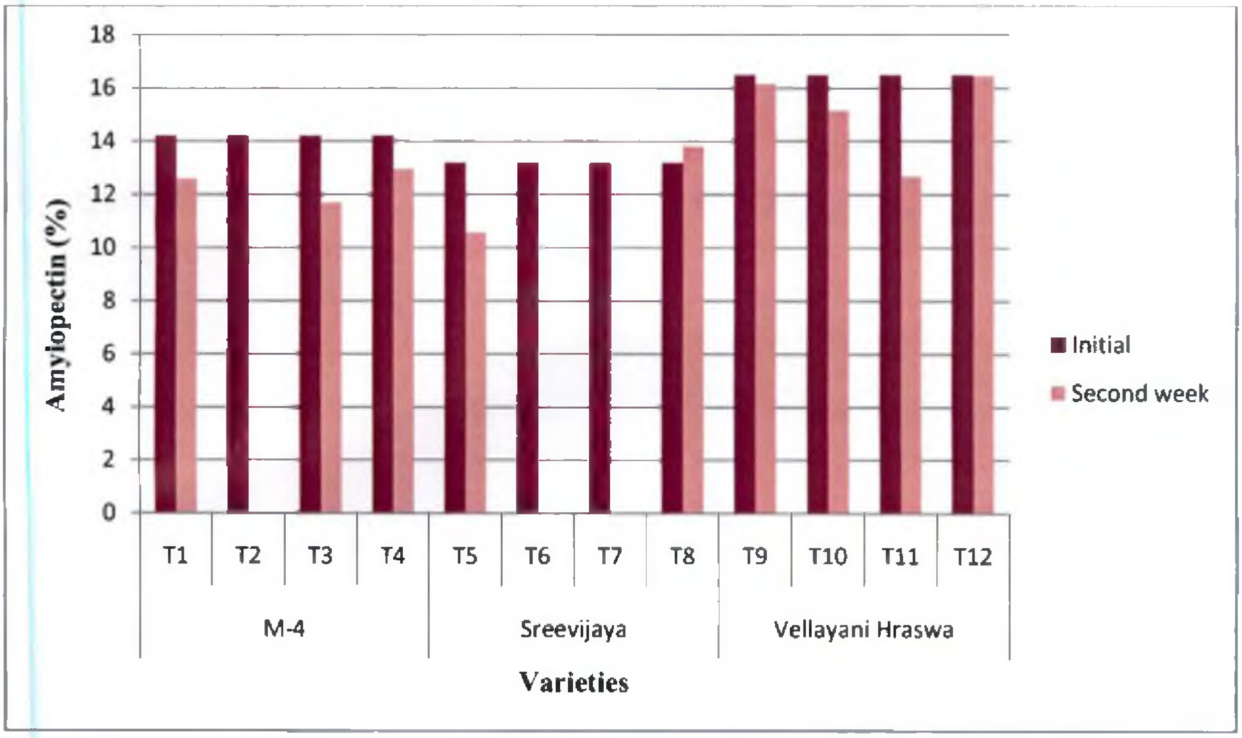


Fig.11. Amylopectin content (%) of waxed cassava tubers in comparison with control during storage

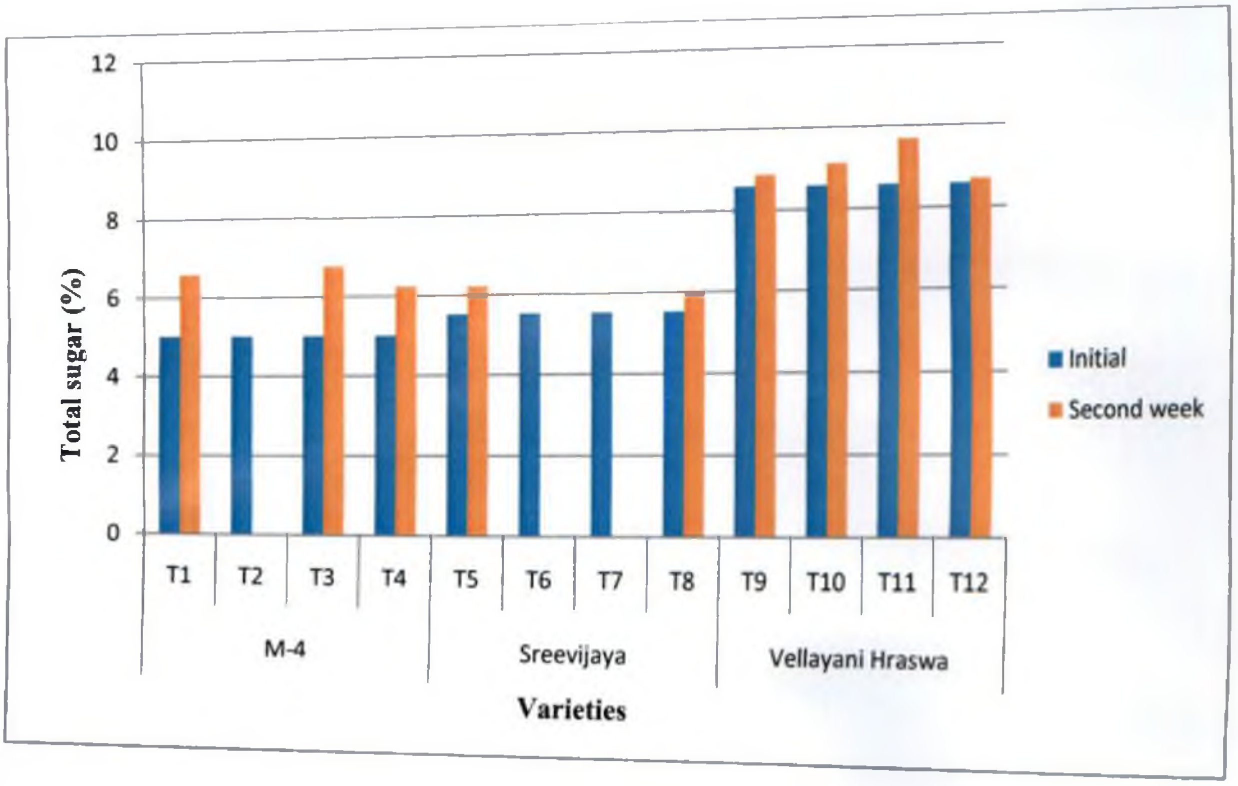


Fig.12. Total sugar content (%) of waxed cassava tubers in comparison with control during storage

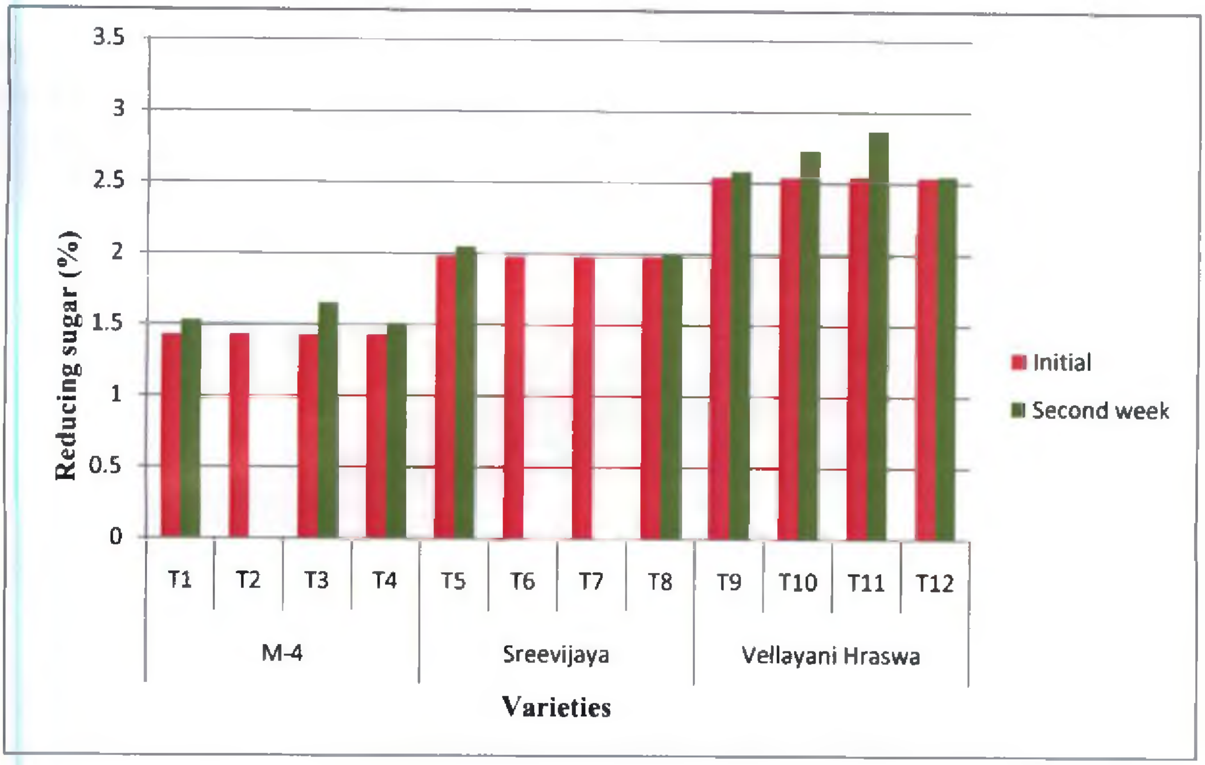


Fig.13. Reducing sugar content (%) of waxed cassava tubers in comparison with control during storage

β-carotene content was not detected in M-4 and Vellayani Hraswa .It was observed in Sreevijaya only which is slight creamy yellow in colour. This was supported by Sanchez *et al.* (2005) that cultivars with yellow roots have higher β-carotene content. After two weeks a slight decrease in β-carotene content was noticed and this may due to the photalabile nature of carotenes.(Chavez *et al.*, 2000).

Gloria and Uritani (1984) found that a decrease in β-carotene is also correlated with severity of PPD and may be related to the production of lipoxygenase or a kind of β-carotene bleaching enzyme in parallel with the appearance of PPD.

Initially the calcium content of cassava tubers ranged between 23.53 to 38.07 mg/100 g which was in accordance with the calcium content of 30 to 33 mg/100 g reported by Sarkiyayi and Agar (2010) in sweet and bitter cassava varieties. In two weeks of storage slight increase in calcium content was observed and the percentage increase varied from 0.21 to 7.35 per cent (Fig 14). The increase in calcium content can be attributed to the decrease in moisture content.

The HCN content in three varieties varied from 32.26 to 59.63 mg/kg of tubers (Fig. 15). This was supported by Breuninger *et al.* (2009) who reported that the HCN content in cassava roots varies depending on the cultivar, harvest time, environmental factors such as drought, pests and diseases and agronomic practices. According to Ndung'u *et al.* (2010), cassava cultivars with less than 50 mg/kg HCN are classified as less poisonous (low cyanide), 50-100 mg/kg as moderately poisonous (medium cyanide) and those over 100 mg/kg are dangerously poisonous (high cyanide).

During second week, the cyanide content in cassava tubers significantly decreased.A percentage reduction upto 17.85 per cent was noticed. Accumulation of cyanogenic glucosides, a decrease in linamarase activity and a slight decline in HCN content under PPD has also been reported (Maini and Balagopal, 1978; Kojima *et al.*, 1983; Westby, 2002). HCN is not uniform throughout the cassava root as there is evidence of a radial gradient from the cortex to the peripheral part in terms of cyanide content and linamarase activity (Kojima *et al.*, 1983).

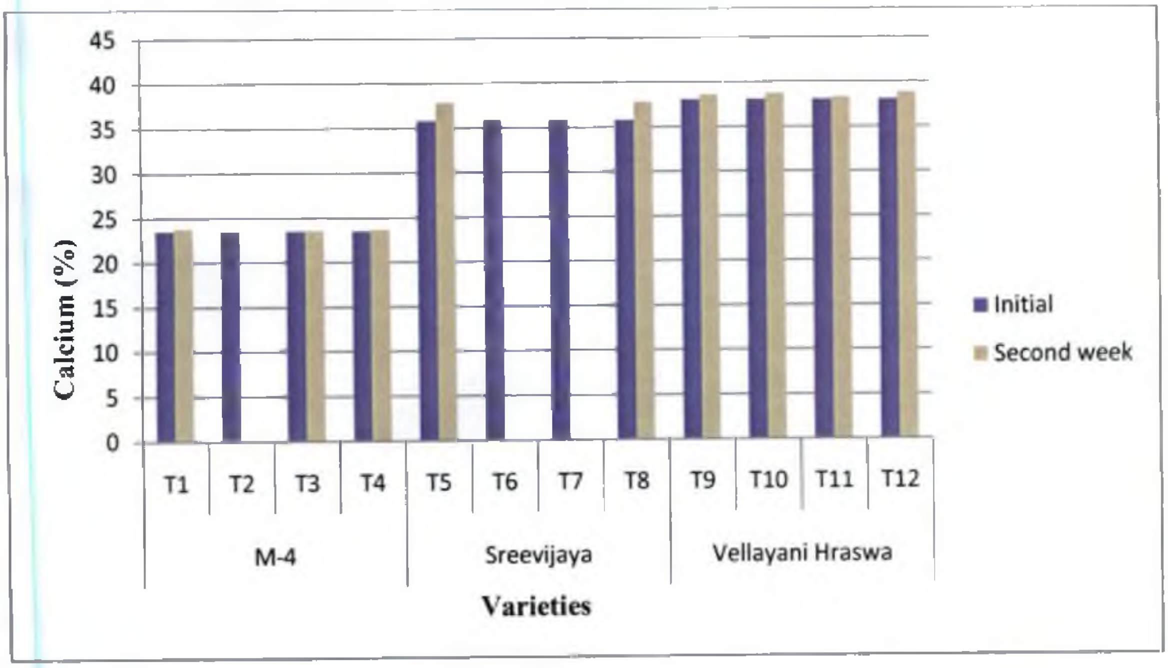


Fig.14. Calcium content (mg 100g-[1]) of waxed cassava tubers in comparison with control during storage

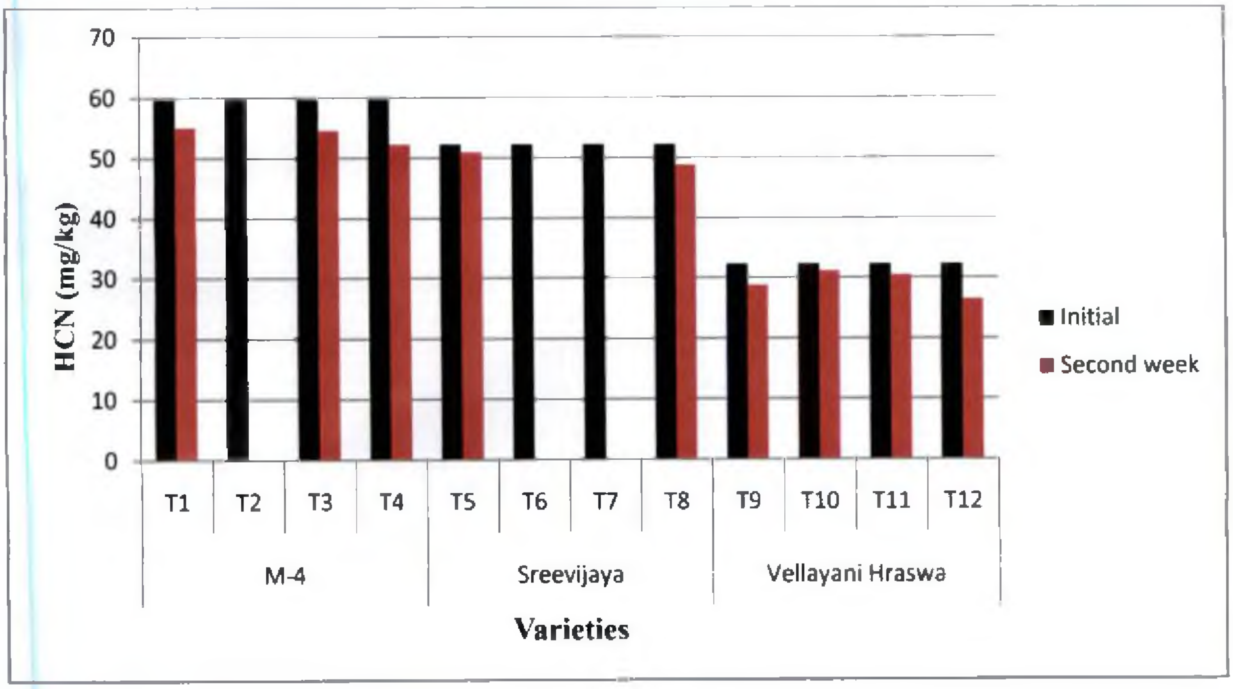


Fig.15. HCN content (mg/kg) of waxed cassava tubers in comparison with control during storage

5.1.4. Organoleptic qualities

According to Asaoka *et al.* (1993) the organoleptic qualities of the cooked roots showed considerable differences in glassiness and hardness of texture, both between varieties and times of harvest. The fresh cassava tubers of three varieties were selected as control in this study. The mean scores for most of the organoleptic qualities of unwaxed cassava tubers showed slight increase during storage. The waxed tubers were less acceptable during storage except semperfresh.The physical and structural changes taking place in the starch due to boiling have a significant influence on the cooking quality of the tubers. (Beleia *et al.*, 2004).

The initial score for appearance of three varieties of cooked cassava tubers varied from 8.60 to 8.96. During storage a gradual increase in the mean score for appearance was noticed among unwaxed tubers except in M-4. But a gradual decrease in the mean score for appearance was noticed in waxed tubers. The gradual decrease in appearance is due to the condensation of moisture resulting in white deposits that are translucent in appearance (Anon, 2004).

The colour of the cooked cassava tubers were light yellow initially. The intensity of the colour slightly differed among varieties. After two weeks of storage, change in cooked colour to deep yellow was noticed among waxed tubers. Much variation in colour was noticed when the unwaxed tubers were cooked.

Initially for flavour of cooked cassava tubers better scores was noticed. But after two weeks, the mean score for flavour gradually decreased in waxed tubers. This was especially noticed in paraffin and beewax coated tubers. The unwaxed tubers and waxed tubers had almost same flavour but comparatively the score for unwaxed tubers was found to be high during storage. As per Anonymous (2004), waxing restricts gas exchange and decreases the O_2level which stimulate anaerobic respiration and production of off-flavours in the tubers. This is also supported by the results of Baldwin*et al.*, (1995) and Nisperos-Carriedo *et al.*, (1990)in which they suggest that coating of fresh produce can result in flavour changes due to the entrapment of volatiles by the wax coating applied or by the effects of coating on metabolism.

Textural properties of raw and cooked tubers depend on variety, maturity, growing environment, physico-chemical and starch properties (Sajeev *et al.*, 2010). After two weeks of storage a decrease in the mean score for texture was noticed from the initialvalue. The unwaxed tubers gained more score for texture than waxed tubers.

Initially better mean score for taste was noticed in three varieties. But after two weeks of storage, a decrease in the mean score for taste was noticed among waxed tubers. The mean score for taste of unwaxed cassava tubers was found to be high in second week of storage except in Vellayani Hraswa. The tubers treated with Semperfresh also showed better mean score for taste compared with the other waxed tubers.

In case of overall acceptability, lower mean score for waxed tubers than unwaxed tubers was noticed after two weeks of storage. The highest score was observed in M-4 and Vellayani Hraswa. The least acceptable treatment was T_7, the tubers treated with beewax formulation indicating a decline in the overall acceptability scores of waxed cassava tubers during storage period.

In general, among waxed tubers comparatively semperfresh tubers were found to be acceptable organoleptically after two weeks of storage. Better acceptance was noticed for unwaxed tubers.

5.5 Cost analysis of wax application

Cost analysis of wax application was done and the cost of production was worked out on the basis of market prices of different waxes. The application of wax on cassava tubers is done by using three waxes such as paraffin wax, beewax and semperfresh. The cost for paraffin wax was Rs.630 for 500g, for beewax it was Rs.10 for 1000g and for semperfresh,the cost was Rs. 5000 for 500 ml. The cost of oil used for application was also taken into account. 100 ml of 1 percent wax emulsion can be applied on three cassava tubers weighing approximately 1 kg. Accordingly the cost for wax application was Rs. 7.96 for paraffin wax, Rs.6.71 for beewax and Rs.10 for semperfresh. Eventhough the semperfresh is an imported costly wax, it was found to be comparatively better in extending the shelf life of cassava tubers.

Summary

6. SUMMARY

The present study entitled "Standardisation of wax coating in cassava (*Manihot esculenta* Crantz) tubers and quality evaluation" was aimed to standardise the percentage of wax coating to be applied on cassava tubers and to evaluate various physico-chemical and nutritional attributes of wax coated cassava tubers.

Three varieties namely, M-4, Sreevijaya and Vellayani Hraswa were selected for the study. The waxes used for application on tubers were paraffin wax, bee wax and semperfresh (commercial wax). After conducting preliminary trials, wax concentration at 1 per cent level, which prolonged the days of storage with minimum physiological loss in weight was selected for application.

Wax coated cassava tubers were stored after packing in ventilated paper cartons under ambient conditions till it showed the signs of deterioration. Unwaxed cassava tubers were taken as the control. The shelf life, physical, chemical, nutritional and organoleptic qualities of tubers were evaluated.

The shelf life qualities of unwaxed and waxed cassava tubers were observed by measuring its respiration rate and physiological loss in weight at two days interval. In variety M-4, the respiration rate of unwaxed and semperfresh coated tubers was similar upto 9th day of storage. Significant variation in the respiration rate was not observed in paraffin and beewax coated tubers but they differed significantly from control and semperfresh coated tubers. The paraffin and beewax coated tubers of Sreevijaya showed the signs of deterioration by 11th day whereas a gradual decrease in respiration rate was noticed in control and semperfresh coated tubers. Wide fluctuation in respiration rate was noticed in all the treatments of Vellayani Hraswa upto 17th day of storage.

In M-4, the rate of PLW of wax coated tubers were found to be higher than the unwaxed tubers initially. Among the wax coated tubers, the minimum PLW was noticed in semperfresh coated tubers (6.76 per cent) of M-4. In variety Sreevijaya, the maximum PLW was noticed in unwaxed tubers, ie, 7.79 per cent and minimum PLW of 1.44 per cent was noticed in semperfresh coated tubers ie, 1.44 per cent. Among Vellayani Hraswa, the PLW increased with advancement in days of storage in waxed as well as unwaxed tubers. Minimum PLW on 17th day of storage was noticed in unwaxed tubers followed by semperfresh coated tubers.

The internal colour of edible portion of three varieties of cassava varied from white in Vellayani Hraswa and M-4, to creamy white in Sreevijaya. The development of slight bluish colour with advancement of days of storage indicated vascular streaking and deterioration of tubers. In M-4, paraffin coated tubers showed signs of deterioration by 9th day itself and in other treatments development of discolouration was noticed by 15th day of storage.

Among Sreevijaya, the unwaxed tubers and the semperfresh coated tubers was found to be creamy white upto 17 days. In paraffin and beewax coated tubers of Sreevijayainitiation of discolouration was noticed after 9 days. The waxed and unwaxed tubers of Vellayani Hraswa retained their white colour upto 17 days and after that it became inedible.

The signs of vascular streaking were seen in paraffin coated tubers of M-4 by 11th day of storage and in other treatments it was observed by 15th day of storage. In Sreevijaya, the vascular streaking was not noticed in unwaxed and semperfresh coated tubers upto 17 days. But in paraffin and beewax coated tubers, this was observed from 11th day, later the tubers were deteriorated. Among the different wax coated tubers of Vellayani Hraswa, vascular streakings were not observed upto 17 days.

The chemical constituents such as moisture, protein, fat, fibre, total carbohydrate, starch, amylose, amylopectin, total sugars, reducing sugars, β-carotene, calcium and HCN contents of wax coated cassava tubers were estimated initially and on 14th day of storage.

The moisture content of unwaxed tubers of M-4, Sreevijaya and Vellayani Hraswa was 54.86, 63.93 and 60 per cent respectively initially. After two weeks of storage, in M-4 and Vellayani Hraswa minimum moisture loss was noticed in unwaxed tubers whereas in Sreevijaya it was noticed in semperfresh coated tubers.

The protein content in cassava tubers decreased during two weeks of storage. The percentage decrease in protein content was found to be minimum in semperfresh coated tubers in M-4 and Sreevijaya. But in Vellayani Hraswa, it was found to be minimum in unwaxed tubers.

The fat content in three varieties of cassava was found to be 0.22 per cent initially. After two weeks of storage an insignificant increase in fat content was noticed in unwaxed as well as waxed tubers. The increase in fat content was minimum in bee wax coated tubers of M-4 and Vellayani Hraswa and in Sreevijaya it was noticed in unwaxed tubers.

The fibre content in three varieties of cassava varied from 0.55 to 0.76 per cent initially. In all treatments the fibre content increased during 14 days of storage. The percentage increase in fibre content was found to be minimum in semperfresh coated tubers.

Initially, the total carbohydrate content of unwaxed tubers of M-4, Sreevijaya and Vellayani Hraswa was 38.22, 29.47 and 31.77 per cent respectively. A decrease in total carbohydrate content was noticed during two weeks of storage. In all the three varieties, the minimum loss in total carbohydrate content was found to be minimum in semperfresh coated tubers.

The starch content in unwaxed tubers of three varieties varied from 23.11 to 28.56 per cent initially. The starch content of waxed and unwaxed tubers decreased during 14 days of storage. The percentage decrease in starch content was found to be minimum in semperfresh coated tubers of three varieties.

A decrease in the amylose and amylopectin content was also noticed during storage of waxed and unwaxed tubers. In M-4 and Vellayani Hraswa, the percentage loss in amylose and amylopectin was found to be minimum in semperfresh coated tubers. In case of Sreevijaya, minimum percentage loss in case of amylose was observed in control and for amylopectin minimum losss was noticed in semperfresh coated tubers.

Initially, the total sugar content of unwaxed tubers of M-4, Sreevijaya and Vellayani Hraswa was 5.01 per cent, 5.52 per cent and 8.58 per cent respectively. The percentage increase in total sugar was found to be minimum in semperfresh coated tubers of three varieties.

The reducing sugar content in unwaxed tubers of three varieties varied from 1.43 to 2.54 per cent initially. The increase in reducing sugar content was found to be minimum in semperfresh coated tubers of three varieties.

The β-carotene content was not detected in Vellayani Hraswa and M-4. Presence of β-carotene was detected in Sreevijaya and was found to be 0.44 μg $100g^{-1}$ initially. In tubers of Sreevijaya coated with semperfresh, the percentage decrease in β-carotene content was lower than the control during two weeks of storage.

The calcium content in unwaxed tubers of three varieties varied from 23.53 to 38.07 mg $100g^{-1}$initially. The calcium content slightly increased during 14 days of storage in both waxed and unwaxed tubers.

The percentage reduction in HCN during 14 days of storage was found to be maximum in semperfresh coated tubers of all the three varieties. The content of HCN in semperfresh coated tubers of M-4, Sreevijaya and Vellayani Hraswa were 52.2, 48.73 and 26.5 respectively after two weeks of storage.

Organoleptic qualities of cooked samples of unwaxed and waxed cassava tubers of three varieties were evaluated for various quality attributes like appearance, colour, flavour, texture, taste and overall acceptability initially and on 14^{th} day of storage. The mean scores for different quality attributes of waxed tubers of three varieties decreased during two weeks of storage. The maximum mean scores for different quality attributes were noticed in unwaxed tubers followed by semperfresh coated tubers.

From this study, it is clear that all types of waxes are not ideal for application in cassava tubers. Among the three types of waxes tried, semperfresh was found to be the most ideal one for application in cassava tubers especially in M-4 and Sreevijaya. In case of Vellayani Hraswa all the three waxes could extend the shelf life. The extended shelf life by application of semperfresh was found to be almost similar to the shelf life of unwaxed tubers. So it can be conclude that harvesting of cassava tubers without any mechanical damage and bruises itself can extend its shelf life. The physico-chemical characters of the tubers were found to be better retained in semperfresh tubers than in control.

Future line of work:

- Wax application can be tried in other varieties
- Effect of other waxes on cassava
- Evaluation of cooking qualities of wax coated cassava
- Standardisation work for determining ideal wax coating for extending the shelf life for more than two weeks in ambient and refrigerated conditions

References

REFERENCES

Aderemi, F. A. and Nworgu, F. C. 2007. Nutritional status of cassava peels and root sievate biodegraded with Aspergillus niger. *Am. Eur. J. Agric. Environ. Sci.* 2 (3): 308-311.

Adewusi, R. and Bradbury, J. H. 2005. Carotenoid in cassava: comparison of open column and HPLC methods of analysis. . *J. Food Sci. Technol.* 44: 32-55.

Afoakwa, E. O. and Sefa-Dedeh, S. 2001. Textural and Microstructural changes associated with post-harvest hardening of trifoliate yam (Dioscorea dumetorum) wax tubers. *Food Chem.* 77: 279-284.

Afolabi, I. S., Baskaran R., Asha, M. R., Aravinda, B. and Ramana, K. V. R. 2003. Development of edible coating bioemulsion for shelf life extension of mandarin oranges. In: Proceedings of the 5th International Food Convention at Mysore- India.Theme Innovative Food Technologies and Quality Systems Strategies for Global competitiveness., 5–8 December 2003, pp. 188-189.

Afolabi, I. S. and Oloyede, O. B. (2006). Biochemical response of sweet potato to bemul-wax coating combined with calcium chloride treatment during ambient storage. *Afr. J. Biotechnol.* 10: 2724-2732.

Ahmed, M., Khalid, Z. M. and Farooqi, W. M. 1997. Effect of waxing and lining materials on storage life of some citrus fruits. In: *Proc. Florida State Hort. Soc.* 92: 237-240.

Akingbala, J. O., Oyewole, O. B., Uzo-Peters, P. I., Karim, R.O. and Baccus-Taylor, G.S.H. 576 2005. Evaluating stored cassava quality in gari production. *J. Food Sci.* Agric. Environ. 3: 75-80.

Alam, M. D. S. and Paul, S. 2001. Efficacy of casein coating on storage behavior of kinnow. *J. Food Sci. Technol.* 38: 235-238.

Anbuselvi, S. and Balamurugan, T. 2013 Physicochemical characteristics of Manihot esculenta plant and its waste. *J. Chemi. Pharma. Res.* 5(2): 258-260.

[Anonymous]. 1975. Uses of tapioca. J. Root Crops. 1(1): 12pp.

[Anonymous]. 2004. Waxing fruits and vegetables. Postharvest handling Tech. Bull. No:33, *Natl. Agric. Res. Ins*, Georgetown. 2-99pp.

A. A. C. C. 1995. American Association of Cereal Chemists Method of the AACC, Method. 14-50pp.

A. O. A. C. 1955. Official and Tentative Methods of Analysis. Eighth edition. Association of Official Agricultural Chemists, Washington, D. C. 155p.

A. O. A. C. 1980. Official and Tentative Methods of Analysis. Thirteenth edition. Association of Official Analytical Chemists, Washington, D. C. 1018p.

Apea-Bah, F.B., Oduro, I., Ellis, W.O. and Safo-Kantanka, O. 2011. Factor Analysis and Age at Harvest Effect on the Quality of Flour from Four Cassava Varieties. *World J. Dairy Food Sci.* 6: 43-54.

Apel, K. and Hirt., H . 2004 Reactive oxygen species: metabolism, oxidative stress, and signal transduction. *Annu. Rev.Plant Biol.* 55:373–399.

Aracena, J. J. 1993. Mechanism of vascular streaking, a post harvest physiological disorder of cassava roots. M. S. Thesis. Hort. Sci. Dept., Univ. Florida, 200p.

Aristizabal, J. and Sanchez, T. 2007.Physiological deterioration in cassava. *Plant Mol Biol.* 34: 134-167.

ARSO [African Organisation for Standardisation]. 2012. *Production and handling of fresh cassava.* ARS 845: 2012 (E) ICS 67.080.01.

Aryee, F. N. A., Oduro, I., Ellis., W. O. and Afuakwa, J. J. 2006. The physicochemical properties of flour samples from the roots of 31 varieties of cassava. *Food Control.* 17: 916-922.

Aro, S. O. 2008. Improvement in the nutritive quality of cassava and its by-products through microbial fermentation. *Afr. J. Biotechnol.* 25: 4789-4797.

Asaoka, M., Blanshard, J. M. V. and Richard, J. E. 1993. The effect of pre-harvest pruning on the quality of cassava starch. *An. Appl. Biol.* 12: 337–344.

Baafi, O. and Safo-Kantanka, O. 2007. Effect of genotype, age and location on cassava starch yield and quality. *J. Agron.* 6 (4): 581-585.

Balagopalan, C. Padmaja, G. and George, M. 1990. Improving the nutritional value of cassava products using microbial techniques Proceedings of 8th symposium of the international society for tropical root crops,Bangkok oct 30, pp: 546-432.

Balagopalan, C. 2002. Cassava utilization in food,feed and industry. In: Hillocks, R.J., Thresh, J.M. & Bellotti, A.C. (eds). *Cassava, Biology, production, and utilization.* Proceedings of an International workshop, Nigeria, pp: 23-39.

Baldwin, E. A., Nisperos-Carriedo,M. S., Shaw, P. E. and Burns, J. K. 1995. Effect of coatings and prolonged storage conditions on fresh orange flavor volatiles, 0brix and ascorbic acid levels. *J. Agr. Food Chem.* 43:1321–1331.

Banks, N. H., Dadzie, B. K. and Cleland, D. J. 1997. Reducing gas exchange of fruits with surface coatings. *Post harvest Biol. and Technol.* 3: 269-284.

Beeching, J. R., Reilly, K., Gomez, V. R., Rodriguez, Y., Buschmann, H., Taylor, N. and Fauquet, C. T. J. 2002. Post-harvest physiological deterioration of cassava. In: Nakatani, M., Komaki, K. (eds.). Proceedings of the twelveth symposium of the International Society for Tropical Root Crops, *Potential of root crops for food and industrial resources*, pp. 60–66.

Beeching, J. R., Dodge, A. D., Moore, K. G., and Wenham, J. E., 1994. Physiological deterioration in cassava: an incomplete wound responses. In: *Proceedings of* *the Second International Scientific Meeting of the Cassava Biotechnology Network (CBN II),* Bogor, Indonesia, pp: 22 - 26.

Beleia, A., Yamashita, F., Moraes S. R, Silveira C. A and Miranda, L.A 2004. Textural changes during cooking of cassava (Manihot esculenta Crantz.) roots. *J. Sci. Food Agric.* 84:1975–1978.

Beyrer, M. and Nindjin, D. 2014. Edible coatings on the basis of native starches for prolonging the shelf life of cassava tubers. http://www. Kfpe.ch.projects/echangesuniv/beyer.php.

Booth, R. H. (1975). *Cassava storage*. MIR Publishes, New York. 183p.

Booth, R. H., Bucle, T. S., Cardenas, O. S. Gomez, G. and Hervas, E. 1976. Changes in quality of cassava roots during storage. *J. Food Technol.* 11: 245-264.

Bradbury, J. H. and Holloway, W. D. 1988. Chemistry of tropical root crops: significance for nutrition and agriculture in pacific. *J. Sci Food Agric.* 53: 234-236.

Bradbury, J. H., Egan, S. V. and Lynch, M. J. 1991. Analysis of cyanide in cassava using acid hydrolysis of cyanogenic glucosides. *J. Sci. Food Agric.* 55: 277-290.

Breuninger, W. F., Piyachomkwan, K. and Sriroth, K. 2009. *Starch: Chemistry an Technology: Tapioca/Cassava Starch: Production and Use.* (3rd Ed). New York, 655p.

Brillouet J. M, Treche, S. and Sealy, L. 1981. Alterations in cell wall constituents of yams (Dioscorea dumetorum and D. rotundata with maturation and storage conditions: Relation with post-harvest hardening of D. dumetorumyamtubers. *J. Food Sci.* 46: 1964–1967.

Burns, A., Gleadow, R., Cliff , J., Zacarias, A. and Cavagnaro, T. 2011. Cassava: the drought, war and famine crop in a changing world. *Sustain*. 2: 3572-3607.

Buschmann, H., Rodriguez, M. X., Thome, J. and Beeching, J. 2000. Accumulation of hydroxycoumarins during post-harvest deterioration of tuberous roots of cassava (Manihot esculenta Crantz). *An. Bot.* 86: 1153-1160.

Ceballos, H., Iglesias, C. A., Pérez, J. C. and Dixon, A. 2004. Cassava breeding: Opportunities and challenges. *Plant Mol. Biol.* 56: 503-516.

Charles, A. L., Sriroth, K. and Tzou-chi, H. 2005. Proximate composition, mineral contents, hydrogen cyanide and phytic acid of five cassava genotypes. *Food Chem.* 92: 615-620.

Chavarriaga, A., Maya, M. M., Bonierbale, M. W., Kresovich, S., Fregene, M. A., Tohme, J. and Kochert, G. 1998. Microsatellites in Cassava (Manihot esculenta Crantz): discovery, inheritance and variability. *Theor. Appl. Genet.* 97: 493—501.

Chavez, A. L. Bedoya, J. M., Sanchez, C., Iglesias, H., Ceballos, S. and Roca, W. 2000. Iron, carotene, and ascorbic acid in cassava roots and leaves. *J. Food Sci. Nutr.* 3:56-68.

Chellammal, S. 1995. Developing complementary food products based on cassava and sweet potato. Ph. D. thesis, Kerala Agricultural University, Vellayani, 75p.

Chijindu, E. N. and Boateng, B. A. 2008. Effect of nutritional content of processed cassava chips on development of Prostephanus truncatus (Horn).*World J. Agric. Sci.*, 4: 404-408.

Chopra, S. L. and Kanwar, J. S. 1978. Analytical Agricultural Chemistry. Kalyani publishers, Ludhiana, 210p.

Coursey, D. G. 1973. Cassava as food toxicity and technology in chronic cassava toxicity. *Int. Dev. Res. Centre.* 10: 27-36.

Crentsil, D., Gallat, S. and Bancroft, R. 1995. Low cost fresh cassava root storage project achievement to date. In: *Proceedings of the workshop on postharvest Experience in Africa, Accra* 4-8 july, 1995.

Dou, H., Ismail, M. A. and Petracek, P. D. 1999. Reduction of post harvest pitting of citrus by changing wax components and their concentrations. *Proc. FL Stat Hort. Soc.* 112: 159-63.

Edison, S., Anantharaman, M. and Srinivas, T. 2006. Status of cassava in India an overall view. Technical Bulletin Series No. 46, Central Tuber Crops Research Institute Sreekariyam, Thiruvananthapuram, Kerala, India,192p.

Eka, O. U. 1999. Roots and Tubers. In: Eka, O. U. and Osagie, A. U. (eds.) *Nutritional Quality of Plant Foods.*, Nigeria, pp: 1-31.

El-Sharkawy, M. A. 2004. Cassava biology and physiology. *Plant Mol. Biol.* 56: 481–501.

Enidiok, S. E., Attah, L. E. and Otuechere, C. A. 2008. Evaluation of moisture, total cyanide and fibre contents of garri produced from cassava (Manihot utilisima) varieties obtained from Awassa in southern Ethiopia. *Pakist. J. nutr.*7(5): 625-629.

Ezeocha, V. C. and Oti, E. 2013. Effects of waxing materials and storage periods on physico- chemical properties of trifoliate yam (Dioscorea dumetorum). *App. Sci. Rep.* 4 : 219-224.

Fan, Y., Xu, Y., Wang, D., Zhang, L., Sun, J. and Sun, L. 2009. Effect of alginate coating combined with yeast antagonist on strawberry (Fragaria×ananassa) preservation quality. *Postharv. Biol. Technol.* 53: 84-90.

FAO [Food and Agricultural Organisation] . 2013. Agricultural statistics. Rome: Food and Agricultural Organization of the United Nations [http://www.faostat.fao.org.03 January 2014].

Fasuyi, A. O. 2005. Nutrient composition and processing effects on cassava leaf (Manihot esculenta, crantz) antinutrients. *Pakist. J. Nutr.* 4: 37-42.

Fregene, M. A., Suarez, M., Mkumbira, J., Kulembeka, H., Ndedya, E., Kulaya, A., Mitchel, S., Gullberg, U., Rosling, H., Dixon, A. G. O. and Kresovich, S. 2003. Simple sequence repeat (SSR) diversity of cassava (Manihot esculenta Crantz) landraces: Genetic structure in a predominantly asexually propagated crop. *Theor. Appl. Genet.* 107: 1083-1093.

Ghosh, S. P. 1984. Trends in disposition of cassava and scope for development of cassava based industry in India. *J. Root Crops.* 10: 1-6.

Gil J. L. and Buitrago, A. J. A. 2002. Yuca : its production, processing, utilization and commercialization. *Int. Agric. Trop.* 5: 29-69.

Gleadow, J., Evans, R., Mc Caffery, S. and Cavagnaro, T.R. 2009. Growth and nutritive value of cassava (Manihot esculenta Cranz.) are reduced when grown in elevated CO_2, *Plant Biol.* 11: 76-82.

Gloria, L. and Uritani, I. 1984. Changes in β-carotene content of golden yellow cassava in relation with physiological deterioration. *Trop. Root Crops.* In Postharvest Physiology and Processing Japan Scientific Societies Press. Tokyo, Japan, , 163- 168pp.

Gopalan, C., Sastri, B. V. R., and Balasubbramanian, S. C. 2012. *Nutritive value of Indian Foods,* NIN, Hydrebad, 161p.

Guilbert, S., Gontard , N. and Gorris, L. G. M. 1996. Prolongation of the shelflife of perishable food products using biodegradable films and coatings. *Food Technol.* 29: 10–17.

Hair, S.K., 1990. *Tropical root and tuber crops.* Timber press, Portland, 428p.

Hahn, S. K., Mahungu, N. M., Otoo, M. A. M. Msabaha, Lutaladio, N. B. and Dahniya. M. T. 1987. Cassava end African food crisis in Tropical root crops - root crops and the African food crisis. Proceedings, Third Triennial Symposium of the International Society for tropical Root Crops - Africa Branch, edited by E.R Terry, M. Akoroda, and O. B. Arene, 17-23 August 1986, Owerri, Nigeria, 24-29.

Hernandezmunoz, P. Almenar, E. Valle, V., Velez, D. and Gavara, R. 2008. Effect of chitosan coating combined with postharvest calcium treatment on strawberry (Fragaria×ananassa) quality during refrigerated storage. *Food Chem.* 110: 428-435.

Hirose, S. 1986. Physiological studies on postharvest deterioration of cassava roots. *Jpn. Agric. Res. Quart.* 19: 241-251.

Hirose, S., Data. E. S., Quevedo, M. A. and Uritani, I. 1984. Relation between respiration and post harvest deterioration in cassava roots. *Jpn. J. Crop Sci.* 53: 187-196.

Hoover, R. 2001. Composition, molecular structure, and physicochemical properties of tuber and root starches: a review. *Carbohydr. Polym.* 45: 253-267.

Huang, J., Bachem, C. W. B., Jacobsen, E. and Visser, R. G. F. 2001.Molecular analysis of differentially expressed genes during postharvest deterioration in cassava (Manihot esculenta Crantz.) tuberous roots. *Euphytica.* 120: 85-93.

Huelin, F. E. 1962. Physiology, chemistry and technology of passion fruit. *Adv. Fd. Res.*12: 221-245.

Ingram, J. U., Mackie, P .O. and Chester, C. 1972. Post-harvest Physiological deterioration of cassava roots. *J. Exp. Biol.* 8: 42-47.

Iyer, S., Mattinson, D. S, Fellman, J. K . 2010. Study of the early events leading to cassava root post harvest deterioration. *Trop. Plant Biol.* 3:151-165.

Jacob, C. J. 1985. Nutritive value of tuber crops. Proceeding of the summer training of recent advances in production and utilization of tropical tuber crops, 218.

Janssen, W. and Wheatley, C.1985. Urban cassava markets: the impact of fresh root storage. *Food policy.* 10: 265-277.

Jia, Y, John, R., Beeching, S. and Peng, Z. 2013. Enhanced reactive oxygen species scavenging by overproduction of superoxide dismutase and catalase delays postharvest physiological deterioration of cassava storage roots. *Plant Physiol.* 161: 1517–1528.

Kader, A. A. 1987. Respiration and gas ex change of vegetables. In: Weichmann J (ed.) Post harvest physiology of vegetables. Marcel Dekker, New York, USA, 25-43.

Karim, O. R. and Fasasi, O. S. 2009. Gari yield and chemical composition of cassava roots stored using traditional methods. *Afr. Crop Sci.* 9(5): 329-332.

KAU [Kerala Agricultural University]. 2011. Package of Practices Recommendations: Crops (14th Ed.). Kerala Agricultural University, Thrissur, 360p.

Kaushal, B. B. L. and Thakur, K. S. 1996. Influence of ambient and evaporative cool chamber storage conditions on the quality of polyethylene packed Kinnow. *Adv. Hort. Sci.* 10: 179-184.

Kawano, K. 2000. The role of improved cassava cultivars in generating income for better farm management, cassava's potential in Asia in the 21st century: Present situation and future research and development needs. In: Howler, R. H. and Tan, S. L. (eds), Proceedings of the Sixth Regional Workshop held in Ho Chi Minh city, Vietnam, 21-25 February, 2000.

Kaynas, K. and Ozelkok, I. S. 1999. Effect of semperfresh on post harvest behavior of cucumber (Cucumis sativus L.) and summer squash (Cucurbito pepo L.) fruits. *Acta Hortic.* 492: 213-220.

Ketiku, A. O. and Oyenuga , V. A. 1972. Changes in the carbohydrate constituents of cassava root-tuber (*Manihot utilissima* pohl) during growth. *J. Sci. Food Agric.* 23: 1451–1456.

Kenneth, M. O. and Barbara, A. Schaal, R. 1999. Evidence on the origin of cassava: phylogeography of manihot esculenta. *Proc. Natl. Acad. Sci.* 3(96): 5586–5591.

Kojima, M., Iwatsuki, N., Data, E., Villegas, C. and Uritani, I. 1983. Changes of cyanide content and linamarase activity in wounded cassava roots. *Plant Physiol*, 72: 186-189.

Kolawole , P. O., Agbetoye, L. and Ogunlowo, S. A. 2010. Sustaining world food security with improved cassava processing technology: The Nigeria experience sustainability 75(2): 3681-3694.

Krochta, J. M. 1997. Edible composite moisture barrier films in packaging. *Food. Technol.* 38: 46-49.

Ladaniya, M. S. 2001. Response of Mosambi sweet orange (Citrus sinensis) to degreening, mechanical waxing, packaging & ambient storage conditions. *Indian J. Agric. Sci.* 71: 234-239.

Lalaguna, F. and Agudo, M. 1989. Relationship between changes in lipid with aging of cassava roots and senescence parameters. *Phytochem.* 28: 2059 - 2062.

Laurence, K., Vijayalakshmi, K. G., Nath, K. G. and Surendra, H. S. 2012. Development of shelf stable products from tapioca and their storage. 2012. *J.Agric.Sci.* 46 (3): 34-45.

Lin Y., Zha, C. and Xie, J. 2011. Effect of different storage ways on the quality 633 of fresh cassava, Trop. Agric. Eng, 2: 5-8.

Maini, S. B.,a nd Balagopal, C, 1978. Biochemical changes during post harvest deterioration ofc assava. *J. Root Crops*.4 : 31- 33.

Manu, J., Lamboll, R., Dankyi, A. and Gibson, R. 2005. Cassava diversity in Ghanaian farming systems. *Euph.* 144: 331-340.

Mathur, P. B and Srivastava, H. C. 1955. Effect of skin coatings on the storage behavior of mango. *Food Res.* 20: 559-566.

Maziya, 2007.Garri yield and chemical composition of cassava roots stored in traditional methods. *Pakist J. nutr*. 8(12):1830-1833.

Mc Hugh, T. H. and Krochta, J. M. 1994. Milk protein based edible films and coatings. Food *Technol.* 48: 97–103.

Meera, R. 1985. Cassava a food for million. *J. Root Crops*. 23: 31-50.

Mollenhauer, H. P. 1954. The passion fruit: Physiology, Chemistry, & technology of passion fruit. *Adv. In. Food Res.*12: 203-282.

Montagnac, J. A., Christopher, R. S., Davis, E. and Sherry, A. T. 2009. Nutritional value of cassava for use as a staple food and recent advances for improvement. *Comprehensive Rev. Food Sci. Food Safety*. 8: 181-194.

Ndung'u, J. N., Wachira, M. G. Kinyua, D. K. and Obiero, H. M. 2010. Biochemical analysis of cassava quality traits in Central Rift Valley of Kenya. Proceedings of 12th Kenya Agricultural Research Institute, Biennial Scientific Conference, 8-12 November 2010, Kenya, pp: 34-67.

Nebiyu, A. and Getachew, E. (2011). Soaking and drying of cassava roots reduce cyanogenic potential of three cassava varieties at Jimma, Southwest Ethiopia. *Afr. J. Biotechnol.* 62: 13465-13469.

Nisperos-Carriedo, M. O., Baldwin, E. A. and Shaw, P. E. 1990. Development of an edible coating for extending postharvest life of selected fruits and vegetables. *Proc. Fla. State Hort. Soc.* 104: 122–125.

Nuwamanya, E., Baguma, Y., Emmambux, N. and Rubaihayo, P., 2010. Crystalline and pasting properties of cassava starch are influenced by its molecular properties. *Afr. J. Food Sci.* 4(1): 008-015.

Nweke, F. I., Spencer, D. S. C. and Lynam, J. K. 2002. The cassava transformation: Africa's best-kept secret. Michigan University Press, USA, 358p.

O' Brien, G. M., Mayer, J. E., Chavez, A. L., Orozco, O., Wheatley, C. C., Wehnam, J. E., 1995. Biochemical studies of cassava root post-harvest physiological deterioration. Proceedings of the 6th Symposium on ISTRC-AB, pp. 279–283.

Onwueme, I. C. 2002. Cassava in Asia and the pacific. *Food. Technol.* 55: 123-156.

Osuji G.O. and Umezurike, G. M. 1985. The biochemistry of yam tuber deterioration: In Advances in Yam Research (G.O. Osuji, ed.), Biochemical Society of Nigeria, Anambra State University of Technology, Anambra State, Nigeria, pp. 261–276.

Osunsami, A. T., Akingbala, J.O. and Oguntimein, G. B. 1989. Effect of storage on starch content and modification of cassava starch. *Stach Strake.* 41: 54-57.

Otegbayo, B. O, Asiedu, R. and Bokanga, M. 2011. Effect of storage on the chemical composition and food quality of yam. *J. Food Process. Preserv.* 36: 438-445.

Padmaja, G. 1980. Post harvest spoilage and preservation aspects of tuber crops. A report on the training on recent advances in production and utilization of tropical tuber crops. CTCRI.386p.

Padonou, W., Mestres, C. and Nago, M. C. 2005. The quality of boiled cassava roots: instrumental characterization and relationship with physicochemical properties and sensorial properties. *Food Chem.* 89: 261–270.

Park, H. J., Chinan, M. S. and Shewfelt, R. L. 1994. Edible coating effects on storage life and quality of tomatoes. *J. Food Sci.* 59: 568–570.

Perkin- Elmer. 1982. Analytical Methods for Atomic Spectrophotometry. Perkin-Elmer Corporation, USA, 114p.

Petracek, P. D., Dou, H. and Pao, S. 1998. The influence of applied waxes on post harvest physiological behaviour and pitting of grapefruit. *Postharvest Biol. Technol.* 14: 99-106.

Philips, T. P. 1974. Cassava utilization and potential markets, *Sustain.* 2: 3883-4082.

Plumbley, R. A. and Richard, J. E. 1991. Post-harvest deterioration of cassava. Trop. Sci. 31: 295-303.

Poulose, K.. P., Soman, T. N. and Mathew, K. J. 1984. Protein digestability of extruded cereal grains. *Kerala Medi.* J. 25: 180-196.

Pruthi, J.S. and Lal, G. 1955. Some technical aspects of manufacture of passion fruit squash. *Chem. Age.* 6 (2): 39.

Quipping, Z. and Wenshui, X. 2007. Effect of 1-methylcyclopropene and/or chitosan coating treatments on storage life and quality maintenance of Indian jujube fruit. *Food Sci. Technol.* 40: 404-411.

Ranganna, S.1986. Manual of Analysis of Fruits and Vegetable products. Tata Mc Graw Hill Publishing Co. Ltd, New Delhi, 1-13p.

Ravi, V., Aked, J. and Balagopalan, C. (1996). Review on tropical root and tuber crops I. Storage methods and quality changes. Crit. Rev. Food Sci. Nutr. 36: 661-709.

Reilly, K., Yuanhuani, H., Thome, J. and Beeching, J. 2001. Isolation and characterization of a cassava catalase expressed during post-harvest physiological deterioration. *Biochem. Biophys. Acta.* 15: 317-323.

Reilly, K., Gomez, R., Buschmann, H., Tohme, J. and Beeching, J. 2004. Oxidative stress responses during cassava post-harvest physiological deterioration. *Plant Mol. Biol.* 56: 625–641.

Reilly, K., Bernal, D., Cortes, D. F., Gomez, R. and Thome, J. 2007. Towards identifying the full set of genes expressed during cassava post-harvest physiological deterioration. *J. Exp. Biol.* 64: 187–203.

Rickard, J. E. 1985. Physiological deterioration of cassava roots. *J. Sci. Food Agric.* 36: 167-176.

Rogers, D. J., Appan, S. G. 1973. Manihot Manihotoides (Euphorbiaceae) Flora Neotropica. Hafner Press, New York, 272p.

Sadasivam, S. and Manickam, A. 1992. Biochemical Methods for Agricultural Sciences. Eighth Edition. Wiley Eastern Ltd., New Delhi and Tamil Nadu Agriculture University, Coimbatore, 233p.

Sajeev, M. S., Sreekumar, J. Unnikrishnan, M., Moorthy, S. N. and Shanavas, S. 2010. Kinetics of thermal softening of cassava tubers and rheological modeling of the starch, *J Food Sci. Technol.* 47(5): 507–518.

Salcedo, A. and Siritunga, D. 2011. Insights into the physiological, biochemical and molecular basis of postharvest deterioration in cassava (Manihot esculenta) roots. *Am. J. Exp. Agric.* 1(4): 414-431.

Sanchez, T., Chavez, A. L., Ceballos, H., Rodriguez, D. B. and Nestel, P. 2005. Reduction or delay of post-harvest physiological deterioration in cassava roots with higher carotenoid content. *J. Sci. Food Agric.* 86: 634–639.

Sandoval, E. R., Quintero, A. F., Cuvelier, G., Relkin, P. and Perez, L. A. 2008. Starch Retrogradation in Cassava Flour From Cooked Parenchyma. *Starch/Starke.* 60: 174-180.

Sarkiyayi, S.and Agar, T. M. 2010. Comparative Analysis on the Nutritional and Anti-Nutritional Contents of the Sweet and Bitter Cassava Varieties. Adv. *J. Food Sci. Techol.* 2(6): 328-334.

Sargent, S. A., Correa T . B. S. and Soares, A. G. 1995. Application of postharvest coatings to fresh cassava roots (*Manihot esculenta*, Crantz) for reduction of vascular streaking. In: Kushwala, L. Serwatowski, R. and Brook, R. (ed.), Proceedings of Post harvest Technology of Fresh Fruits and Vegetables, pp. 331-338.

Sefa-Dedeh, S. and Afoakwa, E. O. 2002. Biochemical and textural changes in trifoliate yam Dioscorea dumetorum tubers after harvest. *Food Chem.* 79: 27-40.

Shellhammer, T. H. and Krochta, J. M. 1997. Whey protein emulsion film performance: Effect of lipid type and amount. *J. Food Sci.* 32: 390-394.

Silva, L. J. B., Souza, M. L., Neto, S. E. D. and Morais, A. P. 2009. Alternative covering in the shelf life conservation of yellow passion fruit produced in organic system. *Rev. Bras. fruiticul.* 31(4): 995-1003.

Soccol, C.R. 1996. Biotechnological products from cassava roots by solid state fermentation. *J. Sci. Indust. Res.* 55: 358-364.

Supriya, M. 2012. Development and quality evaluation of modified atmosphere packed passion fruit (passiflora edulis). M.Tech (Ag) thesis, Kerela Agricultural University, Thrissur, 105p.

Taiwo, O. O., Jimoh, D. and Osundeyi, E. 2010. Functional and Pasting properties of composite cassava- sorghum flour meals. *Agric. Biol. J. N Am.* 1 (4): 715-720.

Tanaka, Y., Data, E. S., Hirose, E. S., Taniguchi, T. and Uritani, I. 1983. Biochemical changes in secondary metabolites in wounded and deteriorated cassava roots. *Agric. Biol. Chem.* 47: 693 - 700.

Teles, F. F. F., Silveira, D. and Batista, C. M. 1979. Soluble , reducing and non reducing carbohydrate in ten cassava clones cultivated in Minas Gerais. *Revista ceres.* 26 (147):513-516.

Tietel, Z. Bar, E., Lewinsohn, E., Feldmesser, E., Fallik, E. and Porat, R. 2010. Effects of wax coatings and postharvest storage on sensory quality and aroma volatile composition of 'Mor' mandarins. *J. Sci. Food Agric.* 90: 995-1007.

Thakur, K.S., Kaushal, B. B. L. and Sharma, R. M. 2002. Effect of different post harvest treatments and storage conditions on the fruit quality of Kinnow. *J. Food Sci.* 39: 609-618.

Thirupathi, V., Sasikala, S. and Kennedy, J. Z. 2006. Preservation of fruits and vegetables by wax coating. In: Sci. Tech. Entrepreneur (Eds. Mittal, H. K. *et al.)* NSTEDB, DST. 1-10.

Toma, R. B. and Tahekia, M. M. 1979. Nutritional composition of some Nigerian meals. *Food Technol.* 19 (2): 189-194.

Treche, S. and Agbor-egbe T. 1996. Biochemical changes occurring during growth and storage of two yam species. *Int. J. Food Sci.Nutr.* 47(2): 93–102.

Tumuhimbise, R., Melis, R., Shanahan, P. and Kawuki , R. 2012. Farmer's perceptions on early storage root bulking in cassava (Manihot esculenta Crantz) in East and Central Uganda and their implication for cassava breeding. *World J. Agric. Sci.* 8 (4): 403-408.

Tzoumaki, M. V., Biliaderis, C. G. and Vasilakakis, M. 2009. Impact of edible coatings and packaging on quality of white asparagus (Asparagus officinalis, L.) during cold storage. *Food Chem.* 117: 55-63.

Udoro, E., Olasunkanmi, S., Gbadamosi, L. and Kehinde , A. 2008. Studies on the production and utilization of dried cassava chips as human food using food science and technology to Improve nutrition and promote national development, Robertson, G.L. & Lupien, J.R. (Eds), *Int. Union Food Sci. Technol.* 24:1-8.

Uritani, I., 1998. Biochemical comparison in storage: Stress response between sweet potatoand cassava. *Trop. Agric.* 75 : 177-182.

Uritani, I., 1999. Biochemistry on postharvest metabolism and deterioration of some tropical tuberous crops. *Bot. Bull. Acad. Sin.* 40: 177-183.

Uthaibutra, J., Chanbang, Y. and Joomwong, A. 2014. Effects of bee-carnauba mixed wax coating on the reduction of respiration rate, weight loss, fruit decay, and the maintanence of visual appearance and quality of Vietnamese longan cv. Long during low temperature storage. *Int. J. Agric. Innov. Res.* 2:554-560.

Vlarr, P. W. L., Beek, P. and Visser, R. G. F. 2001. Reducing post harvest deterioration of cassava : Benefits for the starch industry in Thailand. In: C. M. Fauquet and N.J. Taylor (Eds) cassava : An ancient crop for modern Times, Proceedings of the 5^{th} international meeting of the cassava Biotechnology Network ,4-9 November 2001, Nigeria, pp.141-160.

Wenham, J. E. 1995. Post-harvest deterioration of cassava. A biotechnology perspective.FAO Plant Production and Protection Paper 130. NRI/FAO. Rome., 90pp.

Were, H. K., Winter, S. and Maiss, E. 2004. Virus infecting cassava in Kenya. *Plant Dis*. 88:17-22.

Westby, A. 2002. Cassava utilization, storage and small scale processing In: Hillocks, R. J. and Thresh R.H. and Bellotti A. C. (Eds), *Cassava Biology , Production and Utilization.* Proceedings of an international workshop, Wallingford, UK. pp. 281-300.

Wheatley, C. and Schwabe, W. 1985. Scopoletin involvement in post harvest deterioration of cassava roots (*Manihot esculenta* Crantz). *J. Exp. Bot.* 36: 783-791.

Zauberman, G., Fuchs, Y. and Yanko, U. 1981. Waxing of avocado fruits. *Food Technol.* 36 : 3-6.

Zidenga, T., Guerrero, L. E., Moon, H., Siritunga, D. and Sayre, R. 2012. Extending cassava root shelf life via reduction of reactive oxygen species production. *Plant. Physiol.* 159: 1396-1407.

Zvinavashe, E., Elbersen, H. W., Slingerland, M., Kolijn, S. and Sanders, J. P. M. 2011. Cassava for food and energy: exploring potential benefits of processing of cassava into cassava flour and bioenergy at farmstead and community levels in rural Mozambique. Biofuels, Bioproducts and Biorefining . *J. Dairy Sci.* 86: 3405-3415.

Appendix

APPENDIX - I

Score card for organoleptic evaluation of cooked cassava tubers

Name of judge :

Date :

Sl. No.	Attributes	Treatments		
1.	Appearence			
2.	Colour			
3.	Flavour			
4.	Texture			
5.	Taste			
6.	Overall acceptability			

Evaluate the tubers on the basis of the scores given below

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Signature

STANDARDISATION OF WAX COATING IN CASSAVA (*Manihot esculenta* Crantz) TUBERS AND QUALITY EVALUATION

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The present study entitled "Standardisation of wax coating in cassava (*Manihot esculenta* Crantz) tubers and quality evaluation" was undertaken to standardise the percentage of wax coating to be applied on cassava tubers and to evaluate various physico-chemical and nutritional attributes of wax coated cassava tubers.

Three varieties of cassava, M-4, Sreevijaya and Vellayani Hraswa were selected for the study. The standardisation of wax coating was done by using different concentrations of three waxes namely paraffin wax, bee wax and semperfresh on these varieties. The wax formulation at one per cent level which prolonged the days of storage under ambient conditions was selected for the study.

The tubers coated with one per cent wax formulations were stored after packing in ventilated paper cartons under ambient conditions till it showed the signs of deterioration. The shelf life qualities such as respiration rate and physiological loss in weight and physical qualities like appearance, colour and extent of vascular streaking were determined at two days interval. The chemical, nutritional and organoleptic qualities were evaluated initially and after two weeks of storage.

The respiration of the cassava tubers were determined by the rate of O_2 consumption and CO_2 liberation. Significant variation was noticed in the respiration rate of unwaxed and wax coated cassava tubers. The respiration rate lower than control was observed only in semperfresh coated tubers throughout the storage period. The physiological loss in weight was minimum in unwaxed tubers followed by semperfresh treated ones except in variety Sreevijaya.

In paraffin and bee wax coated tubers the development of vascular streaking and discolouration was at a faster rate than in semperfresh coated and unwaxed tubers. Paraffin and bee wax coated tubers of Sreevijaya and bee wax coated tubers of M-4 showed symptoms of deterioration during second week of storage itself.

Changes in chemical and nutritional constituents were observed during storage of waxed cassava tubers. In tubers treated with semperfresh, the rate of moisture loss was comparatively lower during storage. A reduction in protein content was noticed

during storage of waxed as well as unwaxed tubers. The fat and fibre content of all the treatments increased during storage.

Among wax coated tubers, semperfresh coated tubers showed minimum loss in total carbohydrate content during storage. A significant reduction in starch content during storage was noticed in waxed as well as unwaxed tubers resulting an increase in the total and reducing sugar content of all the treatments. The physico-chemical characters of the tubers were found to be better retained in semperfresh tubers than in control.

β-carotene content was noticed only in variety Sreevijaya which decreased significantly during storage. A slight increase in calcium content of waxed and unwaxed tubers was observed during storage. Nearly 18 percent reduction in hydrogen cyanide content was noticed in waxed and unwaxed tubers of the three varieties.

The mean scores for different quality attributes of waxed as well as unwaxed cassava tubers of M-4, Sreevijaya and Vellayani Hraswa decreased during two weeks of storage. Compared to control, the mean scores for overall acceptability were lower in wax coated cassava tubers. Among wax coated tubers, semperfresh tubers had better mean scores for different quality parameters.

The cost of wax application was found to be maximum for semperfresh, followed by paraffin and bee wax.

From this study, it is clear that all types of waxes are not ideal for application in cassava tubers. Among the three types of waxes tried, semperfresh was found to be the most ideal one for application on cassava tubers. But the extended shelf life by application of semperfresh was found to be almost similar to the shelf life of unwaxed tubers. So it can be concluded that harvesting cassava tubers without any mechanical damage and bruises itself is ideal to extend the shelf life.