INFLUENCE OF NEAR INFRARED REFLECTION AND EVAPORATIVE COOLING ON MANGO FRUIT STORAGE

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Influence of Near Infrared Reflection and Evaporative Cooling on Mango Fruit Storage

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

To my family,

For your prayers and support during this study.

I wish you God's blessings.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of appendices

NOTATIONS

A	Weight of the mango fruit before storage (g)
A_C	Ambient conditions
A_{ft}	Total face area through which air enters the evaporative pad (m^2)
A_I	Apple mangoes before storage
A_N	Apple mangoes after storage in the S_{NR}
AOAC	Association of Official Analytical Chemists
ANOVA	Analysis of variance
A_R	Apple mangoes after storage in the R_C
A_v	Wetted area per unit volume of charcoal material (m^2/m^3)
A_W	Apple mangoes after storage in the S_{NNR}
B	Weight of mango fruit at inspection date (g)
CIE	Commission Internationale de l' Eclairage
c_{pa}	Specific heat of air (J/kgK)
c_{pu}	Specific heat of humid air (J/kgK)
c_{pv}	Specific heat of the water vapour (J/kgK)
FAO	Food and Agriculture Organization
$F_{fA,NNR}$	Estimated firmness of the flesh for Apple mangoes stored in the S_{NNR} (N)
$F_{fA,NR}$	Estimated firmness of the flesh for Apple mangoes stored in the S_{NR} (N)
$F_{fA,R}$	Estimated firmness of the flesh for Apple mangoes stored in the R_C (N)
$F_{fK,NNR}$	Estimated firmness of the flesh for Kent mangoes stored in the S_{NNR} (N)
$F_{fK,NR}$	Estimated firmness of the flesh for Kent mangoes stored in the S_{NR} (N)
$F_{fK,R}$	Estimated firmness of the flesh for Kent mangoes stored in the R_C (N)
$F_{pA,NR}$	Actual firmness of the peel for Apple mangoes stored in the S_{NR} (N)
$F_{pA,R}$	Actual firmness of the peel for Apple mangoes stored in the R_C (N)
$F_{pA,NNR}$	Actual firmness of the peel for Apple mangoes stored in the S_{NNR} (N)
$F_{pK,NNR}$	Actual firmness of the peel for Kent mangoes stored in the S_{NNR} (N)
$F_{pK,NR}$	Actual firmness of the peel for Kent mangoes stored in the S_{NR} (N)
$F_{pK,R}$	Actual firmness of the peel for Kent mangoes stored in the R_C (N)

H	Height of the evaporative pad (m)
$\mathbf{H^o}$	Hue angle (^{o})
$\mathbf{h_c}$	Convective heat transfer coefficient (W/m^2K)
HCDA	Horticultural Development Authority
$\mathbf{H^o_{f,NNR}}$	Estimated hue angle of the flesh for Apple mangoes stored in the S_{NNR} (^{o})
$\mathbf{H^o_{f,NR}}$	Estimated hue angle of the flesh for Apple mangoes stored in the S_{NR} (^{o})
$\mathbf{H^o_{f,R}}$	Estimated hue angle of the flesh for Apple mangoes stored in the R_C (^{o})
$\mathbf{H^o_{p,NNR}}$	Actual hue angle of the peel for Apple mangoes stored in the S_{NNR} (^{o})
$\mathbf{H^o_{p,NR}}$	Actual hue angle of the peel for Apple mangoes stored in the S_{NR} (^{o})
$\mathbf{H^o_{p,R}}$	Actual hue angle of the peel for Apple mangoes stored in the R_C (^{o})
I	Thickness of the evaporative pad (m)
$\mathbf{l_c}$	Characteristics dimension (m)
$\mathbf{K_a}$	Thermal conductivity of air (W/mK)
KARI	Kenya Agricultural Research Institute
$\mathbf{K_I}$	Kent mangoes before storage
$\mathbf{K_N}$	Kent mangoes after storage in the S_{NR}
$\mathbf{K_R}$	Kent mangoes after storage in the R_C
$\mathbf{K_W}$	Kent mangoes after storage in the S_{NNR}
L	Length of the evaporative pad (m)
$\mathbf{m_a}$	Mass flow rate of air through the evaporative pad (kg/s)
N	Number of observations
NIR	Near infrared reflecting
Nu	Nusselt number (dimensionless)
$\mathbf{pH_{a,NNR}}$	Actual pH for Apple mangoes stored in the S_{NNR}
$\mathbf{pH_{a,NR}}$	Actual pH for Apple mangoes stored in the S_{NR}
$\mathbf{pH_{a,R}}$	Actual pH for Apple mangoes stored in the R_C
$\mathbf{pH_{k,NNR}}$	Actual pH for Kent mangoes stored in the S_{NNR}
$\mathbf{pH_{k,NR}}$	Actual pH for Kent mangoes stored in the S_{NR}
$\mathbf{pH_{k,R}}$	Actual pH for Kent mangoes stored in the R_C

PPR	Polypropylene random copolymers
Pr	Prandtl number (dimensionless)
PV	Photovoltaic
Q_a	Actual cooling capacity (kJ/h)
Q_p	Predicted cooling capacity (kJ/h)
R^2	Coefficient of determination
R_C	Room conditions
Re	Reynolds number (dimensionless)
RH	Relative humidity (%)
RH_A	Relative humidity for ambient conditions (%)
RH_{NNR}	Estimated relative humidity of storage environment for S_{NNR} (%)
RH_{NR}	Estimated relative humidity for S_{NR} (%).
RH_R	Estimated relative humidity for room conditions (%)
RMSE	Root mean square error
S_{NNR}	Non-NIR store
S_{NR}	NIR store
t_a	Actual outlet air dry bulb temperature
T_A	Temperature for ambient conditions (^oC)
T_{db}	Dry bulb temperature (^oC)
T_{NR}	Estimated temperature of storage environment for S_{NR} (^oC)
t_p	Predicted dry bulb temperature of the outlet air (^oC)
T_R	Estimated temperature for room conditions (^oC)
TSS	Total soluble solids (% Brix)
$TSS_{a,NNR}$	Estimated total soluble solids for Apple mangoes stored in the S_{NNR} (% Brix)
$TSS_{a,NR}$	Estimated total soluble solids for Apple mangoes stored in the S_{NR} (% Brix)
$TSS_{a,R}$	Estimated total soluble solids for Apple mangoes stored in the R_C (% Brix)
$TSS_{k,NNR}$	Estimated total soluble solids for Kent mangoes stored in the S_{NNR} (% Brix)
$TSS_{k,NR}$	Estimated total soluble solids for Kent mangoes stored in the S_{NR} (% Brix)
$TSS_{k,R}$	Estimated total soluble solids for Kent mangoes stored in the R_C (% Brix)

TTA	Total titratable acid (%)
$\mathbf{TTA_{a,NNR}}$	Actual total titratable acid for Apple mangoes stored in the S_{NNR} (%)
$\mathbf{TTA_{a,NR}}$	Actual total titratable acid for Apple mangoes stored in the S_{NR} (%)
$\mathbf{TTA_{a,R}}$	Actual total titratable acid for Apple mangoes stored in the R_C (%)
$\mathbf{TTA_{k,NNR}}$	Actual total titratable acid for Kent mangoes stored in the S_{NNR} (%)
$\mathbf{TTA_{k,NR}}$	Actual total titratable acid for Kent mangoes stored in the S_{NR} (%)
$\mathbf{TTA_{k,R}}$	Actual total titratable acid for Kent mangoes stored in the R_C (%)
$\mathbf{T_{NNR}}$	Estimated temperature of storage environment for S_{NNR} (^oC)
$\mathbf{t_{wb}}$	Wet bulb temperature of the inlet air (^oC)
$\mathbf{t_1}$	Actual dry bulb temperature of the inlet air (^oC)
$\mathbf{v_a}$	Air velocity of air through the evaporative pad (m/s)
V	Kinematic viscosity of air (m^2/s)
w	Specific humidity (kg/kg of dry air)
$\mathbf{W_l}$	Percentage physiological loss in weight
$\mathbf{X_{act,i}}$	Predicted performance parameters
$\mathbf{X_{pre,i}}$	Actual performance parameters
$\boldsymbol{\rho}$	Air density (kg/m^3)
a*	Degree of redness to greenness
b*	Degree of yellowness to blueness
L*	Degree of lightness to darkness
$\boldsymbol{\eta_a}$	Percentage actual saturation efficiency
$\boldsymbol{\eta_p}$	Percentage predicted saturation efficiency
Ø	Diameter (mm)

ABSTRACT

Mango (*Mangifera indica L.*) fruit is valuable in Kenya due to its nutritive and economic value. However, at least 40 to 45% of mango fruit is lost during postharvest handling primarily due to inadequate availability of storage facilities during the peak harvest seasons. As a result, farmers are often forced to sell their fruits at a throw away price in fear of spoilage. Thus, this study is aimed at developing and evaluating the performance of an improved store for mangoes. The improved store combined reflection of near infrared radiation and evaporative cooling to lower the temperature inside the storage chamber.

A computer simulation model was developed in a Java programming language and was used to predict the performance of the improved store. The input parameters of the model were ambient conditions (dry and wet bulb temperature, specific humidity and air velocity), coolant conditions (coolant temperature and flow rate), cooler characteristics (length, thickness and height of the evaporative pad, wetted area per unit volume of the evaporative medium) and air properties (specific heat of air and water vapour, thermal conductivity of air, Prandtl number, kinematic viscosity of air and density of air). The performance parameters of the cooler which included saturation efficiency and cooling capacity were evaluated at various inlet air velocities ranging from 3.0 to 4.0 m/s at a regular interval of 0.2 m/s.

The effect of storage conditions on the shelf-life and properties of two mango varieties namely Apple and Kent were evaluated. Room conditions were used as a control during the experiment. The physical (weight, colour, and firmness) and chemical (total soluble solids, total titratable acids, and pH) properties were monitored on daily basis.

Results from the simulation model did indicate that actual saturation efficiency of the near infrared reflecting store (S_{NR}) ranged from 66.9 to 68.9 % while the simulated was 66.9 to 69.0% which was highly correlated to the actual measurements (R^2 = 0.999). The actual cooling capacity of the S_{NR} ranged from 105.67 to 136.48 mJ/h while the simulated was 105.73 to 136.68 mJ/h which was strongly correlated to the actual data (R^2 = 0.998). The S_{NR} lowered ambient temperature by 11.4^{o}C and increased relative

humidity by 6.7%. In addition, a 3.2 °C temperature difference was recorded between the S_{NR} and non-near infrared reflecting store (S_{NNR}). The difference was significant (P<0.05).

The S_{NR} increased the shelf-life for both mango varieties by 3 and 9 days compared to the S_{NNR} and room conditions (R_C), respectively. The S_{NR} reduced weight loss in Apple mangoes by 4.64 and 9.77% compared to S_{NNR} and R_C, respectively while the weight loss in Kent mangoes was decreased by 4.09 and 8.82% compared to S_{NNR} and R_C, respectively. The difference was significant (P<0.05). Except for the colour of the flesh for Kent, the storage environment did not have any significant effect (P>0.05) on the colour of the peel or flesh of the Apple. Moreover, the storage environment had no significant effect (P>0.05) on the firmness of the peel or flesh for Apple except for Kent. In addition, the effect of storage environment on the total soluble solids (TSS), total titratable acids (TTA), and pH for both mango varieties were not significant (P>0.05).

The results from this study therefore indicate that the combination of near infrared reflection and evaporative cooling has a potential of improving the shelf-life and preserving the quality of the mango fruits. Thus, this technology can provide an applicable solution to storage challenges in mangoes.

CHAPTER ONE

INTRODUCTION

1.1 Background information

Mango (*Mangifera indica L.*) is an adaptable fruit tree in Kenya, suitable for different agro-ecological zones ranging from sub-humid to semi-arid (Griesbach, 2003). The tree thrives well at 0 to 1500 m above sea level in Kenya, although it can grow in higher elevations (Nakasone and Paull, 1998). Coast and the semi-arid parts of Eastern are the main mango producing areas of Kenya. In Kenya, 280,884 metric tonnes of mango fruit are produced at an estimated production area of 14,387 Ha (HCDA, 2008). Due to expansion of mango production area and increasing productivity, mango production has increased to about 450,000 metric tonnes. However, only 1,800 metric tonnes of the mango produced are exported (HCDA, 2010). The remaining mangoes in the year are mainly utilized as supplies to the local fresh market and the processing industry. Mango juice, chutney, prickles, jam, jelly, canned and dried fruits include some of the products from the processed mangoes (Griesbach, 2003).

Mango fruit is known for its nutritive value and its potential source of income for farmers. In addition, the mango fruit is a source of raw material for industries and foreign exchange earner. However, mango fruits are riddled with challenges along the postharvest chain. At least 40 to 45% of the fruit is lost along the postharvest handling (KARI, 1994). Mechanical damage (bruises), pests and diseases and immature harvesting are the causes of losses. Moreover, postharvest losses are also due to inadequate storage facilities for mangoes particularly during the peak harvesting seasons. It is possible to develop effective storage systems and use them to reduce the losses thus improving the net returns for the resource poor farmers (Jha, 2008). An effective storage of the fruit can be achieved by controlling the storage environment.

The critical parameters in the modern storage systems include temperature, humidity, air velocity, lighting, air (gas) composition, and pressure (Uluko *et al.*, 2006). Temperature and relative humidity greatly influence the shelf-life of fruit. Low temperature extends the shelf-life of the fruit by slowing down the rate of respiration and microbial activities. In addition, high relative humidity reduces fruit deterioration by minimising the rate of transpiration. An improved store which combines near infrared reflection (NIR) and evaporative cooling can be developed and used to lower the temperature in the storage chamber. This technology can improve the shelf-life and preserve the quality of the fruit by reducing the heating effect of the near infrared radiation.

During storage, it is important to ensure that the fruits are of good quality and free from damages or diseases. The damaged or diseased fruits respire rapidly and hence deteriorate more quickly. Moreover, the damage fruits are susceptible to microbial attack (Shitanda and Wanjala, 2006). Therefore, before storage it is necessary to inspect and discard the damaged or diseased fruits.

1.2 Problem statement and justification

1.2.1 Problem statement

Mango (*Mangifera indica L*.) is an important food and cash crop in Kenya. The commercial production of the crop varies from small scale farming to huge, highly organized orchards, where the best available technology is applied. As an export fruit crop, mango fruit earns the country foreign exchange while at the same time it is a source of household income for the resource poor farmers. However, despite the benefits of mango fruit, postharvest losses are among the most serious challenges facing the fruit primarily due to inadequate storage facilities during the peak harvest season. Thus, the farmers are often forced to sell their fruits at a throw away price due to fear of spoilage, while huge quantities of mangoes, in the range of 40 to 45% of the total production are spoilt. Measures aimed at development of technology to improve the shelf-life of mangoes would not only increase farmer's income, but would also avail more mangoes to the market hence improving food security.

1.2.2 Justification

The modern preservation systems such as refrigerators rely heavily on electricity which is costly and inappropriate for remote areas without electricity. Therefore, the modern storage technologies are inapplicable for these areas and hence it is worth to explore other technologies which would provide solution to storage problem engulfing subsistence mango farmers. Thus, this project aimed at developing and testing an improved store for mangoes which combines reflection of near infrared radiation and evaporative cooling to lower the temperature of the storage chamber. This technology would not only extend the shelf-life but also preserve the quality of the fruit thereby reducing the losses.

1.3 Objectives

1.3.1 General objective

To develop an improved evaporative cooled store for mango fruit and predict its performance using a computer simulation model.

1.3.2 Specific objectives

1. To assess postharvest challenges facing subsistence mango farmers in the Lower Eastern region of Kenya.
2. To develop an improved store for mangoes that combines near infrared reflection and evaporative cooling to lower temperature in the storage chamber.
3. To evaluate the cooling performance of the developed store.
4. To determine the effect of storage environment on weight, colour, firmness, total soluble solids, total titratable acid and pH of Apple and Kent mangoes.
5. To develop a computer simulation model for predicting saturation efficiency and cooling capacity of the developed store.

CHAPTER TWO

LITERATURE REVIEW

2.1 Evaporative cooling technology

2.1.1 Principles of evaporative cooling

Rusten (1985) reported that cooling achieved by evaporation of water is an ancient and effective way of cooling. In addition, the plants and animals use this method of cooling to reduce body temperature. Evaporative cooling requires certain conditions in order to take place. These include high temperatures, low humidity, water, and air movement. Further, addition of energy or heat is needed during change of state of liquid to vapour. The energy that is added to water to change its state to vapour is sourced from the environment and hence cooling the environment. Thus, using the psychrometric chart will help to know whether evaporative cooling has taken place.

The potential of evaporative cooling is evaluated by considering the difference between the wet bulb temperature and dry bulb temperature. The greater the difference between the two temperature the greater the evaporative cooling effect. Conversely, there is no cooling effect when the two temperatures are equal due to no net evaporation of water in air occurs. Thus temperature and the relative humidity measurement are critical variables in optimum cooling efficiency using the evaporative cooling technique. The psychrometric chart describes these variables at various stages.

2.1.2 Factors affecting rate of evaporation

In an evaporative cooling process there is reduction in temperature and increase in relative humidity (Olosunde, 2006). The rate of evaporation is affected by four major factors namely air temperature, air movement, surface area and relative humidity of the air. Although these factors are discussed separately they interact with each other to influence the overall rate of evaporation and consequently the rate of cooling (Rusten, 1985).

Evaporation process takes place when water gain sufficient energy to change its state from liquid to vapour. Evaporation process is stimulated by air with relatively high temperature. Also such air has a high water vapour holding capacity. Thus, areas with high temperatures experience more cooling due to high rate of evaporation. When the temperature is low less water vapour can be held and as a result less evaporation and cooling will occur.

The velocity of the moving air is one of the factors that influence rate of evaporation. Air movement can be natural (wind) or forced (fan). As water evaporates from a moist surface, humidity of the air that is close to it increases. The rate of evaporation slows down as the humidity of the air raises. However, as the humid air near the water surface is constantly removed and replaced with drier air, the rate of evaporation will either increase or remain constant.

Moreover, the area of the evaporating surface is an important factor that affects the rate of evaporation. The greater the surface area from which the water evaporates, the greater the rate of evaporation. Further, relative humidity is a critical factor which affects efficiency of evaporative cooling system. Low relative humidity of the air means only a portion of the total quantity of water which the air is capable of holding is being held. With this condition air can hold additional moisture and with all other conditions favourable, efficiency of the evaporative cooling system is expected to be higher due to a higher rate of evaporation.

2.1.3 Methods of evaporative cooling

According to Rusten (1985) the two main evaporative cooling methods are direct evaporative cooling and indirect evaporative cooling. In a direct evaporative cooling process air is passed through a media that is flooded with water. The latent heat of vaporization of the water cools and humidifies the air streams allowing the moist and cool air to move to its intended direction. Sellers (2004) and Sanjeev (2008) presented major limitations of direct evaporative cooling which include undesirable increase humidity of air, the lowest temperature achievable is the wet-bulb temperature of the outside air, high concentration and precipitation of salts in water deposit on the pads and the other parts causing blockage and corrosion thus needs frequent cleaning, replacement, and servicing.

A study done by Dzivama (2000) on the forms of evaporative cooling process showed two forms in which the principle of direct evaporative cooling can be applied. The difference is due to the means of providing the air movement through the moist materials. These include passive and non-passive forms. In the passive form of direct evaporative cooling natural wind velocity is used as a means of moving the air through the moist surface for evaporation to occur. This form can be developed for short term on farm storage. In non- passive form a fan is used to provide air movement.

In the passive-direct evaporative cooling system the general principles are the same but the construction and design varies. The cooler consists of cabinets where the produce is stored, absorbent material used to hold water against the moving air. Water trickles down from an overhead tank/through and wet the absorbent material. The absorbent material covering the cabinet absorbs water from the tank on top of the cabinets. The entire cloth used as cabinet is soaked in water and as the air moves past the wet cloth and evaporation occurs. With continued evaporation process, the cabinet contents will be kept at a temperature lower than that of the environment. The temperature reduction achieved in this type of cooler ranged from 5°C to 10°C.

In the non-passive direct evaporative cooling system a small fan and a water pump which is powered by electricity is used. The cooler consists of storage cabins for keeping the products, an absorbent material which absorbs water from the overhead tank and expose it to evaporation, a fan which draws air through the pad, and an overhead tank which supplying water to the absorbent material. The absorbent materials used included hessian materials, cotton waste and celdek. The body frame of the cooler is made of wood. The pad and the fan are placed in the direction opposite to each other.

In an indirect evaporative cooling a heat exchanger is combined with an evaporative cooler. The common approach used is the passes return/exhaust air through an evaporative cooling process and then to an air heat exchanger which in turn cools the air. Another approach is the use of a cooling tower to evaporatively cool a water circuit through a coil to a cool air stream. Sellers (2004) and Sanjeev (2008) reported that indirect cooling differs from direct cooling. This is because in an indirect cooling process, air cools by the evaporation of water but there is no direct contact of water with process air. Instead a secondary airstream is used for evaporation of water and hence the moisture content of process air remains the same.

2.1.4 Advances in evaporative cooling technology

Several evaporative coolers have been developed for preservation of fruits and vegetables (Redulla, 1984a; FAO, 1986; Roy, 1989; Thompson and Scheureman, 1993; Acedo, 1997,). The designs developed range from the simple straw packing houses to sophisticated complex system. According to FAO (1986) the packing houses of typical evaporative coolers are developed from natural materials that can be moistened with water. Evaporative cooling condition in the pack house can be created by wetting the walls and the roof. However, the construction material for these structures deteriorates within a short period and both the stored product and construction material are susceptible to attack by rodents.

Vakis (1981) presented a low cost cool store in Kenya for vegetable storage. The roof and walls were kept moist by dripping water from the roof top. In some developing countries like India, China and Nigeria evaporative cooler that utilizes wind pressure to force air through moist pads have been developed (FAO, 1986).

Redulla (1984b) developed an evaporative cooler suitable for preservation of fruits and vegetables. The cooler can use either natural air or forced air to cool the produce. In addition, drip coolers can be developed from simple material which includes burlap and bamboo. These coolers rely on evaporation and do not involve the use of fan.

Rusten (1985) developed different evaporative systems using available materials as evaporative pads. These materials included canvas, jute curtains and hourdis clay blocks. A mechanical fan in some of the developed coolers was used to pass air through the evaporative pads. Further, Rusten (1985) also investigated various evaporative cooling systems developed using locally available materials such as canvas, jute curtains as pads. In some designs, mechanical fans were used to force air through the moist evaporative pad. The evaporative pad was kept moist by placing overhead water basins on the fabric material. The material absorbed water gradually by capillary action and eventually became saturated.

Roy and Khurdiya (1986) developed a cooled storage structure for fruits and vegetables. The structure had a double wall constructed with baked bricks and a roof made of gunny cloth in a bamboo framed structure.

Acedo (1997) used jute bag and rice husk cooling pad in the Philippines to developed two simple evaporative coolers for storage of vegetables. Decay was prevented by washing the product in the chlorinated water.

Sanni (1999) developed an evaporative cooling system for storage of vegetable crops. The system had a regulated fan speed, water flow rate and wetted-thickness. This was possible due to varying temperature and relative humidity within the facility.

Dvizama (2000) did performance evaluation of an active cooling system for storage of fruits and vegetables based on the principles of evaporative cooling. A Mathematical model for the evaporative process at the pad-end and the storage chamber was developed. In this study, the stem variety of sponge was established to be the best pad material amongst the local materials tested.

Mordi and Olorunda (2003) investigated the performance of evaporative cooling system for storage of tomatoes. The evaporative cooler temperature reduced by 8.2°C from ambient condition of 33°C, while a relative humidity increased by 36.6% from ambient condition 60.4%. They also reported an increased storage life of unpacked fresh tomatoes in evaporative cooler environment from 4 days to 11 days. Storage life under ambient conditions, and in sealed but perforated polyethylene bags was 18 days and 13 days, respectively.

Anyanwu (2004) designed a porous wall, termed pot in pot, evaporative cooler for preservation of fruits and vegetables. In this study, an evaporative cooler was developed using locally available materials and evaluated. The evaporative cooler made of mud (clay) directly excavated from the swamp which does not rely on electricity helped farmers and marketers of fruits and vegetables to store and preserve efficiently their products. The storage life of less than four days was achieved on tomato.

Olosunde (2006) evaluated the performance of evaporative pads materials for the storage of fruits and vegetables. Jute, hessian and cotton waste were selected as pad materials. The walls, basement and roof of the cooler were constructed with plywood, and the main body frame constructed with thick wood. The cooling efficiency, heat load removed and the quality of the stored products were evaluated. The jute material had overall advantage compared to the other pad materials. The cooling efficiency of the cooler could be increased by having two of its sides padded.

Jain (2007) developed a two stage evaporative cooler with a heat exchanger for fruits and vegetable. A storage life of 14 days was achieved. However, the cost of this kind of design is high.

Sushmita *et al.,* (2008) investigated storage of fruits and vegetables in an evaporative cooling chamber and in ambient condition. The evaporative cool chamber was made of baked bricks and riverbed sand. The results showed a lower weight loss for the fruits and vegetables kept inside the chamber than those stored outside the chamber. The storage life of fruits and vegetables was 3 to 5 days more than outside storage.

2.2 Cooling by reflection of near infrared radiation

Light energy from the sun has a wide range of wavelengths with a small portion having wavelength ranging from 295 to 2500 nm reaching the Earth's surface. The light energy within the range includes Ultraviolet (UV), visible, and near infrared (Fang *et al.*, 2013).

The UV light accounts for about 5 % of the sun's energy and has wavelength ranging from 295 to 400 nm. It is a form of radiation which is not visible to the human eyes and affects human health both positively and negatively. Short exposure to UV radiation of wavelength ranging 290 to 320 nm generates vitamin D but can also lead to sunburn (Fang *et al.*, 2013).

The visible light is estimated to be 50 % of the sun's energy with wavelength ranging from 400 to 700 nm. It is the only electromagnetic wave which human beings can see as the colours of the rainbow with each colour having a different wavelength. Pigment selectively absorb the visible light and reflect the remaining. Therefore, the visible region consists of wavelengths that give us the perception of colour (Fang *et al.,* 2013).

The near infrared light lies within a wavelength ranging from 700 to 2500 nm. It has wavelengths that are longer compared to that of visible light, meaning invisible to human eye. Approximately 45 % of the total solar energy is in the infrared radiation region. The heat producing region of the infrared radiation ranges from 700 to 1100 nm, which results in heating of the surface if absorbed (Fang *et al.*, 2013).

The infrared radiation emitted by the sun is absorbed by roofs, walls, facades, and the like, leading to a heat build-up inside. All energy that is not reflected, convected or re-emitted is conducted into the inside of the structure and thus increases the interior temperature. It is possible to reduce the increasing temperature by coating exterior surfaces of the structure with near infrared reflecting paints (Fang *et al.*, 2013).

A cool coating reflects a high percentage of incident near infrared radiation, while transmitting high levels in the visible spectra. This will reduce the amount of solar energy entering structures hence resulting in a cool surface when exposed to the sun. During the hot seasons, cool coatings helps to keep the roof temperature down hence minimizing the energy required to keep structures at a required temperature (Fang *et al.*, 2013).

2.2.1 Reflection mechanism of infrared radiations

Absorption of light takes place when light energy promotes electrons from one bonding state to another. If light of a different wavelength is used to cause this energy transition, it will not be absorbed. This implies there are electronic transitions which cause absorption of light with wavelengths of energy ranging from 400 to 700 nm. Thus, light of lower energy having wavelength greater than 700 nm is not absorbed. In this case, a beam of light with a wavelength of 1500 nm is too low in energy to cause any electronic transitions in the material. Therefore, it not absorbed. Instead the 1500 nm light beam is refracted, reflected and scattered, leading to the diffuse reflection of near infrared light. There is no method to predict the near infared reflectivity of an inorganic or organic compound (Fang *et al.*, 2013).

When a beam of light falls on a powdered sample, reflection, transmission, and absorption can occur. If the sample is adequately optically thick, the transmitted light is negligible. There are two kinds of reflection which include specular and diffuse reflection. Specular reflection is important for optically smooth surfaces and for highly absorbing samples. Diffuse reflection takes place when the incident radiation penetrates into the powder and gets reflected by grain boundaries of the particles. Diffusion reflection is influence by size of particle. When the particle size decrease the number of reflections at the grain boundaries increases. Thus, the depth of penetration of incident light decreases leading to a decrease in absorption and increase in reflectance. The net effect will be a decrease in the absorbed portion of light and an increase in the reflected portion of light (Fang *et al.,* 2013).

2.2.2 Factors affecting near infrared reflectivity

Paint is a fine dispersion of pigments in binders in the presence of solvents and a small amount of additives. The final properties of the paint or coating depend on the properties of the binder, pigments and additives. Many other ingredients or additives in the paint such as solvent which mostly water, thickener, coalescent, dispersing agent, antifoaming agent, extender, anticorrosion agent, and different colour pigments for the visual colour, will improve various properties of the paint. Pigments alter the appearance of the coating by selective absorption or by scattering of light. The important physical optical properties of pigments include their light absorption and light scattering properties. If absorption is very small compared with scattering, the pigment is a white pigment. If absorption is much higher than scattering over the entire visible region, the pigment is a black pigment (Fang *et al.,* 2013).

The near infrared reflectivity depends on the relative refractive index of the particles and that of their surrounding medium, distribution of particles in the coating, loading of particles, binder concentration and wavelength of the incident light. A significant physical data for inorganic pigments consist of optical constants and geometric data such as mean particle size, particle size distribution, and particle shape (Fang *et al.,* 2013).

Particle size of the pigment is an important parameter affecting near infrared reflectivity. For the highest reflectivity, the particle size should be more than half the wavelength of the light to be reflected. Thus for reflecting infrared light of 800 to 1200 nm wavelength, particle size should be at least 0.4 to 0.6 microns (Fang *et al.,* 2013).

Binder weight ratio affects the final reflectance of the coating. With the increase in the binder weight ratio, there is an increase in the diffuse reflectance of the coating. With higher binder weight ratio, there is a strong capillary action between the binder particles, causing them to fuse together and bind reflective pigment particles into a continuous film. It has been found that coating materials, with less than certain weight ratios are unable to form a stable coating layer and are easily detached from the plastic sheet. However, coatings with more than one certain weight ratio develop cracks which might be from the large surface tension of the coating. Coating thickness is another factor which affects film reflectance. Higher coating thickness leads to better reflectance because of the higher number of reflective pigment particles on the substrate for reflecting (Fang *et al.*, 2013).

2.3 Factors affecting the shelf-life of fruits and vegetables

The shelf-life of fruits and vegetables is affected by various factors leading to their spoilage. These include ambient conditions such as temperature and relative humidity, variety and stage of ripening.

The shelf-life of agricultural products is greatly influenced by temperature. Low temperature extends storage life of the products by reducing respiration rate and the growth of spoilage micro-organisms (Watada *et al.*, 1996). According to Sommer (1989), an effective management of temperature is critical to postharvest disease control and considered all other treatments as supplements to refrigeration.

Relative humidity has a great effect on the deterioration of fruits and vegetables due to its direct relationship with the moisture content in the atmosphere which determines the shelf-life. Water loss in produce is directly influenced by the relative humidity of storage unit (Wilson *et al.*, 1995).

Variety and stage of ripening are important factors which affect the shelf-life of fruits and vegetables. Fruits and vegetables have different storage conditions depending on the variety and stage at which the fruits are harvested, which in practice varies from mature green to fully ripened (Olosunde, 2006).

2.4 Effect of postharvest operations on quality of fruits and vegetables

Quality attributes of fruits and vegetables occur during postharvest handling resulting in decreased in their shelf-life and hence a decrease in the quantity supplied for consumption and for export market. Dzivama (2000) presented common and notable quality attributes of fruits and vegetables which changes during postharvest handling. These include colour, weight, firmness and soluble solids. Fruits continue to ripen after harvesting and hence ripening process is an important factor to be considered during postharvest handling. According to Wilson *et al.*, (1995) stage of maturity affects the storage life of the produce. The storage life of immature or over mature produce may not be long compared to that picked at proper maturity stage. Colour is the most notable quality that changes in many fruits and vegetables. It is an important quality that the consumers use to evaluate whether the fruit is ripe, unripe, over-ripe or spoiled. Evaluation of colour change is based on comparison of the colour of produce under investigation against a standard colour chart (Dzivama, 2000).

The moisture content of most fresh produce ranges from 65 to 95% when harvested (FAO, 1989). Water is a critical component of most fruits and vegetables because it adds up to the total weight. Reduction in the weight of the produce is as a result of water losses. In addition, FAO (1989) reported that when the harvested produce loses 5 or 10% of its fresh weight, it begins to wilt and soon becomes unusable. Weight loss involves respiratory and evaporative losses. Respiratory losses are due respiration and depend mainly on the temperature of the surrounding air while evaporative losses are due to water vapour deficit of the environment compared with that of the produce. Moreover, FAO (1989) reported the higher the rate of movement of air over the produce the higher the water losses. Air movement through produce is necessary to carry away the heat of respiration. However, low rate of air movement must be observed.

Firmness has a direct relationship with the ripening of fruit. Since respiration process continues to take place even after harvest fruits tend to over-ripen. Dzivama (2000) reported that chemical activity within the fruit tissues continues to take place even after harvest and thus making the fruits to become over-ripe and soft. Changes in fruit firmness can be controlled by slowing down respiration rate by storing the fruits at low temperature. Dzivama (2000) reported that during ripening carbohydrate are broken down into simpler units. The starch is converted to sugar giving the fruits sweet taste characteristics. The degree of ripening can be determined by measuring level of sugar content in an extracted fruit juice.

2.5 Conclusions of the literature review

The following specific conclusions were drawn from the literature review:

1) Cooling by reflection of near infrared radiation is a potential technology that can be explored. The combination of near infrared reflection and evaporative cooling to lower the temperature of the storage environment is technology that can provide an applicable solution to storage challenges facing the subsistence mango farmers hence reduction in the postharvest losses.
2) The required conditions for evaporative cooling include high temperature, low relative humidity, water and air movement.
3) Temperature and relative humidity of the storage environment are the critical factors which greatly influence the shelf-life and quality of the fruit.
4) The most common and notable quality attributes of the fruits that changes during storage include colour, weight, firmness and soluble solids

CHAPTER THREE

MATERIALS AND METHODS

3.1 Determination of challenges facing subsistence mango farmers in the Lower Eastern region of Kenya

3.1.1 The study area

Figure 3.1 shows the location of the study area in relation to the map of Kenya.

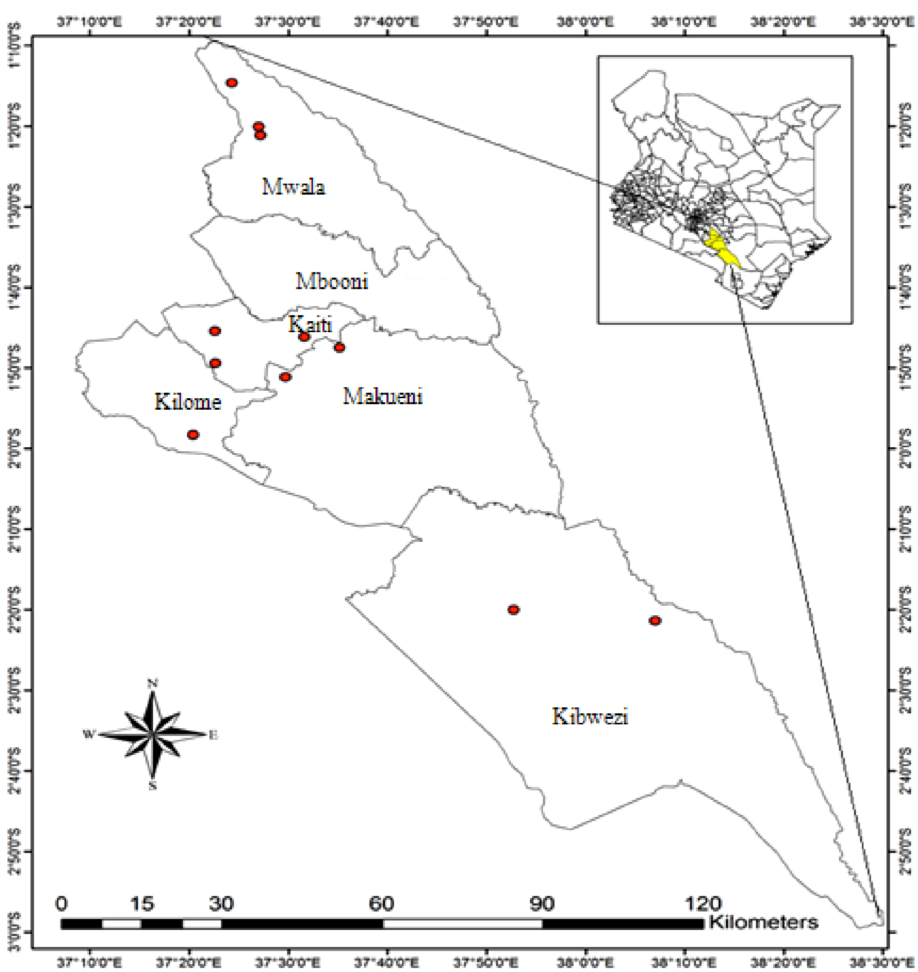


Figure 3. 1 Location of the Lower Eastern region in relation to the map of Kenya

3.1.2 The survey description

A baseline survey was conducted in Lower Eastern region of Kenya with eleven Locations selected for the study. The study involved subsistence mango farmers in the region. Purposive sampling was used to select the Lower Eastern region of Kenya. This region has the highest mango output due to introduction of improved mango varieties such as Apple, Kent, Tommy Atkins, among others that are high yielding. The sample size was evaluated based on equation 3.1 (Kothari, 2004). In this equation *s, n, N* and *P* are the sample size, total sample size, location population and total population, respectively.

$$s = \frac{nN}{P} \tag{3.1}$$

Well structured questionnaires were used for abstracting information on postharvest challenges facing the farmers in the region. These were further complemented through information obtained from interviews with the target group. The postharvest data collected was on methods for mango harvesting, types of packaging for mangoes, storage methods for mangoes, need for an improved store for mangoes and storage period for mangoes.

3.2 Development of an improved evaporative cooled store for mangoes

Two identical evaporatively cooled stores were developed in the Department of Biomechanical and Environmental Engineering, Jomo Kenyatta University of Agriculture and Technology (JKUAT). The dimensions of the stores namely length, width, and height were 0.84 m, 0.84 m, and 1.5 m, respectively based on the existing evaporative cooler. To prevent splash water from entering the store, it was raised 0.4 m above the ground. The main frame was made using hardwood timber (10 cm x 5 cm). The storage chamber was surrounded by a pad made from wire mesh (Ø 0.24 mm) and charcoal sourced from a local market. Aluminium sheet (0.5 mm thick) was fixed around the internal surface of the storage chamber to prevent charcoal dust from contaminating the stored product. The dimensions of the pad which included the length (L), height (H), and thickness (I) (Figure 3.2) were 0.84 m, 1.1 m, and 0.1 m thick, respectively.

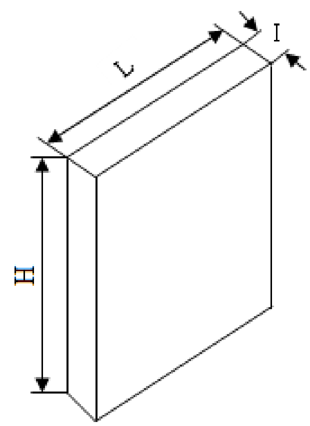


Figure 3. 2 Geometrical dimensions of the evaporative pad

Inside the storage chamber were shelves made from coffee tray mesh (Ø 0.5 mm, spacing 5 mm). The front face (door side) of the storage chamber was covered with plywood (6.4 mm thick). The side opposite the door was extended to accommodate a 12 V fan used to draw ambient air into the cooler (Figure 3.3).

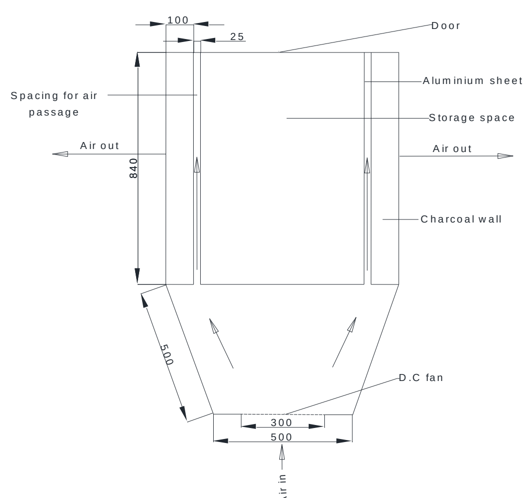


Figure 3. 3 A top view of the cooler for mango storage showing position of the 12 V fan, direction of air flow, and evaporative pads arrangement

The evaporative pad was kept moist by water dripping by gravity from PPR pipes (Ø 12.7 mm) connected to a 100 litre overhead storage tank raised 2 m above the ground. A gutter below the pad collected the water draining from the bottom of the pads to a 100 litre temporary storage tank. A 12 V shurflo pump (2088-443-144; Mexico) with a capacity of 13.2 l/min and 2.7 m head was used to recycle the water from the temporary storage tank to the overhead tank (Figure 3.4).

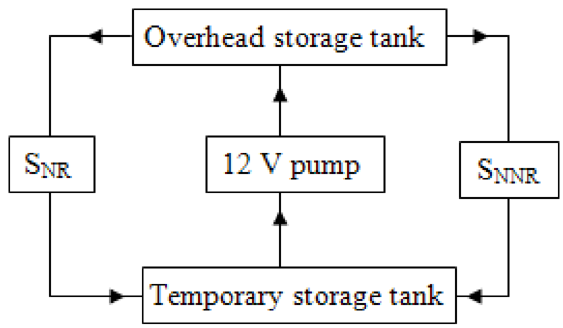


Figure 3. 4 A schematic diagram of a water circulation system for the coolers

The pump and fan were connected to solar PV system comprising of a charge controller (Apple 15, Sundaya International Pte., Ltd, Singapore) and a 70 Ah battery recharged by a 125 W solar panel (Figure 3.5). The external surfaces of one of the coolers were sprayed with NIR paint (Redusol, Mardenkro company, Baarle-Nassau, Netherlands). Before application the paint was diluted by mixing it with water in the ratio of 1:2, respectively as per the manufacturer's recommendations. The acronyms S_{NR} and S_{NNR} were used to refer NIR store and non-NIR store, respectively.

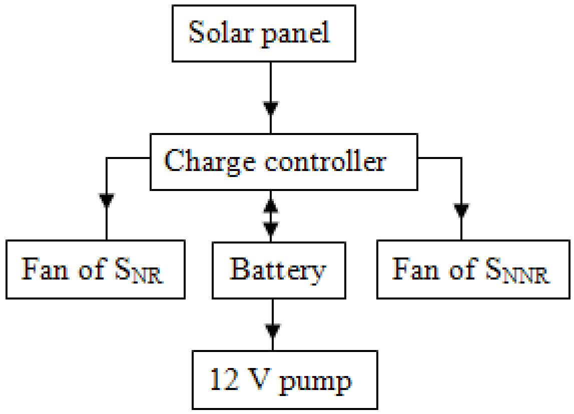


Figure 3. 5 A schematic diagram of a solar PV system for the coolers

3.3 Performance evaluation of the evaporative cooler

This was performed by comparing the psychrometric properties of the air inside the storage chamber of an unloaded S_{NR} and S_{NNR}. The parameters that were considered included dry bulb temperature and relative humidity measured using Tinytag Ultra 2 data logger (TGU-4500, Gemini Data Loggers Limited, United Kingdom) and recorded at 30 minutes intervals. Three trials were performed at the every time interval, average values obtained and recorded. The data was collected between 8 a.m and 6 p.m when the wet bulb depression was expected to be maximum. Room conditions were used as control experiment. During the evaluation process the pads were kept moist and air was drawn into the coolers at a steady velocity of 3.0 m/s.

3.4 Effect of storage environment on quality of Apple and Kent mangoes

Two mango varieties were selected based on the results of the baseline survey. Apple and Kent were identified as the most common mango varieties grown by the farmers in the Lower Eastern region of Kenya. Three trials were run during the 2014 mango season. Mature and green fruits were sourced directly from the farmer in Ukia market. At the start of each trial 36 fruits of each variety were selected from the farmer’s harvest and transported in plastic crates to the experimental site. Harvesting was done in the morning and the fruits transported on the same day and kept in a cool dry place overnight. The fruits were washed separately using tap water, wiped, labelled and stored in the S_{NR}, S_{NNR}, and R_C. Four labelled fruits of each variety were randomly selected in each storage method for evaluation of physiological weight and peel colour changes during storage. Subsequent evaluation was repeated on the same fruits since the measurement of weight and peel colour was non-destructive. The measurement of firmness, pulp colour, total soluble solids (TSS), total titrable acid (TTA) and pH which involves destruction of fruits, the fruits were randomly selected, evaluated and discarded. The shelf-life and quality attributes (viz., physiological weight, colour, firmness, TTS, TTA and pH) of the fruit stored in the S_{NR} were evaluated against the fruits stored in the S_{NNR} and room conditions (R_C).

The effect of storage conditions on physiological weight was evaluated by monitoring the weight of the fruit on daily basis using a digital scale (PB3002, Mittler Toledo, Switzerland). The percentage physiological loss in weight was calculated based on equation 3.2, in which W_l, A, and B are the physiological loss in weight (%), weight of a mango fruit before storage (g), and weight of the mango fruit at inspection date (g), respectively.

$$W_l = 100 \left(\frac{A - B}{A} \right) \tag{3.2}$$

In order to evaluate the effect of storage conditions on colour, the colour values L^*, a^*, b^* were measured daily using the Minolta colour difference meter (CR-200, Osaka, Japan) after calibrating it with white and black tiles. The parameters a^*, b^*, and L^* represent the degree of redness to greenness, degree of yellowness to blueness, and degree of lightness to darkness, respectively. The hue angle, $H°$ was determined from L^*, a^*, b^* values using equation 3.3 and 3.4 (McGuire, 1992).

$$H^o = \tan^{-1}\left(\frac{b^*}{a^*}\right) \text{, when } a^*>0 \text{ and } b^*\geq 0 \quad (3.3)$$

$$H^o = 180 + \tan^{-1}\left(\frac{b^*}{a^*}\right) \text{, when } a^*<0 \quad (3.4)$$

Based on the computed values for hue angle, the colour of the fruits was evaluated using a CIE-L.a.b colour chart plot (Figure 3.6).

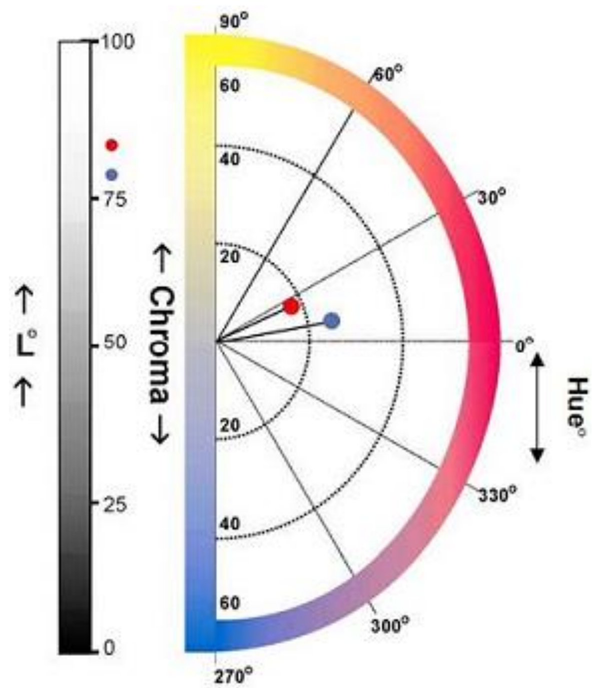


Figure 3. 6 A CIE-L.a.b colour chart plot (Source: Mohammadi, 2008)

The effect of storage conditions on firmness of the fruit was evaluated on daily basis using a penetrometer (CR-100D, Sun Scientific Co. Ltd Japan).

The chemical properties evaluated were the total soluble solids (TSS), total titratable acids (TTA), and pH for the fruits stored in the S_{NR}. These properties were measured daily and evaluated against those stored in the S_{NNR} and under R_C. To determine effect of storage conditions on TSS, the TSS was determined as percentage Brix using a digital hand held pocket refractometer (PAL-1, ATAGO Company, Tokyo, Japan). In addition, the effect of storage conditions on TTA was determined by titrating homogenized mango juice extract with 0.1N NaOH in the presence of phenolphthalein indicator according to AOAC method. TTA was expressed as percentage citric acid which is the main organic acid in mango fruit. Moreover, the effect of storage condition on pH was evaluated by measuring the pH values of the mango juice extract using pH meter (HI 98130, Hanna instruments, Mauritius).

3.5 Development of a computer simulation model for predicting performance of an improved evaporative cooled store for mangoes

3.5.1 Background information

A computer simulation model for predicting the performance of the improved evaporative cooled store for mangoes was developed in Java computer programming language. The inputs parameters of the model were inlet air conditions (dry bulb temperature, wet bulb temperature, specific humidity, and air velocity), coolant conditions (coolant temperature and coolant flow rate), cooler characteristics (length of evaporative pad, thickness of evaporative pad, height of evaporative pad, and wetted area per unit volume of evaporative medium), and air properties (specific heat of air, specific heat of the water vapour, thermal conductivity of air, Prandtl number, kinematic viscosity of air, and density of air).

The output parameters of the model included the total face area of the evaporative pads, total face area through which the air enters the evaporative pad, total wetted surface area of the evaporative pad, characteristic dimension, Nusselt number, Reynolds number, air mass flow rate, convective heat transfer coefficient of air, saturation efficiency, specific heat of humid air, dry bulb temperature of the outlet air, and cooling capacity.

3.5.2 Measurement of the model input parameters

The dry bulb temperature and relative humidity of the inlet air into the cooler which corresponded to the ambient air was measured using Tinytag Ultra 2 data logger (TGU-4500, Gemini Data Loggers Limited, United Kingdom) at an interval of 1 hour from 8 a.m. to 6 p.m at some selected sunny days. The corresponding wet bulb temperature and specific humidity was determined based on psychrometric chart equations. The inlet air velocity was measured using EMPEX digital electronic anemometer wind MESSE (FG-561, Tokyo, Japan). A slide rheostat (D-4; No, Y-95; Yambishi Electric Co. Tokyo, Japan) connected in series with the 12 V fan was used to vary the inlet air velocity in the range of 3.0 to 4.0 m/s at an interval of 0.2 m/s. Three trials were performed at each interval, average values obtained and recorded.

3.5.3 Evaluation of the model inlet air properties

Daily ambient dry bulb temperature (T_{db}) and relative humidity (RH) data for the Jomo Kenyatta University of Agriculture and Technology (JKUAT) for the month of January, February and March, 2014 were collected and grouped into 5 categories (Table 3.1).

Table 3. 1 Weather data for the JKUAT from January to March, 2014

Ambient condition	Maximum T_{db} (°C)	Total days	Mean Maximum T_{db} (°C)	Mean RH (%)	Mean T_{wb} (°C)
A	Below 25.5	3	24.1	80.6	21.5
B	25.6 to 27.5	9	26.4	76.4	23.2
C	27.6 to 29.5	23	28.7	66.8	23.9
D	29.6 to 31.5	35	30.5	60.0	24.4
E	Above 31.6	20	32.2	52.4	24.6

The most prevailing ambient condition D (Table 3.1) of mean maximum T_{db} of 30.5°C and mean RH of 60% were selected for analysis. The air properties were evaluated based on the ambient condition D. Thus, at the ambient condition D, the values of specific heat of air, specific heat of water vapour, thermal conductivity, Prandtl number, kinematic viscosity, and density of air were 1005 J/kgK, 1865 J/kgK, 0.02644 W/mK, 0.7135, 16.09x10^{-6} m^2/s, and 1.164 kg/m^3, respectively.

3.5.4 Equations for the simulation model

The total face area through which air enters the cooler was determined as indicated in equation 3.5, in which A_{ft}, L, and H are total face area (m^2), length of the evaporative pad (m), and height of the evaporative pad (m) respectively.

$$A_{ft} = 2LH \tag{3.5}$$

The total volume of the evaporative pads was determined using equation 3.6, where I and ϑ are thickness of the evaporative pad (m) and total volume of the evaporative pad (m^3), respectively.

$$\vartheta = 2LHI \tag{3.6}$$

Total wetted surface area for the evaporative pads was evaluated base on equation 3.7. In this equation, A_v and A_w are wetted area per unit volume of the evaporative pad material (m^2/m^3) and total wetted area of the evaporative pad (m^2), respectively.

$$A_w = A_v \vartheta \tag{3.7}$$

The characteristic dimension was determined as indicated in equation 3.8, in which l_c is characteristic dimension (m).

$$l_c = \frac{\vartheta}{A_w} \tag{3.8}$$

The Nusselt number was computed using equation 3.9 (Camargo *et al*., 2005), where Nu, Re, and Pr are dimensionless Nusselt, Reynolds, and Prandtl numbers, respectively.

$$Nu = 0.10\left[\frac{l_c}{l}\right]^{0.12} \mathrm{Re}^{0.8} \mathrm{Pr}^{0.33} \tag{3.9}$$

The Reynolds number was evaluated based on equation 3.10 (Kulkarni *et al.*, 2011), in which v_a and V are the velocity (m/s) and kinematic viscosity (m/s^2) of air through the evaporative pad, respectively.

$$\mathrm{Re} = \frac{v_a l_c}{V} \tag{3.10}$$

The saturation efficiency was determined using equation 3.11 (Camargo *et al.*, 2005), where η_p, h_c, m_a, and c_{pu} are predicted saturation efficiency (%), convective heat transfer coefficient (W/m^{2}K), mass flow rate of air through the evaporative pad (kg/s), and specific heat of humid air (J/kgK), respectively.

$$\eta_p = 100\left[1 - \exp\left(-\frac{h_c A_w}{m_a c_{pu}}\right)\right] \tag{3.11}$$

The convective heat transfer coefficient of air was evaluated based on equation 3.12, where K_a is thermal conductivity of the air through the evaporative pad (W/mK).

$$h_c = \frac{N_u K_a}{l_c} \tag{3.12}$$

The specific heat of humid air was determined using equation 3.13, in which c_{pa}, c_{pv}, and w are specific heat of air (J/kgK), specific heat of water vapour (J/kgK), and specific humidity (kg/kg of dry air), respectively.

$$c_{pu} = c_{pa} + wc_{pv} \tag{3.13}$$

The mass flow rate was determined based on equation 3.14, in which ρ is density of air (kg/m^3).

$$m_a = A_{ft} v_a \rho \tag{3.14}$$

The dry bulb temperature of outlet air was calculated using equation 3.15 (Kulkarni *et al.*, 2011), in which t_1, t_p, and t_{wbt} are the dry bulb temperature of the inlet air (°C), dry bulb temperature of the outlet air (°C), and wet bulb temperature of the inlet air (°C), respectively.

$$t_p = t_1 - 0 \cdot 01 \eta_p (t_1 - t_{wbt}) \tag{3.15}$$

The predicted cooling capacity was evaluated based on equation 3.16, where Q_p predicted cooling capacity of the S_{NR} (kJ/h) (Kulkarni *et al*., 2011).

$$Q_p = 3 \cdot 6 m_a c_{pa} (t_1 - t_p) \tag{3.16}$$

The actual saturation efficiency was calculated using equation 3.17 where, η_a and t_a are the percentage actual saturation efficiency and dry bulb temperature (°C) of the outlet air, respectively.

$$\eta_a = 100 \left(\frac{t_1 - t_a}{t_1 - t_{wbt}} \right) \tag{3.17}$$

The actual cooling capacity of the cooler was determine using equation 3.18, in which Q_a is the actual cooling capacity (kJ/h).

$$Q_a = 3 \cdot 6 m_a c_{pa} (t_1 - t_a) \tag{3.18}$$

Figure 3.7 shows a flow chart of a computer simulation model for predicting the performance parameters of the improved store for mangoes.

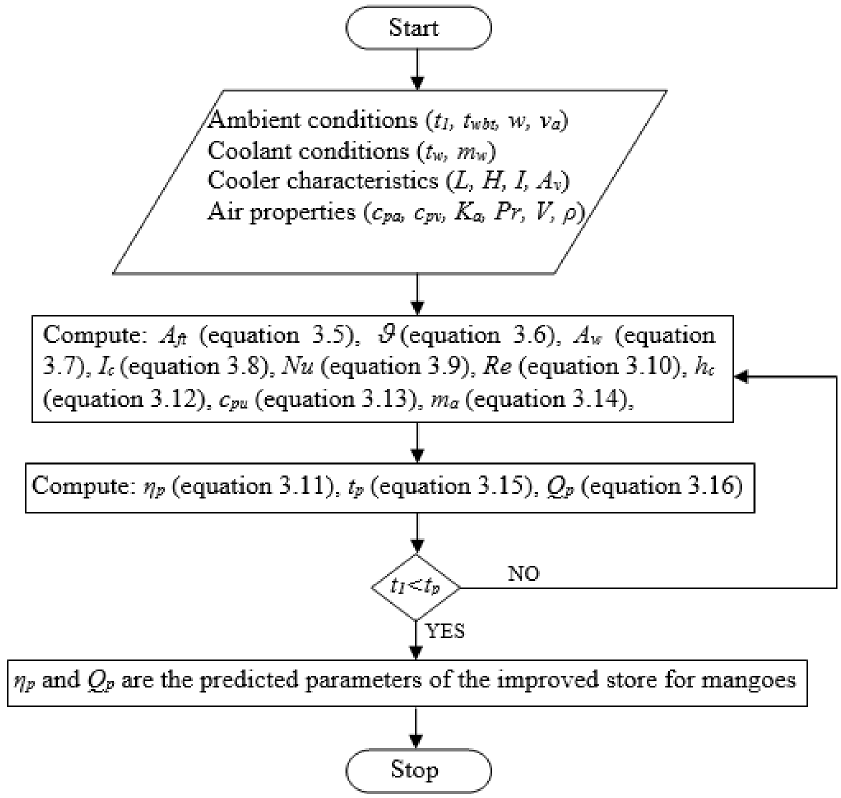


Figure 3. 7 A flow chart of the simulation model for predicting the performance parameters of the improved store for mangoes

3.5.5 Model validation

This was performed by comparing the model results with the experimental results. The coefficient of determination (R^2) and root mean square error (*RMSE*) between the model and experimental results were determined to test the reliability of the model. Yaldiz and Ertekin (2001), Sacilik and Elicin (2006) reported that the higher the R^2 value and the lower the *RMSE* value, the better the goodness of fit. The *RMSE* was evaluated using equation 3.18 (Doymaz *et al.*, 2004; Sarsavadia *et al.*, 1999), in which N is the number of observations, $X_{pre,i,}$ and $X_{act,i}$ are the actual and predicted performance parameters, respectively.

$$RMSE = \left[\frac{1}{N} \sum_{i=1}^{N} \left(X_{pre,i} - X_{act,i} \right) \right]^{1/2} \tag{3.18}$$

3.6 Data analysis

The baseline survey data was analyzed using Statistical Package for Social Science (SPSS) version 16.0 and Microsoft office Excel (2007). In addition, GenStat (4^{th} edition) and Microsoft office Excel (2007) was used to analyse the data on the performance of the cooler, while Microsoft office Excel (2007) was used to analyse the performance of the simulation model. ANOVA, regression, and graphical representation were used in the analysis of the data for the performance evaluation of the developed store, effect of storage conditions on the quality of Apple and Kent mangoes, while the model results were analysed using *Student's t*-test and graphical representation.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Challenges facing subsistence mango farmers in the Lower Eastern region of Kenya

4.1.1 Method of mango harvesting

The study revealed that 7% of the farmers harvested the fruit by shaking the mango tree for the mature ripe fruit to fall on the ground (Figure 4.1). This method was practiced mainly by the farmers growing indigenous variety who believed that the variety is resistant to mechanical damage due to ground impact. However, this kind of method is not a good practice since it reduces the fruit quality and shelf-life. In addition, the damaged fruit respire more and deteriorate within a short period. Moreover, the damaged fruits are exposed to attack by micro-organisms responsible for spoilage. Gathambiri *et al.* (2009) reported that postharvest losses in mangoes occur as a result of ineffective harvesting methods which cause mechanical damage to the fruits thus lowering their quality and shelf-life.

The exotic variety was mainly harvested by having someone climbing the tree with a basket and picks the fruit. The survey showed that 38% of the farmers practiced this method with 55% harvesting the fruit using untreated hooks (Figure 4.1). Gathambiri *et al* (2009) stated that the use of untreated hooks exposes the fruit to disease infections hence leading to spoilage. Therefore, when harvesting the fruit treated hooks should be used.

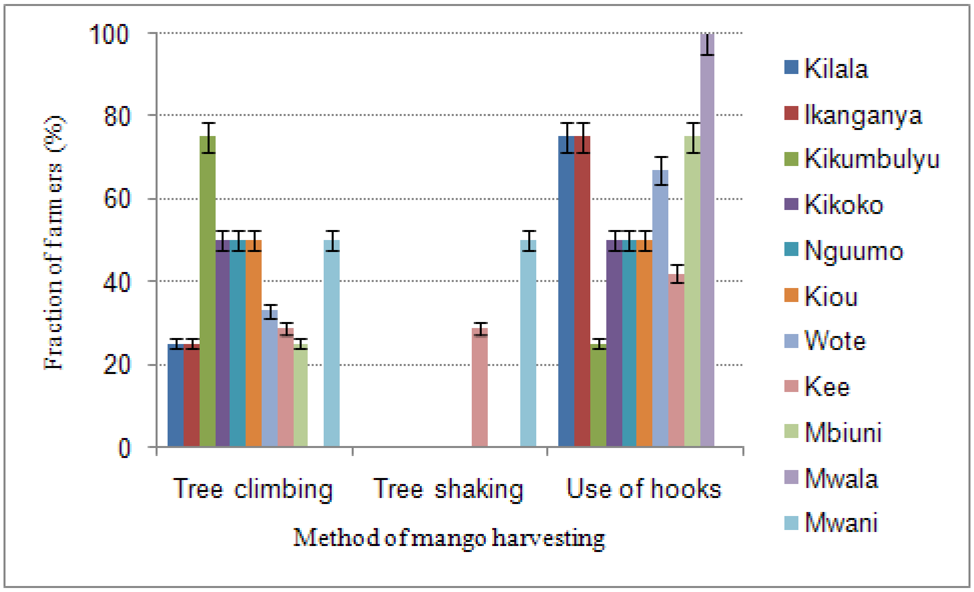


Figure 4. 1 Distribution of methods for mango harvesting among the farmers in various Locations of Lower Eastern region of Kenya

4.1.2 Types of packaging for mangoes

The study showed that 40% of the farmers did use gunny bags to pack the fruit (Figure 4.2). The other types of packaging for mangoes included cartons, plastic crates, baskets, and sisal bags with 37%, 18%, 3%, and 2% of the farmers using these types, respectively (Figure 4.2). If mangoes are to be packed in crates and cartons the fruit should be packed in a single layer. Due to great sensitivity to pressure the fruit should be wrapped in paper or padded with wool, straw or hay. However, this study revealed that the farmers packed the fruit in crates unwrapped resulting in physical injuries or bruises of the fruits particularly during transportation. According to Gathambiri *et al.* (2009), improper packaging of mangoes is one of the challenges facing the subsistence farmers in the region.

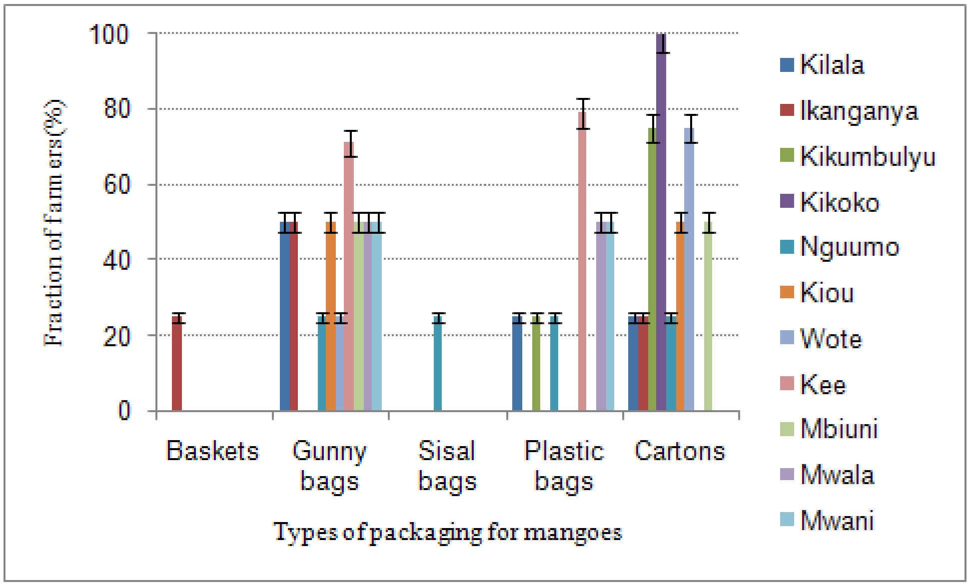


Figure 4. 2 Distribution of types of packaging among the farmers in various Locations of Lower Eastern region of Kenya

4.1.3 Method of storage for mangoes

The study showed that 63% of the farmers in the region did not have stores for mangoes with 25%, 7%, and 5% of the farmers storing the fruit in their houses, barns, and ineffective stores, respectively (Figure 4.3). This implied that inadequate availability of storage structures for mangoes is one of the postharvest challenges facing the farmers in the region. Therefore, there is a need for development and use of improved store for mangoes that extends the shelf-life thereby reducing spoilage. This would result in more fruits availed in the market leading to increased income earning hence improved standard of living.

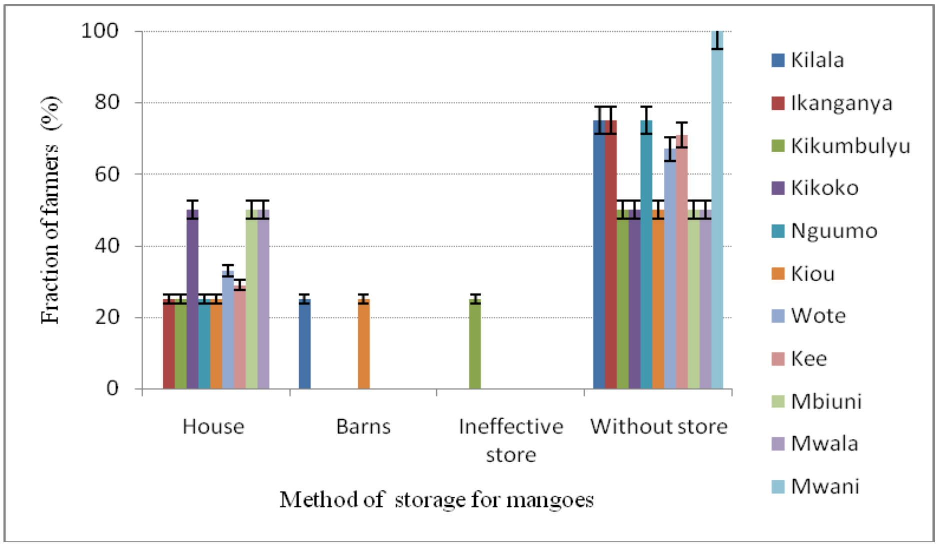


Figure 4. 3 Distribution of methods for mango storage among the farmers in various Locations of Lower Eastern region of Kenya

The study further revealed that 95% of the farmers require an improved storage structure for mangoes (Figure 4.4). This showed that most of the farmers in the region did not have adequate stores for mangoes particularly during the peak harvest season. Therefore, a technology aimed at addressing the farmers' need by developing an improved store for mangoes would be necessary.

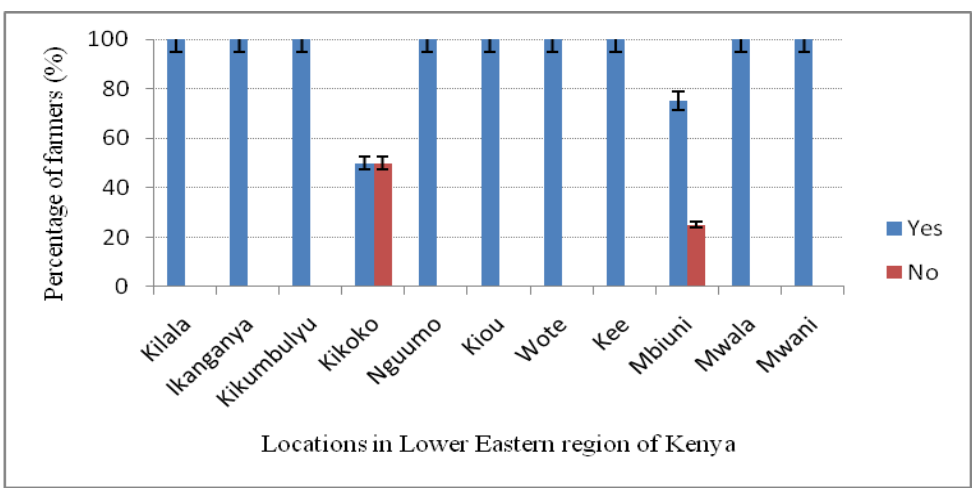


Figure 4. 4 Distribution of opinions on the need for an improved store for mangoes among the farmers in various Locations of Lower Eastern region of Kenya

4.1.4 Storage period for mangoes

The study revealed that 95% of the farmers could not store the fruit for over a period of 7 days with 5% of the remaining storing the fruit up to a maximum of 14 days (Figure 4.5**)**. The shelf-life of the fruit is influenced by storage conditions of temperature and relative humidity and hence for effective storage of mangoes it is important to control these conditions. Thus, the short storage period for mangoes indicated that a majority of the farmers in the region lack effective storage structures for mangoes.

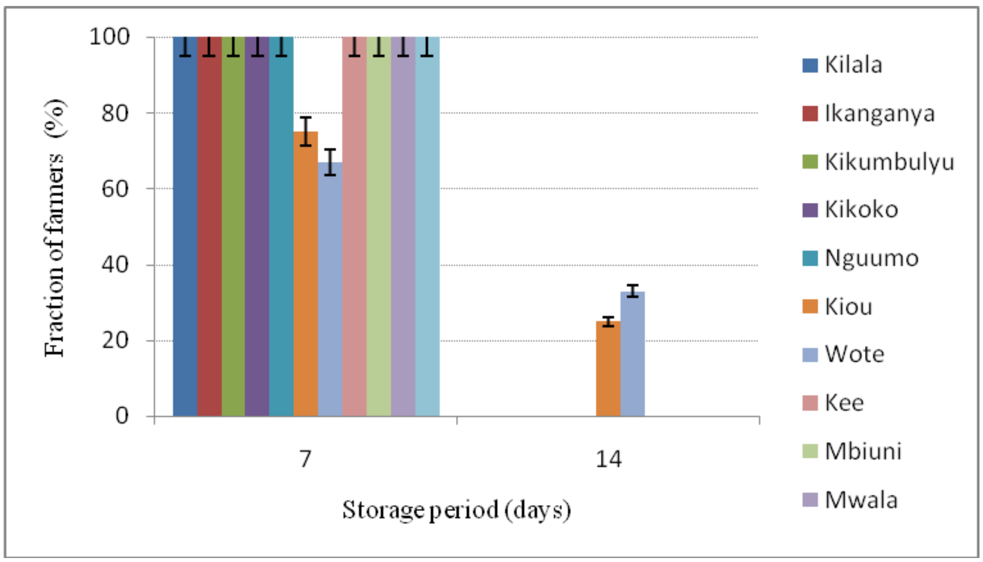


Figure 4. 5 Distribution of storage period for mangoes among the farmers in various Locations of Lower Eastern region of Kenya

4.2 The developed evaporative cooled store for mango storage

Figure 4.6 shows the improved store for mango storage at no load condition.

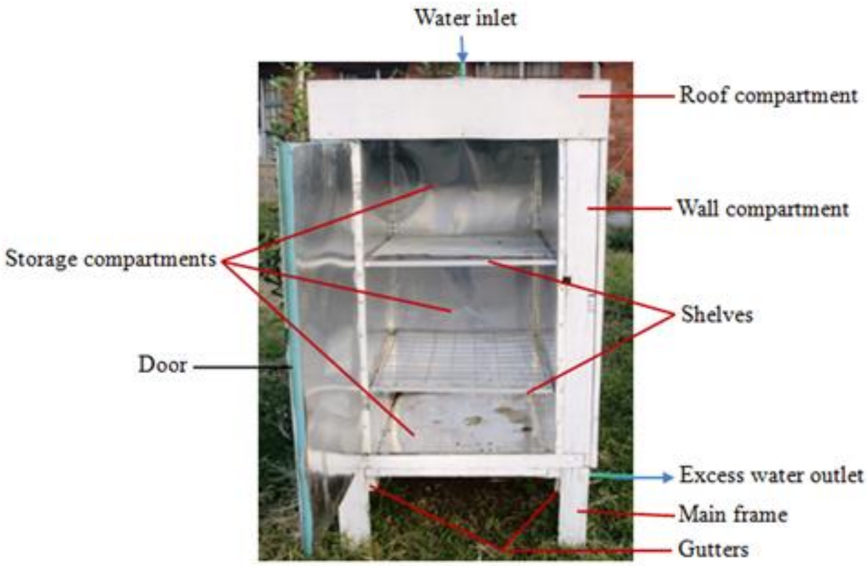


Figure 4. 6 A photograph of unloaded S_{NR} for storage of mangoes

4.3 Performance evaluation of the developed evaporative cooled store at no load conditions

Figure 4.7 presents variation in temperature of storage environment for the S_{NR} and S_{NNR}, ambient and room temperature with time of day. The temperature of storage environment for the S_{NR} and S_{NNR} ranged from 15.4 to 18.6°C (average value of 16.8°C) and 16.4 to 22.9°C (average value of 20.0°C), respectively. Further, the room and ambient temperature was in the range of 21.6 to 25.5°C (average value of 23.8°C) and 23.6 to 31.9°C (average value of 28.2°C), respectively. This implied the temperature in S_{NR} was lower by 3.2, 7.0, and 11.4°C compared to S_{NNR}, R_C, and ambient conditions (A_C), respectively.

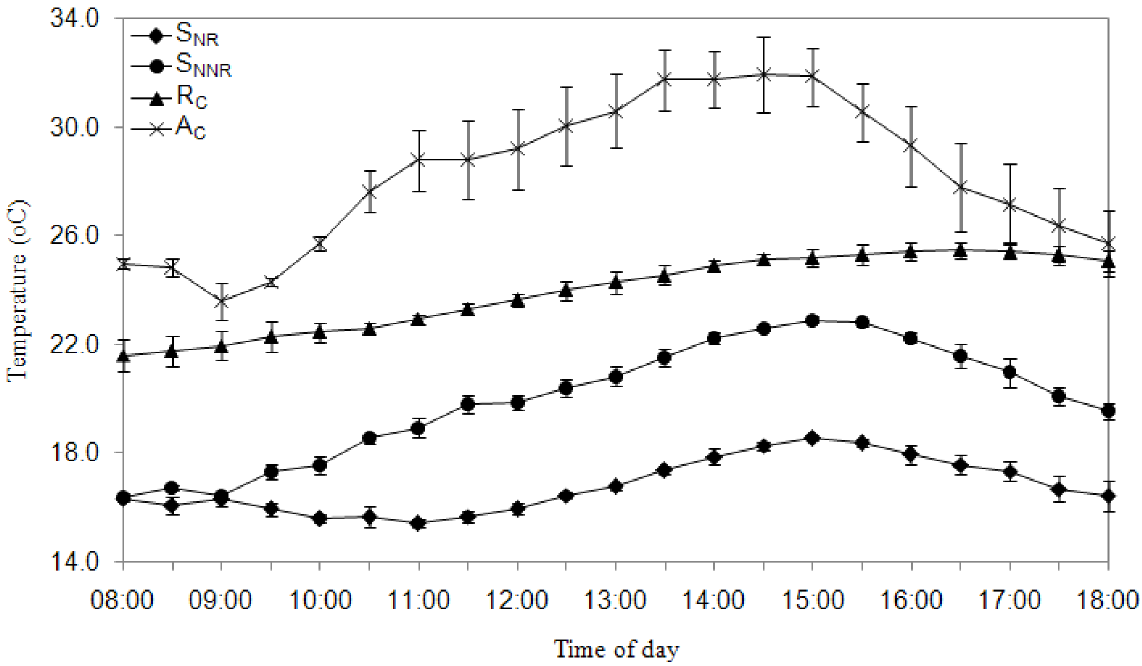


Figure 4. 7 Comparison of temperature in the S_{NR}, S_{NNR}, R_C, and A_C

Analysis of variance results (Table 4.1) indicated significant difference (P<0.05; $F_{computed}$ = 135.211; $F_{crit,5\%}$, = 2.719) in temperature for the S_{NR}, S_{NNR}, R_C, and A_C. The ANOVA results (Table 4.2) further showed significant difference (P<0.05; $F_{computed}$ = 106.519; $F_{crit,5\%}$ = 3.150) in temperature for the S_{NR}, S_{NNR}, and R_C. Moreover, the ANOVA results (Table 4.3) showed a significant difference (P<0.05; $F_{computed}$ = 37.469; $F_{crit,5\%}$, = 4.085) in temperature of storage environment for the S_{NR} and S_{NNR}.

Table 4. 1 ANOVA for temperature in the S_{NR}, S_{NNR}, R_C, and A_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	1529.758	3	509.919	135.211	3.1E-31	2.719
Residual	301.702	80	3.771			
Total	1831.460	83				

Table 4. 2 ANOVA for temperature in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	537.209	2	268.604	106.519	1.81E-20	3.150
Residual	151.300	60	2.522			
Total	688.508	62				

Table 4. 3 ANOVA for temperature in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	105.611	1	105.611	37.469	3.19E-07	4.085
Residual	112.744	40	2.819			
Total	218.354	41				

The variation in relative humidity of storage environment for S_{NR} and S_{NNR}, R_C and A_C relative humidity with time of day was also investigated (Figure 4.8). The relative humidity of S_{NR} and S_{NNR} ranged from 58.3 to 88.4% (average value of 69.5%) and 53.0 to 87.0% (average value of 65.8%), respectively. The R_C and A_C relative humidity was in the range of 56.9 to 61.9% (average value of 59.1%) and 51.9 to 74.6% (average value of 62.5%), respectively. This indicated that the relative humidity in S_{NR} was higher by 3.5, 10.1, and 6.7% compared to S_{NNR}, R_C, and A_C, respectively.

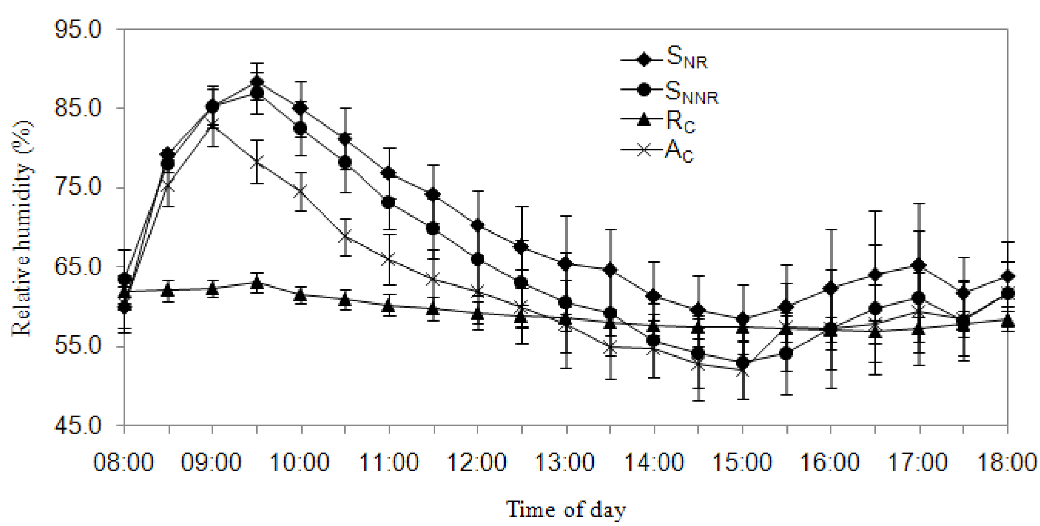


Figure 4. 8 Comparison of relative humidity in the S_{NR}, S_{NNR}, R_C, and A_C

The ANOVA results (Table 4.4) showed significant difference (P<0.05; $F_{computed}$ = 5.466; $F_{crit,5\%}$, = 2.719) in relative humidity for the S_{NR}, S_{NNR}, R_{C}, and Ac. The analysis of variance results (Table 4.5) did indicate a significant difference (P<0.05; $F_{computed}$ = 6.476; $F_{crit,5\%}$, = 3.150) in relative humidity for S_{NR}, S_{NNR}, and R_{C}. The ANOVA results (Table 4.6) showed the existence of significant difference (P<0.05; $F_{computed}$ = 23.318; $F_{crit,5\%}$, = 4.098) in relative humidity of storage environment for the S_{NR} and S_{NNR}.

Table 4. 4 ANOVA for relative humidity in the S_{NR}, S_{NNR}, R_{C} , and A_{C}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	1181.215	3	393.738	5.466	0.002	2.719
Residual	5762.683	80	72.034			
Total	6943.898	83				

Table 4. 5 ANOVA for relative humidity in the S_{NR}, S_{NNR}, and R_{C}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	919.410	2	459.705	6.476	0.003	3.150
Residual	4259.436	60	70.991			
Total	5178.846	62				

Table 4. 6 ANOVA for relative humidity in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	1134.976	1	1134.976	23.318	2.26E-05	4.098
Residual	1849.596	38	48.674			
Total	2984.572	39				

Regression analysis yielded equation 4.1 for estimating the temperature of storage environment for the S_{NR} expressed as a function of the ambient temperature and relative humidity. In this equation, T_{NR}, T_{A}, and RH_{A} are the estimated temperature of storage environment of the S_{NR}, ambient temperature, and ambient relative humidity, respectively.

$$T_{NR} = 0.05\,T_A - 0.07\,RH_A + 19.78 \tag{4.1}$$

Similarly, relative humidity of storage environment for S_{NR} was expressed as a function of ambient temperature and relative humidity (Equation 4.2), in which RH_{NR} is the estimated relative humidity of storage environment for the S_{NR}.

$$RH_{NR} = 1.35\,T_A + 1.39\,RH_A - 56.70 \tag{4.2}$$

In addition, a regression analysis yielded equation 4.3 for estimating the temperature of storage environment for the S_{NNR} as a function of ambient temperature and relative humidity. In this equation, T_{NNR} is the estimated temperature of storage environment for the S_{NNR}.

$$T_{NNR} = 0.40\,T_A - 0.11\,RH_A + 15.94 \tag{4.3}$$

The relative humidity of the storage environment for the S_{NNR} was expressed as a function of ambient temperature and relative humidity (Equation 4.4), where RH_{NNR} is the estimated relative humidity of storage environment for S_{NNR}.

$$RH_{NNR} = 1.35\,T_A + 1.39\,RH_A - 56.70 \tag{4.4}$$

The room temperature was also expressed as a function of the ambient temperature and relative humidity (Equation 4.5), in which T_R is the estimated temperature for R_C.

$$T_R = 33.10 - 0.03\,T_A - 0.13\,RH_A \tag{4.5}$$

Similarly, the R_C relative humidity was further expressed as a function of the ambient temperature and relative humidity (Equation 4.6). In this equation, RH_R is the estimated relative humidity for $R_{C.}$

$$RH_R = 48.42 - 0.04\,T_A + 0.19\,RH_A \tag{4.6}$$

4.4 Effect of storage environment on the quality of Apple and Kent mangoes

Figure 4.9 shows the developed S_{NR} loaded with mangoes at the beginning of an experiment to determine the effect of storage environment on quality of the fruit.

Figure 4. 9 A photograph of S_{NR} loaded with mangoes

4.4.1 Effect of storage environment on the shelf-lives of the Apple and Kent mangoes

The shelf-life of the Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C were 18, 15, and 9 days, respectively. Thus, using the S_{NR} and the S_{NNR}, the shelf-life of Apple mangoes would be extended by 9 and 6 days, respectively, compared to storage under R_C, respectively. In addition, the shelf-life of Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C were 24, 21, and 15 days, respectively. This implied that with the use of the S_{NR} and the S_{NNR}, the shelf-life of the fruit would be extended by 9 and 6 days, respectively, compared to storage under R_C.

The Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C had shorter shelf-life compared to Kent mangoes stored under the corresponding conditions. This indicated that beside the storage conditions, shelf-life also depends on the mango variety. Carrillo *et al*. (2000) reported that the self-life varies among the mango varieties depending on the storage conditions.

4.4.2 Effect of storage environment on the physical properties of Apple and Kent mangoes

Figure 4.10 shows increasing trend in physiological weight loss for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C. At the end of the experiment, the corresponding weight losses were 17.28±0.57, 24.43±2.45, and 19.03±1.04%, respectively. Similarly, a progressive weight loss in Kent mangoes was observed under the three conditions (Figure 4.11). Weight losses of 15.39±1.54, 18.70±1.27, and 18.48±0.58% were observed at the end of the experiment for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively. In this study, the loss in weight results are in agreement with that reported by Rathore *et al.* (2007) and Doreyappa-Gowda and Huddar (2001) who investigated weight loss of different varieties of mangoes during storage.

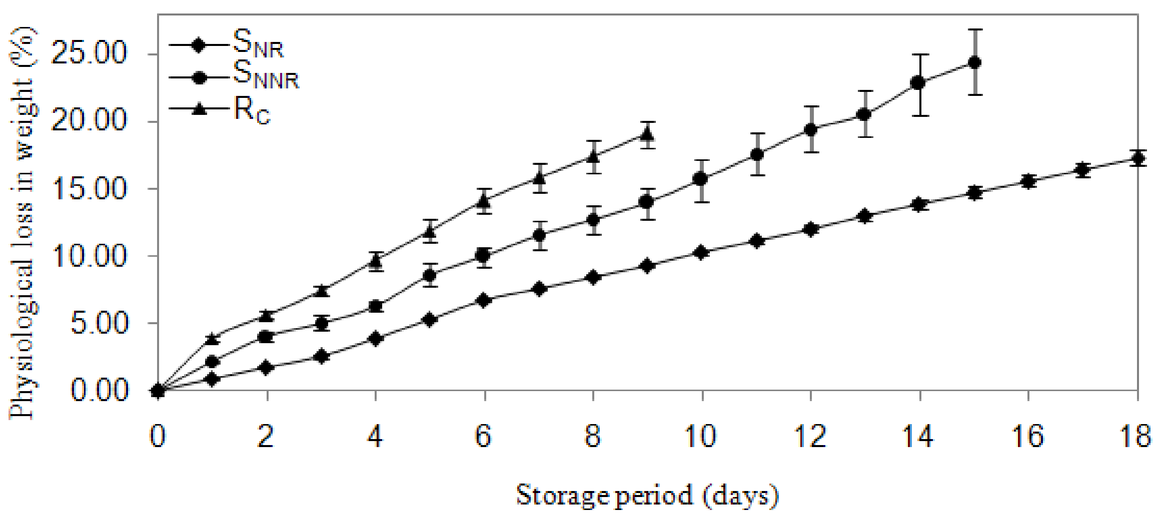


Figure 4. 10 Comparison of weight loss with storage period for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

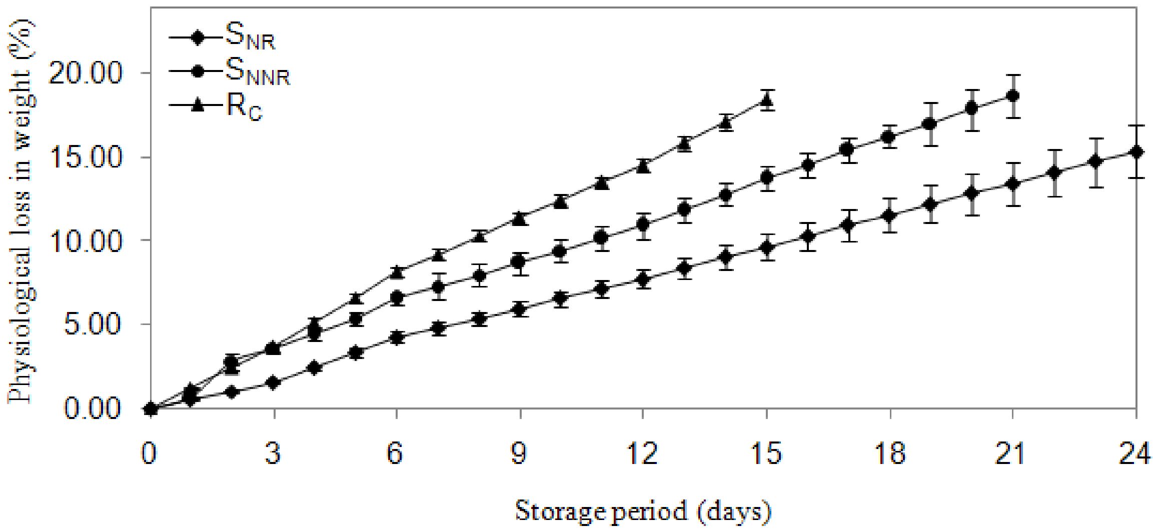


Figure 4. 11 Comparison of weight loss with storage period for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

The physiological weight loss in Apple mangoes stored in the S_{NR} was reduced by 4.64 and 9.77% compared to S_{NNR} and R_C, respectively. Similarly, the weight loss in Kent mangoes was decreased by 4.09 and 8.82% compared to S_{NNR} and R_C, respectively. According to Rathore *et al*. (2007), physiological loss in weight is due to respiration, transpiration of water through the peel tissue, and other biological changes taking place within the fruit. The variation in weight loss among the storage conditions is therefore due to difference in temperature and relative humidity of the storage environment which influence the rate of water losses and biological activities within the fruit. Thus, it can be concluded that the use of the S_{NR} can significantly reduce the weight loss leading to increased income earnings by the farmers particularly if the fruits are to be sold based on the physiological weight. This also implied less shriveling would occur and the appearances of the fruit would not deteriorate hence increasing its market value.

The ANOVA results (Table 4.7) did show the existence of significant difference ($P<0.05$; $F_{computed} = 3.587$; $F_{crit,5\%} = 3.354$) in physiological weight loss for the Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C. Further, the ANOVA results (Table 4.8) showed significant difference (P<0.05; $F_{computed}$ = 4.260; $F_{crit,5\%}$ = 4.171) in physiological loss in weight for the fruit stored in the S_{NR} and S_{NNR}.

Table 4. 7 ANOVA for weight loss for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

Sources of variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	172.516	2	86.258	3.587	0.0416	3.354
Residual	649.353	27	24.050			
Total	821.869	29				

Table 4. 8 ANOVA for the weight loss for Apple mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage method	169.662	1	169.662	4.260	0.048	4.171
Residual	1194.802	30	39.827			
Total	1364.464	31				

The ANOVA results (Table 4.9) indicated a significant difference (P<0.05; $F_{computed}$ = 4.010; $F_{crit,5\%}$ = 3.204) in physiological weight loss for the Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C. Similarly, the ANOVA results (Table 4.10) showed the existence of significant difference (P<0.05; $F_{computed}$ = 4.171; $F_{crit,5\%}$ = 4.073) in physiological weight loss for the fruit stored in the S_{NR} and S_{NNR}.

Table 4. 9 ANOVA for weight loss for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	163.078	2	81.538	4.010	0.0250	3.204
Residual	914.992	45	20.334			
Total	1078.069	47				

Table 4. 10 ANOVA for weight loss for Kent mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	101.879	1	101.879	4.171	0.047	4.073
Residual	1025.897	42	24.426			
Total	1127.775	43				

Table 4.11 shows changes in hue angle of the peel with storage time for Apple mangoes stored under the three treatments. A decreasing trend in the hue angle of the peel indicated a continuous ripening process of the fruit during storage. The colour of the peel for Apple mangoes before storage was greenish yellow with hue angle ranging from 105.63±0.90^o to 105.90±1.78^o while at the end of the experiment was orange yellow with a hue angle of 70.42±0.94^o, 70.96±0.63^o, and 70.84±0.54^o for the Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively.

Wills *et al.* (1982) reported that the loss of green colour in mangoes is due to physico-chemical changes by degradation of the chlorophyll structure and increased in carotenoid pigments during storage. In addition, according to Doreyappa-Gowda and Huddar (2001), the increased in the concentration of carotenoids was responsible for changes in the peel colour for green mature mangoes during storage.

Table 4. 11 Variation in hue angle of the peel with storage period for Apple mangoes stored in S_{NR}, S_{NNR}, and R_C

Storage period (days)	S_{NR}	S_{NNR}	R_C
	H^o	H^o	H^o
0	105.63±0.90[a]	105.80±1.60[a]	105.90±1.78[a]
1	105.15±1.11[a]	104.14±1.66[a]	104.99±1.13[a]
2	104.65±1.42[a]	102.52±1.82[a]	104.14±0.68[a]
3	103.92±1.22[a]	100.96±2.07[a]	103.34±0.76[a]
4	94.91±1.45[a]	92.72±1.32[a]	94.89±1.32[a]
5	86.61±1.69[a]	84.14±1.34[a]	86.97±2.06[a]
6	78.91±2.09[a]	76.57±1.48[a]	79.81±2.81[a]
7	76.53±1.86[a]	75.88±1.27[a]	77.01±1.84[a]
8	76.10±1.68[a]	75.21±1.05[a]	74.19±0.94[a]
9	75.89±1.56[a]	74.53±0.84[a]	70.84±0.54[b]
10	74.72±1.49[a]	73.87±0.64[a]	
11	74.56±1.41[a]	73.21±0.44[a]	
12	73.40±1.34[a]	72.55±0.28[a]	
13	72.23±1.27[a]	71.01±0.37[a]	
14	72.07±1.20[a]	71.48±0.49[a]	
15	71.91±1.13[a]	70.96±0.63[a]	
16	71.75±1.07[a]		
17	71.59±1.00[a]		
18	70.42±0.94[a]		

Mean values ± standard error with different superscripts in a row are significantly different at 5% level of significance.

The ANOVA results (Table 4.12) did not indicate the existence of any significant difference (P>0.05; $F_{computed}$ = 0.082; $F_{crit,5\%}$ = 3.328) in hue angle of the peel for the Apple mangoes stored in the S_{NR}, S_{NNR}, and $R_{C.}$ In addition, the ANOVA results (Table 4.13) showed no significant difference (P>0.05; $F_{computed}$ = 0.002; $F_{crit,5\%}$ = 4.171) in hue angle of the peel for the fruit stored in the S_{NR} and $S_{NNR.}$

Table 4. 12 ANOVA for hue angle of the peel for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	31.981	2	15.990	0.082	0.922	3.328
Residual	5684.055	29	196.002			
Total	5716.036	31				

Table 4. 13 ANOVA for hue angle of the peel for Apple mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	0.432	1	0.432	0.002	0.963	4.171
Residual	5821.104	30	194.037			
Total	5821.535	31				

A decreasing trend in hue angle of the flesh with storage time was observed for Apple mangoes under the three conditions (Table 4.14). The colour of the flesh for the Apple mangoes before storage was greenish yellow with hue angle ranging from 97.44±0.15^o to 98.05±0.56^o while at the end of the experiment was orange yellow with hue angle of 76.41±0.06^o, 76.62±0.76^o, and 75.28±0.52^o for the fruit stored in the S_{NR}, S_{NNR}, R_C, respectively. These findings correlated with that of Doreyappa-Gowda and Huddar (2001) who investigated changes in colour of the pulp for different varieties of mangoes during storage. The variation in the hue angle during storage indicated degradation of chlorophyll structure as the fruit ripens. According to Wills *et al.* (1982), the change in pulp colour for mangoes during storage is due breakdown of chlorophyll structure and formation of carotenoid pigments.

Table 4. 14 Variation in hue angle of the flesh with storage period for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

Storage period (days)	S_{NR}	S_{NNR}	R_C
	H^o	H^o	H^o
0	97.44±0.15[a]	97.78±0.20[a]	98.05±0.56[a]
1	90.22±1.12[a]	87.58±0.96[a]	91.02±0.89[a]
2	82.45±1.60[a]	80.63±1.88[a]	86.05±0.67[a]
3	83.27±0.78[a]	80.23±2.28[a]	82.37±0.27[a]
4	81.92±0.53[a]	80.17±1.41[a]	81.65±0.53[a]
5	80.61±0.29[a]	80.15±1.11[a]	80.94±0.79[a]
6	79.33±0.05[a]	79.73±1.78[a]	80.22±1.06[a]
7	78.84±0.03[a]	79.39±0.79[a]	78.49±0.86[a]
8	78.36±0.01[a]	78.86±0.47[a]	76.84±0.68[a]
9	77.90±0.01[a]	78.35±0.17[a]	75.28±0.52[b]
10	77.44±0.04[a]	78.06±0.27[a]	
11	77.00±0.06[a]	77.77±0.37[a]	
12	76.56±0.09[a]	77.48±0.46[a]	
13	76.54±0.08[a]	77.19±0.56[a]	
14	76.51±0.08[a]	76.90±0.66[a]	
15	76.49±0.07[a]	76.62±0.76[a]	
16	76.46±0.07[a]		
17	76.44±0.06[a]		
18	76.41±0.06[a]		

Mean values ± standard error with different superscripts in a row are significantly different at 5% level of significance.

Analysis of variance results (Table 4.15) did not show the existence of significant difference (P>0.05; $F_{computed}$ = 0.067; $F_{crit,5\%}$ = 3.354) in hue angle of the flesh for the Apple mangoes stored in the SNR, SNNR, RC. Further, ANOVA results (Table 4.16) did not indicate a significant difference (P>0.05; $F_{computed}$ = 0.041; $F_{crit,5\%}$ = 4.171) in hue angle of the flesh for the fruit stored in the S_{NR} and S_{NNR}.

Table 4. 15 ANOVA for hue angle of the flesh for Apple mango stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	5.497	2	2.748	0.067	0.935	3.354
Residual	1106.866	27	40.995			
Total	1112.363	29				

Table 4. 16 ANOVA for hue angle of the flesh for Apple mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	1.271	1	1.271	0.041	0.841	4.171
Residual	928.036	30	30.935			
Total	929.306	31				

A regression analysis relating hue angle of the peel and hue angle of the flesh for Apple mangoes with storage period yielded linear relationships which were presented by equation 4.7, 4.8 and 4.9 for the fruit stored in the S_{NR}, S_{NNR}, R_C, respectively. In these equations, $H^o_{f,NR}$, $H^o_{f,NNR}$, and $H^o_{f,R}$ are the estimated hue angles of the flesh for Apple mangoes stored in the S_{NR}, S_{NNR}, R_C, respectively, while $H^o_{p,NR}$, $H^o_{p,NNR}$, and $H^o_{p,R}$ are the actual hue angles of the peel for Apple mangoes stored in the S_{NR}, S_{NNR}, R_C, respectively, and S_p is the storage period in days.

$$H^o_{f,NR} = 58.10 + 0.29 H^o_{p,NR} - 0.17 S_p \tag{4.7}$$

$$H^o_{f,NNR} = 68.10 + 0.18 H^o_{p,NNR} - 0.35 S_p \tag{4.8}$$

$$H^o_{f,R} = 163.70 - 0.64 H^o_{p,R} - 5.00 S_p \tag{4.9}$$

Table 4.17 presents changes in hue angle of the flesh for Kent with storage period under the three storage conditions.

Table 4. 17 Variation in hue angle of the flesh with storage period for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

Storage period (days)	S_{NR}	S_{NNR}	R_C
	H^o	H^o	H^o
0	99.49 ± 0.24^a	100.18 ± 0.55^a	100.47 ± 0.60^a
1	98.39 ± 0.12^a	97.69 ± 0.28^a	94.98 ± 0.24^b
2	97.32 ± 0.00^a	95.51 ± 0.10^b	90.67 ± 0.04^c
3	96.26 ± 0.12^a	93.57 ± 0.01^b	87.21 ± 0.06^c
4	94.71 ± 0.02^a	93.50 ± 0.31^a	87.61 ± 0.02^b
5	93.36 ± 0.14^a	93.45 ± 0.57^b	87.97 ± 0.01^c
6	92.19 ± 0.23^a	93.40 ± 0.81^a	88.32 ± 0.04^b
7	91.66 ± 0.16^a	92.54 ± 0.53^a	87.07 ± 0.26^b
8	91.14 ± 0.10^a	91.69 ± 0.27^a	85.84 ± 0.55^b
9	90.63 ± 0.05^a	90.86 ± 0.03^a	84.62 ± 0.82^b
10	89.29 ± 0.09^a	89.41 ± 0.06^a	83.74 ± 0.60^b
11	88.04 ± 0.19^a	87.97 ± 0.08^a	82.85 ± 0.39^b
12	86.87 ± 0.28^a	86.54 ± 0.09^a	81.95 ± 0.19^b
13	86.24 ± 0.25^a	86.15 ± 0.09^a	81.08 ± 0.23^b
14	85.59 ± 0.22^a	85.76 ± 0.09^a	80.18 ± 0.27^b
15	84.94 ± 0.19^a	85.36 ± 0.09^a	79.24 ± 0.30^b
16	84.28 ± 0.16^a	84.96 ± 0.08^a	
17	83.61 ± 0.14^a	84.56 ± 0.08^b	
18	82.93 ± 0.11^a	84.15 ± 0.07^b	
19	82.25 ± 0.08^a	83.74 ± 0.07^b	
20	81.55 ± 0.06^a	82.39 ± 0.06^b	
21	80.85 ± 0.03^a	79.41 ± 0.51^a	
22	80.15 ± 0.01^a		
23	79.43 ± 0.01^a		
24	78.71 ± 0.03^a		

Mean values ± standard error with different superscripts in a row are significantly different at 5% level of significance.

The peel colour for Kent mangoes at the start and end of the experiment was greenish yellow with hue angle ranging from 112.91±1.38^{o} to 124.75±1.53^{o}. This indicated that the peel colour is unreliable attribute for monitoring the quality of the fruit during storage. Therefore, changes in the colour of the flesh of the fruit were investigated. The colour of the flesh of the fruit at the beginning of experiment was greenish yellow with hue angle ranging from 99.49±0.24^{o} to 100.47±0.60^{o} while at the end of the experiment was orange yellow with hue angle of 78.71±0.03^{o}, 79.41±0.51^{o}, and 79.24±0.30^{o} for the fruit stored in the S_{NR}, S_{NNR}, and R_C, respectively (Table 4.17). Doreyappa-Gowda and Huddar (2001) reported that the changes in the pulp colour of mangoes are due to the development of carotenoids during storage.

Analysis of variance results (Table 4.18) did indicate the existence of significant difference (P<0.05; $F_{computed}$ = 5.739; $F_{crit,5\%}$ = 3.204) in hue angle of the flesh for the Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C. In addition, the ANOVA results (Table 4.19) did not show significant difference (P>0.05; $F_{computed}$ = 0.001; $F_{crit,5\%}$ = 4.073) in hue angle of the flesh for the fruit stored in the S_{NR} and S_{NNR}.

Table 4. 18 ANOVA for hue angle of the flesh for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	*Fcomputed*	*P-value*	*F critical*
Storage method	273.880	2	136.940	5.739	0.006	3.204
Residual	1073.817	45	23.863			
Total	1347.698	47				

Table 4. 19 ANOVA for hue angle of the flesh for Kent mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	0.034	1	0.034	0.001	0.974	4.073
Residual	1300.018	42	30.953			
Total	1300.052	43				

The firmness of the peel for Apple mangoes decreased significantly during storage. Figure 4.12 shows changes in the peel firmness during storage for Apple mangoes under the three treatments. The average firmness of the peel for Apple mangoes at the beginning of the experiment was 40.80±0.55 N of which decreased to 3.53±0.06 N for the fruit stored in the S_{NR} and S_{NNR}, and to 3.50±0.12 N for the fruit stored in the R_C at the end of experiment.

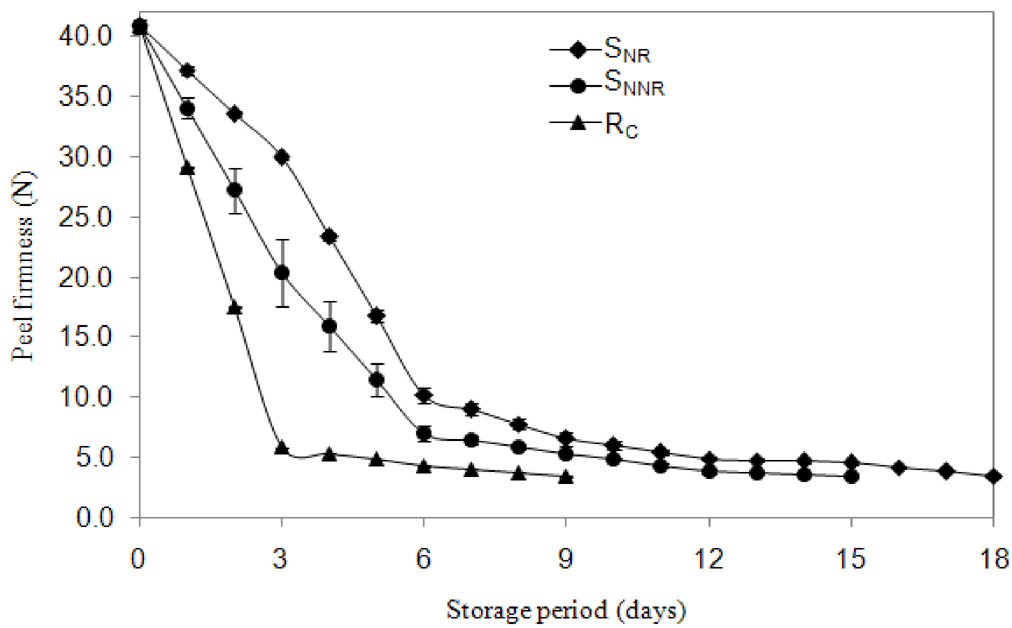


Figure 4. 12 Variation in firmness of the peel with storage period for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

A rapid decline in peel firmness was observed within first 3 days and then stabilized to the end of the experiment for the Apple mangoes stored in the R_C (Figure 4.12). The decrease in firmness was high within the first 6 days and then became gradual until the end of experiment for the fruit stored in S_{NR} and S_{NNR} (Figure 4.12). This implied the rate of softening for the fruit stored in the R_C was higher compared to those stored in the S_{NR} and S_{NNR}. Figure 4.13 presents changes in firmness of the peel for Kent mangoes stored under the three conditions. At the start of experiment, the average firmness was

66.88±2.81 N. This value decreased to 9.54±0.66, 9.54±0.68, and 9.46±0.23 N at the end of experiment for the fruit stored in the S_{NR}, S_{NNR}, and R_C, respectively. The decrease in firmness with time indicated the softness of the fruit as it ripens.

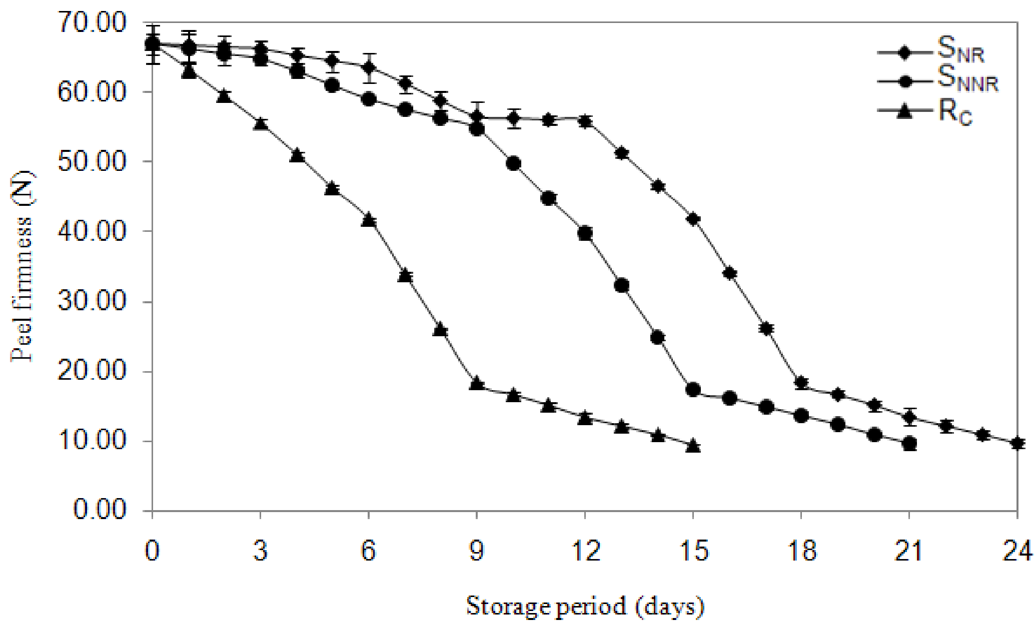


Figure 4. 13 Variation in firmness of the peel with storage period for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

The decrease in firmness was rapid in the first 9, 15, and 18 days and then stabilized towards the end of experiment for the fruit stored in the $R_{C,}$ S_{NNR}, and $S_{NR,}$ respectively (Figure 4.13). This showed that the decline in firmness was lower in S_{NR} by 3 and 9 days compared to S_{NNR} and R_C, respectively. During the experiment the fruits were handled in a similar way hence the softening was due to breakdown of pectic substances and changes in the cells wall structure. Weichmann (1987) reported that the reduction in firmness of mangoes during storage might be due to the breakdown of insoluble pectic substances to soluble forms by a series of physico-chemical changes due to enzymatic reactions. Kalra *et al*. (1995) further reported that the rapid decline of firmness in the mangoes during ripening is due to changes in the structure of the pectin polymers of cells wall which later stabilized indicating completion of ripening. Further, Hosakote *et* *al.* (2006) reported that ripening of mangoes is accompanied by a series of biochemical changes resulting in gradual textural softening. Moreover, Jha *et al*. (2006) indicated that the firmness of the mango fruits remained almost constant over the period of growth and it decreased after attaining the maturity.

The ANOVA results (Table 4.20) did not show any significant difference (P>0.05; $F_{computed}$ = 1.367; $F_{crit,5\%}$ = 3.354) in firmness of the peel for the Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C. The ANOVA results (Table 4.21) further did not indicate significant difference (P>0.05; $F_{computed}$ = 0.652; $F_{crit,5\%}$ = 4.196) in firmness of the peel for the fruit stored in the S_{NR} and S_{NNR}.

Table 4. 20 ANOVA for firmness of the peel for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	462.248	2	231.124	1.367	0.272	3.354
Residual	4564.067	27	169.040			
Total	5026.315	29				

Table 4. 21 ANOVA for firmness of the peel for Apple mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	73.654	1	73.654	0.652	0.426	4.196
Residual	3161.202	28	112.900			
Total	3234.856	29				

Further, the analysis of variance results (Table 4.22) indicated the existence of significant difference (P<0.05; $F_{computed}$ = 10.977; $F_{crit,5\%}$ = 3.204) in the firmness of the peel for Kent mangoes under the three storage conditions. The ANOVA results (Table 4.23) did not show significant difference (P>0.05; $F_{computed}$ = 1.489; $F_{crit,5\%}$ = 4.073) in firmness of the peel for the fruit stored in the S_{NR} and S_{NNR}.

Table 4. 22 ANOVA for firmness of the peel for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	*F_{computed}*	*P-value*	*F_{critical}*
Storage methods	5374.554	2	2687.277	10.977	0.0001	3.204
Residual	11016.192	45	244.804			
Total	16390.746	47				

Table 4. 23 ANOVA for firmness of the peel for Kent mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	*F_{computed}*	*P-value*	*F_{critical}*
Storage methods	628.881	1	628.881	1.489	0.229	4.073
Residual	17734.828	42	422.258			
Total	18363.709	43				

A decreasing trend in firmness of the flesh was observed for Apple mangoes stored under the three storage conditions (Figure 4.14). The average firmness of the flesh for Apple mangoes at the beginning of the experiment was 25.33±0.23 N. This value decreased to 0.95±0.07, 0.98±0.10, and 0.98±0.15 N at the end of for the experiment for the fruit stored in the S_{NR}, S_{NNR}, and R_C, respectively. The decline in firmness of the flesh was high within the first 3 days and became gradual until the end of the experiment in all the storage conditions (Figure 14). The figure further revealed that decrease in firmness was lower for the fruits stored in the S_{NR} compared to those stored under S_{NNR} and R_C. Goulao and Oliveira (2008), and Hosakote *et al.* (2006) reported that the loss of firmness of the pulp might be attributed to many physiological and biochemical changes which include conversion of starch to sugars, biosynthesis of flavour and aromatic volatiles, changes in the cell wall ultra-structure and metabolism. Further, Kalra *et al.* (1995) reported that the decline in firmness is due changes in the structure of the cell wall.

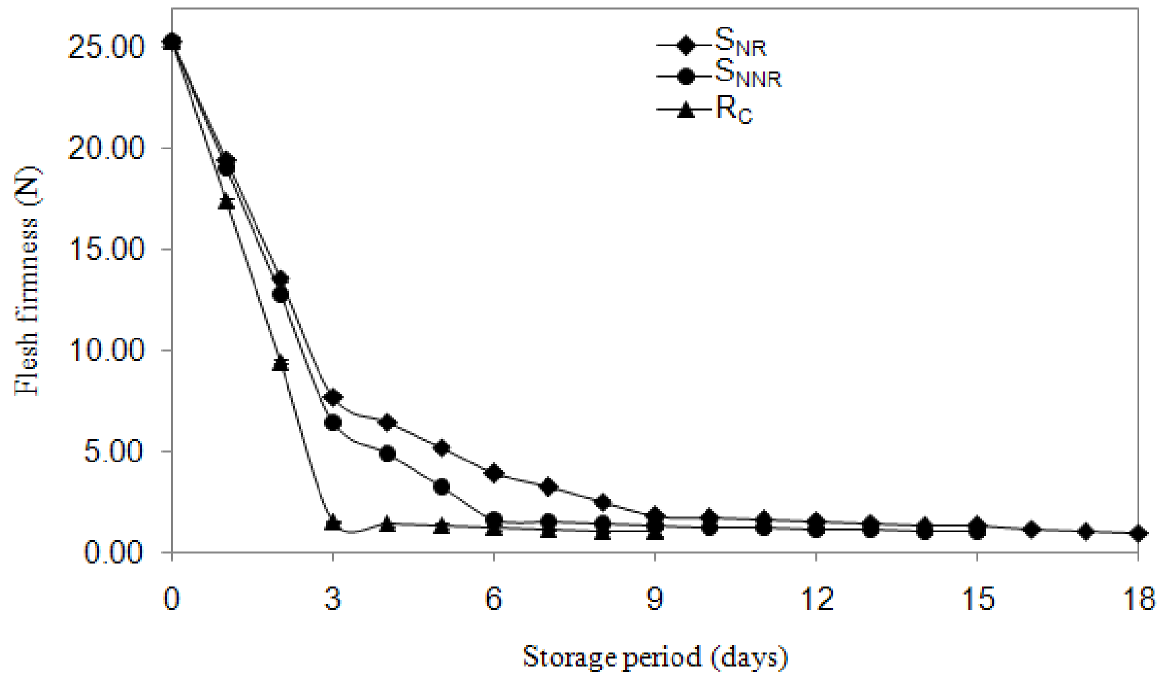


Figure 4. 14 Variation in firmness of the flesh with storage period for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

Figure 4.15 presents variation in firmness of the flesh for Kent mangoes during storage under the three storage conditions. The average firmness of the flesh for the fruit was 47.29±0.35 N at the start of experiment of which it decreased to 1.59±0.24, 1.51±0.01, and 1.57±0.09 N at the end of the experiment for the fruit stored in the S_{NR}, S_{NNR}, and R_C, respectively. These results are comparable to those reported by Jha *et al*. (2010) and Hosakote *et al.* (2006) who investigated changes in firmness of the flesh for different varieties mango fruits during storage. A lower decline in firmness of the Kent mangoes was also observed for the fruit stored in the S_{NR} as compared to those stored in the S_{NNR} and $R_{C.}$ The fruits were handled in a similar way hence the decrease in flesh firmness was therefore due to change of starch to sugars, formation of flavour and aromatic volatiles, alteration of the cell wall structure, and metabolism (Hosakote *et al.*, 2006).

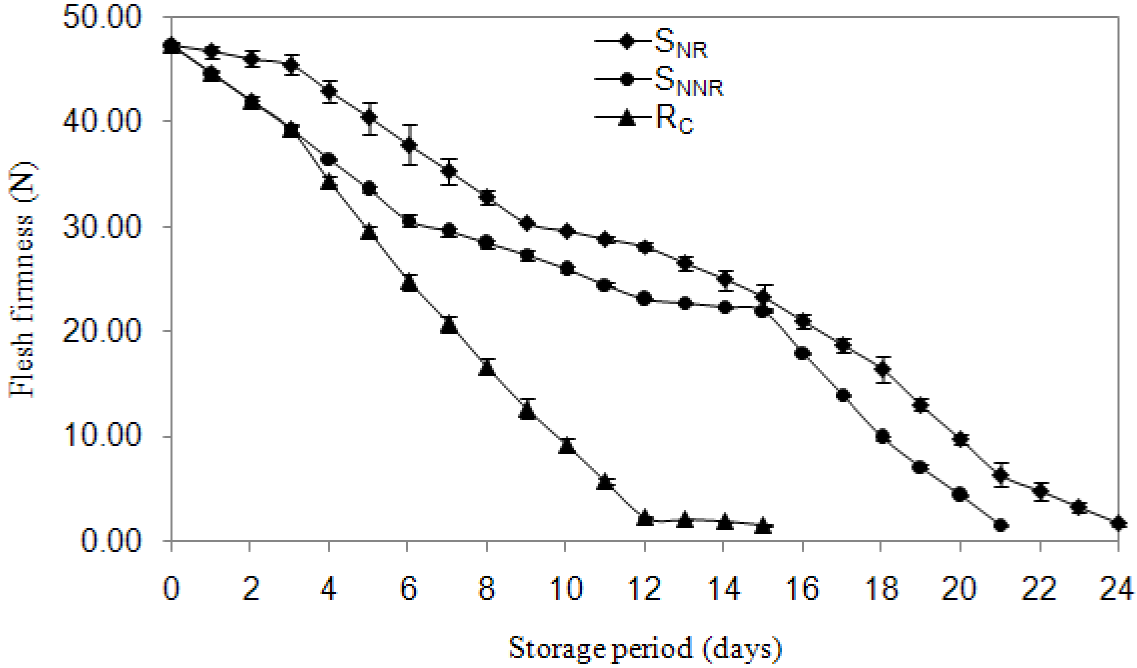


Figure 4. 15 Variation in firmness of the flesh with storage period for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

The ANOVA results (Table 4.24) did not show significant difference (P>0.05; $F_{computed}$ = 0.290; $F_{crit,5\%}$ = 3.354) in firmness of the flesh for Apple mangoes under the three conditions. Further, the ANOVA results (Table 4.25) also did not indicate significant difference (P>0.05; $F_{computed}$ = 0.112; $F_{crit,5\%}$ = 4.171) in firmness of the flesh for the fruit stored in the S_{NR} and S_{NNR}.

Table 4. 24 ANOVA for firmness of the flesh for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	40.873	2	20.437	0.290	0.750	3.354
Residual	1901.075	27	70.410			
Total	1941.948	29				

Table 4. 25 ANOVA for firmness of the flesh for Apple mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	5.975	1	5.975	0.112	0.740	4.171
Residual	1598.589	30	53.286			
Total	1604.564	31				

The ANOVA results (Table 4.26) did reveal significant difference (P<0.05; $F_{computed}$ = 6.328; $F_{crit,5\%}$ = 3.204) in firmness of the flesh for Kent mangoes under the three treatments. In addition, the ANOVA results (Table 4.27) showed no evidence of significant difference (P>0.05; $F_{computed}$ = 1.370; $F_{crit,5\%}$ = 4.073) in firmness of the flesh for the fruit stored in the S_{NR} and S_{NNR}.

Table 4. 26 ANOVA for firmness of the flesh for Kent mangoes stored in the $S_{NR,}$ $S_{NNR,}$ and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage method	1783.040	2	891.520	6.328	0.004	3.204
Residual	6340.192	45	140.893			
Total	8123.232	47				

Table 4. 27 ANOVA for firmness of the flesh for Kent mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	214.111	1	214.111	1.370	0.248	4.073
Residual	6565.151	42	156.313			
Total	6779.262	43				

Regression analysis showed linear relationship among the firmness of the peel, firmness of the flesh, and storage period for Apple mangoes under the three storage conditions. Equation 4.10, 4.11, and 4.12 presents the relationship for the fruit stored in the $S_{NR,}$ $S_{NNR,}$ and R_C, respectively. In these equations, $F_{fA,NR}$, $F_{fA,NNR}$, and $F_{fA,R}$ are estimated firmness of the flesh for Apple mangoes stored in the S_{NR}, S_{NNR} and R_C, respectively while $F_{pA,NR}$, $F_{pA,NNR}$, and $F_{pA,R}$ are actual firmness of the peel for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively.

$$F_{fA,NR} = 0.58\,F_{pA,NR} + 0.20\,S_p - 4.33 \tag{4.10}$$

$$F_{fA,NNR} = 0.76\,F_{pA,NNR} + 0.46\,S_p - 7.64 \tag{4.11}$$

$$F_{fA,R} = 0.70\,F_{pA,R} + 0.20\,S_p - 3.20 \tag{4.12}$$

The regression analysis further yielded linear relationship among the firmness of the flesh, firmness of the peel, and storage period for Kent mangoes stored under the three conditions. Equation 4.13, 4.14, and 4.15 presents the relationship for the fruits stored in the S_{NR}, S_{NNR}, and R_C, respectively. Where, $F_{fK,NR}$, $F_{fK,NNR}$, and $F_{fK,R}$ are estimated firmness of the flesh for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively while $F_{pK,NR}$, $F_{pK,NNR}$, and $F_{pK,R}$ are actual firmness of the peel for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively.

$$F_{fK,NR} = 0.10\,F_{pK,NR} - 1.66\,S_p + 41.79 \tag{4.13}$$

$$F_{fK,NNR} = -0.30\,F_{pK,NNR} - 2.92\,S_p + 68.26 \tag{4.14}$$

$$F_{fK,R} = 0.57\,F_{pK,R} - 1.02\,S_p + 9.25 \tag{4.15}$$

4.4.3 Effect of storage environment on the chemical properties of Apple and Kent mangoes

The average TSS for Apple mangoes at the beginning of experiment was 6.80±0.13% Brix of which it increased to 19.10±0.04, 19.08±0.09, and 19.08±0.06% Brix at the end of the experiment for the fruit stored in the S_{NR}, S_{NNR}, and R_C, respectively. At the start of experiment, Kent mangoes had an average TSS of 5.40±0.13% Brix which also increased to 14.75±0.54% Brix at the end of the experiment for the fruit stored in the S_{NR}, and to 14.75±0.57% for those stored in the S_{NNR} and R_C. These results are comparable to those reported by Doreyappa-Gowda and Huddar (2001) who investigated different varieties of mango fruits during storage. Further, Mamiro *et al.* (2007) reported TSS of 18.9% for the *Dodo* mango during room temperature ripening.

Figure 4.16 and 4.17 shows changes in TSS for Apple and Kent mangoes stored under the three storage conditions, respectively. In both varieties, an increasing trend in the TSS was observed with the fruits stored in the S_{NR} having lowest increasing TSS compared to those stored in S_{NNR} and RC. Thus, it can be deduced that the rate of ripening will always be lower for the fruit stored in the S_{NR} than those stored in the S_{NNR} and R_C. A rapid increase in TSS was observed at the initial period of storage and then became gradual until the end of the experiment due to decline in the amount of substrate and conversion of non-reducing sugars to reducing sugars.

The same trend was observed by Sagar and Khurdiya (1996) who further indicated that the gradual increase in TSS at later stage of ripening is as a result of less substrate remaining due to more rapid and partial breakdown of non-reducing sugars and other polysaccharides and their subsequent inversion to reducing sugars as the fruit ripens. In addition, Kays (1991) also reported that the increase in TSS might be as a result of changes in cell wall structure and breakdown of complex carbohydrates into simple sugars during storage. The increase and decrease in TSS is linked to hydrolytic changes in starch and conversion of starch to sugar being an important index of ripening process in mango and other climacteric fruit and further hydrolysis decreased the TSS during storage.

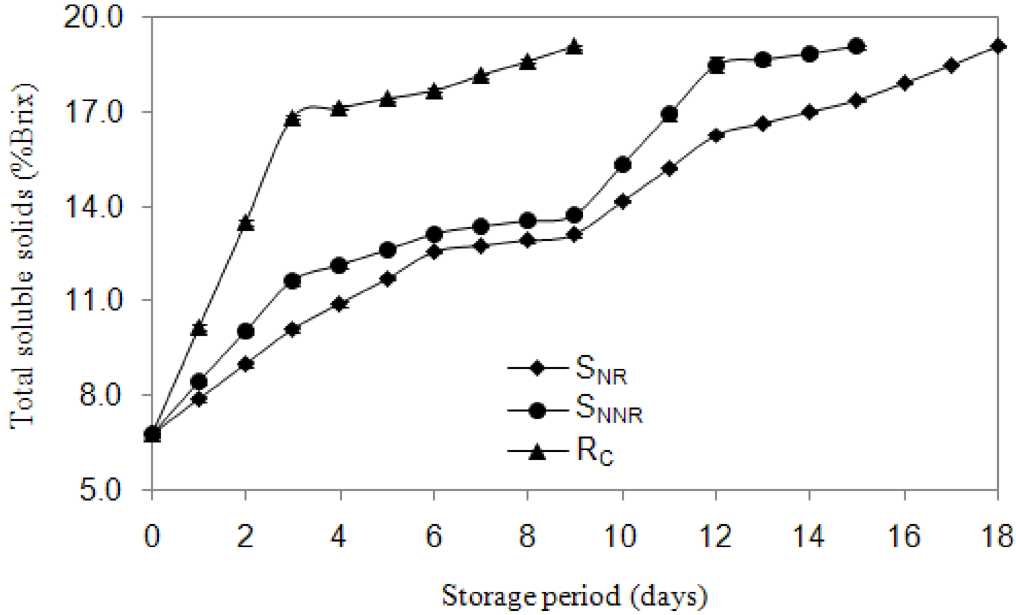


Figure 4. 16 Variation in TSS with storage period for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

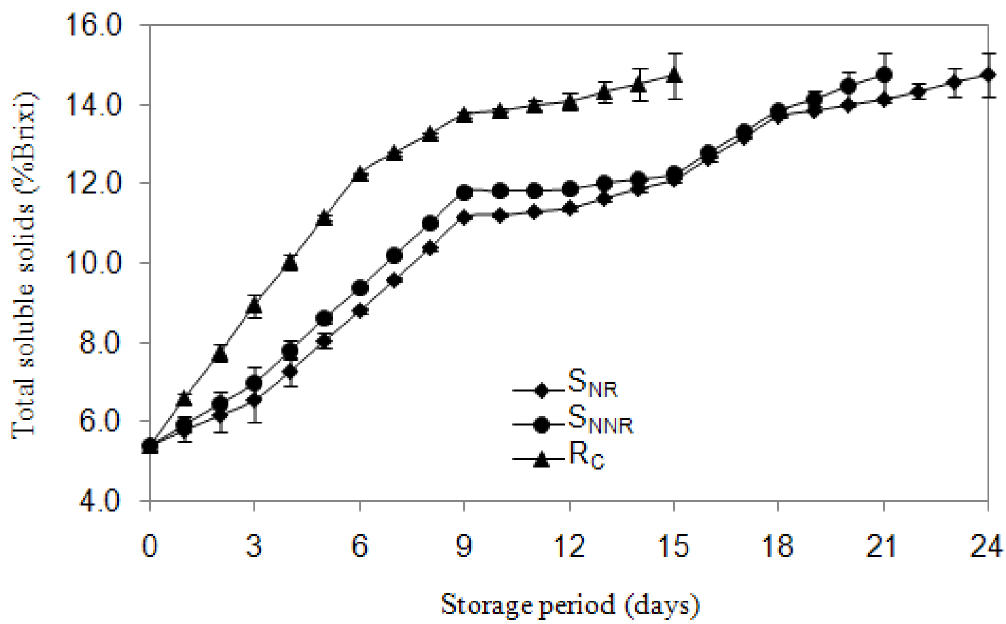


Figure 4. 17 Variation in TSS with storage period for the Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

ANOVA results (Table 4.28) did show the existence of significant difference (P<0.05; $F_{computed}$ = 7.136; $F_{crit,5\%}$ = 3.354) in TSS for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C. In addition, the ANOVA results (Table 4.29) did not indicate any significant difference (P>0.05; $F_{computed}$ = 0.856; $F_{crit,5\%}$ = 4.171) in TSS for the fruit stored in the S_{NR} and S_{NNR}.

Table 4. 28 ANOVA for TSS for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	130.753	2	65.377	7.136	0.003	3.354
Residual	247.351	27	9.161			
Total	378.104	29				

Table 4. 29 ANOVA for TSS for Apple mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	10.638	1	10.638	0.856	0.362	4.171
Residual	372.790	30	12.426			
Total	383.428	31				

The analysis of variance results (Table 4.30) did indicate a significant difference (P<0.05; $F_{computed}$ = 3.769; $F_{crit,5\%}$ = 3.204) in TSS for Kent mangoes stored under the three conditions. In addition, the ANOVA results (Table 4.31) did not show significant difference (P>0.05; $F_{computed}$ = 0.215; $F_{crit,5\%}$ = 4.073) in TSS for the fruit stored in the S_{NR} and S_{NNR}.

Table 4. 30 ANOVA for TSS for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	53.772	2	26.886	3.769	0.031	3.204
Residual	321.019	45	7.134			
Total	374.792	47				

Table 4. 31 ANOVA for TSS for Kent mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	1.750	1	1.750	0.215	0.645	4.073
Residual	341.377	42	8.128			
Total	343.127	43				

The average TTA for Apple mangoes at the start of experiment was 1.66±0.07%. This value decreased to 0.17±0.04% at the end of the experiment for the fruit stored under the three storage conditions. Similarly, the average TTA for Kent mangoes at beginning of the experiment was 1.28±0.01% of which it reduced to an average value of 0.17±0.04% at the end of the experiment. Therefore, it can be concluded that TTA for Apple and Kent mangoes decreases as the fruit ripens due to reduction in citric acid content. Medlicott and Thomson (1985) indicated that the reduction in TTA is due to the high rate of loss of citric acid with only small losses of malic acid. Upadhyay *et al.* (1994) observed a decreasing trend of titratable acidity in *Thai* mangoes during storage. A similar trend was also observed by Kudachikar *et al*. (2001) who reported a decrease in TTA of *Neelum* mangoes during storage. Doreyappa-Gowda and Huddar (2001) reported a decrease of TTA in different varieties of mangoes during storage. Moreover, Srinivasa *et al.* (2002) observed a reduction in TTA of *Aphonoso* during storage at ambient conditions. Mamiro *et al.* (2007) also reported decrease in TTA during ripening of mangoes. Further, Rathore *et al.* (2007) observed a decreasing trend in TTA for the *Dosehari* mango as the fruit ripen.

Figure 4.18 and 4.19 present variation in TTA with storage period for the Apple and Kent mangoes stored under the three storage conditions, respectively. The decrease in TTA was lower for the fruit stored in the S_{NR} compared to those stored in the S_{NNR} and R_C. This implied the fruit stored in S_{NR} will always be characterized by the lower rate of loss of citric acid than those stored in the S_{NNR} and R_C.

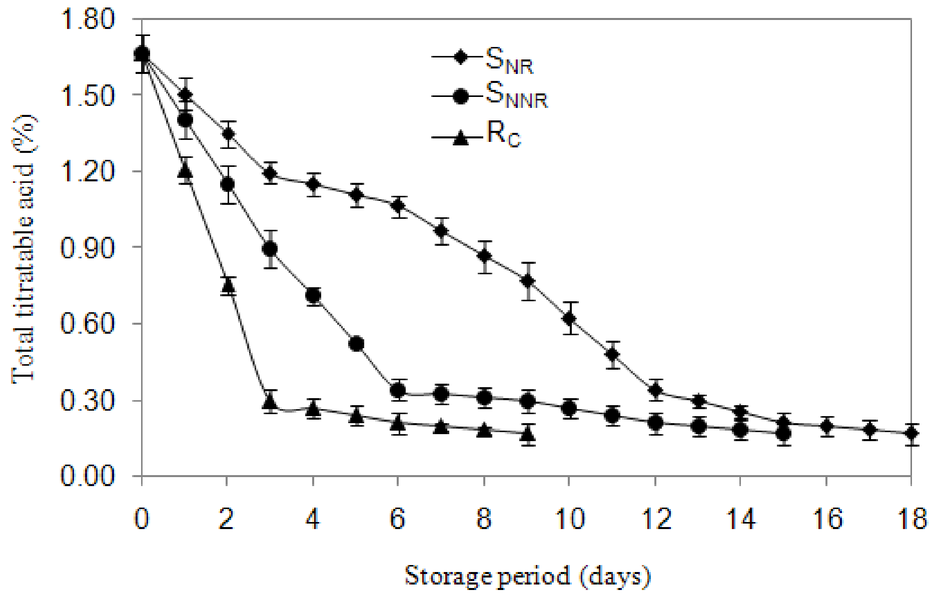


Figure 4. 18 Variation in TTA with storage period for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

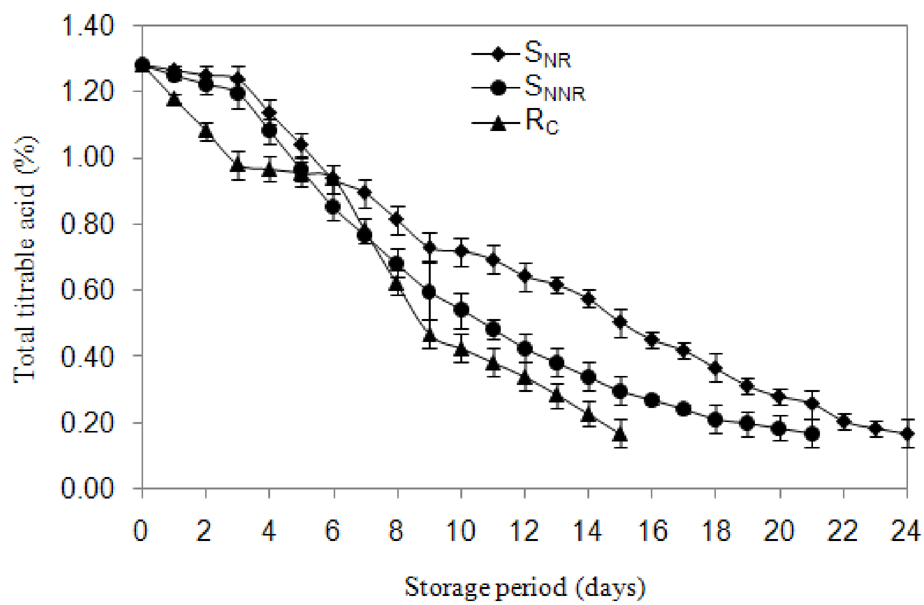


Figure 4. 19 Variation in TTA with storage period for Kent mangoes stored in the S_{NR}, S_{NNR} and R_C

The ANOVA results (Table 4.32) did show the existence of significant difference (P<0.05; $F_{computed}$ = 5.293; $F_{crit,5\%}$ = 3.354) in TTA for Apple mangoes stored under the three storage conditions. The ANOVA results (Table 4.33) did not indicate significant difference (P>0.05; $F_{computed}$ = 3.492; $F_{crit,5\%}$ = 4.171) in TTA for Apple mangoes stored in the S_{NR} and S_{NNR}.

Table 4. 32 ANOVA for TTA for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage method	2.117	2	1.058	5.293	0.011	3.354
Residual	5.400	27	0.200			
Total	7.517	29				

Table 4. 33 ANOVA for TTA for Apple mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	0.765	1	0.765	3.492	0.071	4.171
Residual	6.577	30	0.219			
Total	7.342	31				

The ANOVA results (Table 4.34) did not show evidence of any significant difference (P>0.05; $F_{computed}$ = 1.907; $F_{crit,5\%}$ = 3.204) in TTA for Kent mangoes stored under the three treatments. Similar, the ANOVA results (Table 4.35) did not show significant difference (P>0.05; $F_{computed}$ = 2.116; $F_{crit,5\%}$ = 4.073) in TTA for Kent mangoes stored in the S_{NR} and S_{NNR}.

Table 4. 34 ANOVA for TTA for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	0.412	2	0.206	1.907	0.160	3.204
Residual	4.864	45	0.108			
Total	5.277	47				

Table 4. 35 ANOVA for TTA for Kent mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	0.271	1	0.271	2.116	0.153	4.073
Residual	5.388	42	0.128			
Total	5.659	43				

The average pH for the Apple mangoes was 3.60±0.06 at the beginning of experiment. This value increased to 5.18±0.06 for the fruit stored in the S_{NR}, and to 5.27±0.01 for the fruit stored in the S_{NNR} and R_C. At the start of experiment, the Kent mangoes had an average pH value of 3.22±0.01 of which it increased to 5.22±0.01 at the end of the experiment in all the storage conditions. The corresponding pH values at the start and end of the experiment for both varieties were at a close range. This revealed that the variation in the pH during storage also depends on the mango variety. In addition, the increased in pH with storage time indicated a decrease in acid content due to oxidation. According to Shahjahan *et al.* (1994), the increase in pH might be due to oxidation of acid during storage resulting in a higher pH and also due to genetical differences between varieties.

Figure 4.20 and 4.21 presents variation in pH with storage time for Apple and Kent mangoes under the three storage conditions, respectively. An increasing trend in pH values was observed in both varieties during storage. A similar trend was observed by Doreyappa-Gowda and Huddar (2001) who reported an increased in pH for different varieties of mangoes during storage.

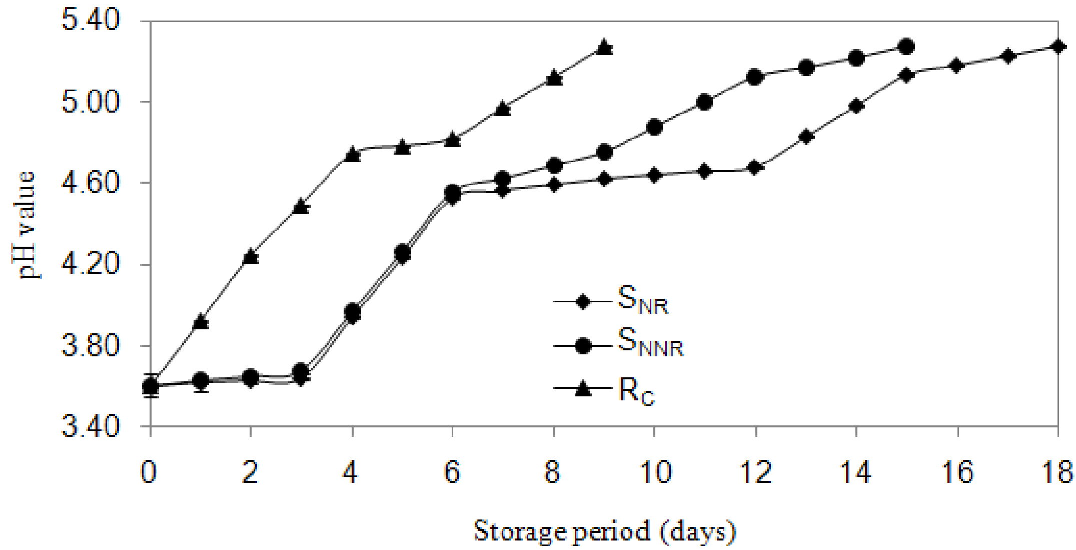


Figure 4. 20 Variation in pH value with storage time for Apple mangoes stored in S_{NR}, S_{NNR}, and R_C

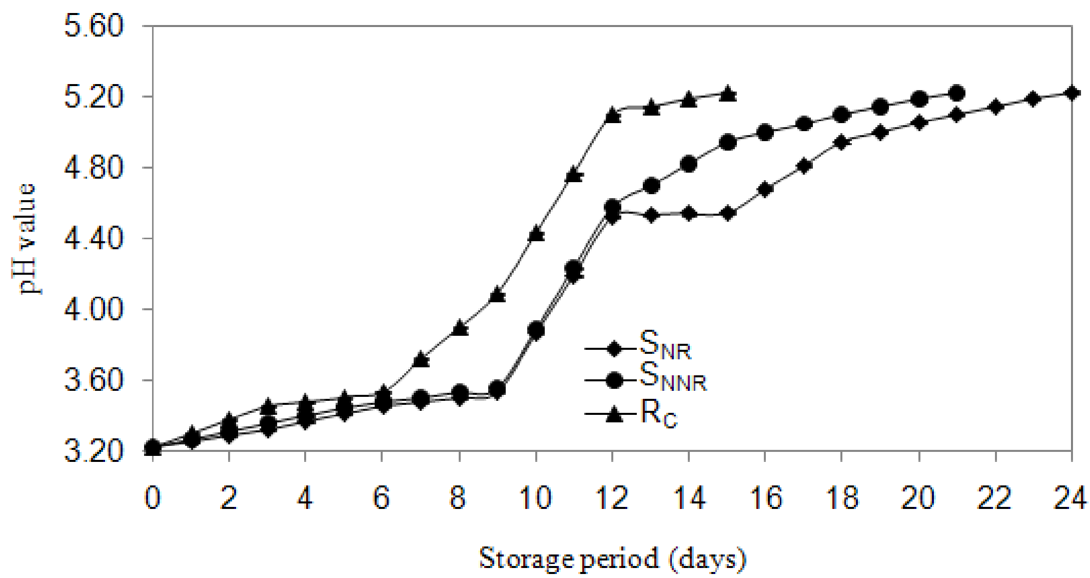


Figure 4. 21 Variation in pH value for Kent mangoes stored in S_{NR}, S_{NNR}, and R_C

The ANOVA results (Table 4.36) did not indicate significant difference (P>0.05; $F_{computed}$ = 3.170; $F_{crit,5\%}$ = 3.354) in pH for Apple mangoes stored under the three storage conditions. In addition, the ANOVA results (Table 4.37) showed no evidence of significant difference (P>0.05; $F_{computed}$ = 0.437; $F_{crit,5\%}$ = 4.171) in pH for Apple mangoes stored in the S_{NR} and S_{NNR}.

Table 4. 36 ANOVA for pH for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	1.541	2	0.771	3.170	0.058	3.354
Resdual	6.564	27	0.243			
Total	8.105	29				

Table 4. 37 ANOVA for pH for Apple mangoes in stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
storage condition	0.143	1	0.143	0.437	0.514	4.171
Residual	9.830	30	0.328			
Total	9.973	31				

The ANOVA results (Table 4.38) did not show significant difference (P>0.05; $F_{computed}$ = 1.228; $F_{crit,5\%}$ = 3.204) in pH for the Kent mangoes stored under the three storage conditions. In addition, the ANOVA results (Table 4.39) did not indicate significant difference (P>0.05; $F_{computed}$ = 0.218; $F_{crit,5\%}$ = 4.0731) in pH for Kent mangoes stored in the S_{NR} and S_{NNR}.

Table 4. 38 ANOVA for pH for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	1.003	2	0.501	1.228	0.303	3.204
Residual	18.377	45	0.408			
Total	19.379	47				

Table 4. 39 ANOVA for pH for Kent mangoes stored in the S_{NR} and S_{NNR}

Source of Variation	*S.S.*	*d.f.*	*M.S.*	$F_{computed}$	*P-value*	$F_{critical}$
Storage methods	0.120	1	0.120	0.218	0.643	4.073
Residual	23.199	42	0.552			
Total	23.319	43				

Figure 4.22 and 4.23 present variations in TSS to TTA ratio with storage time for Apple and Kent mangoes stored under the three conditions, respectively.

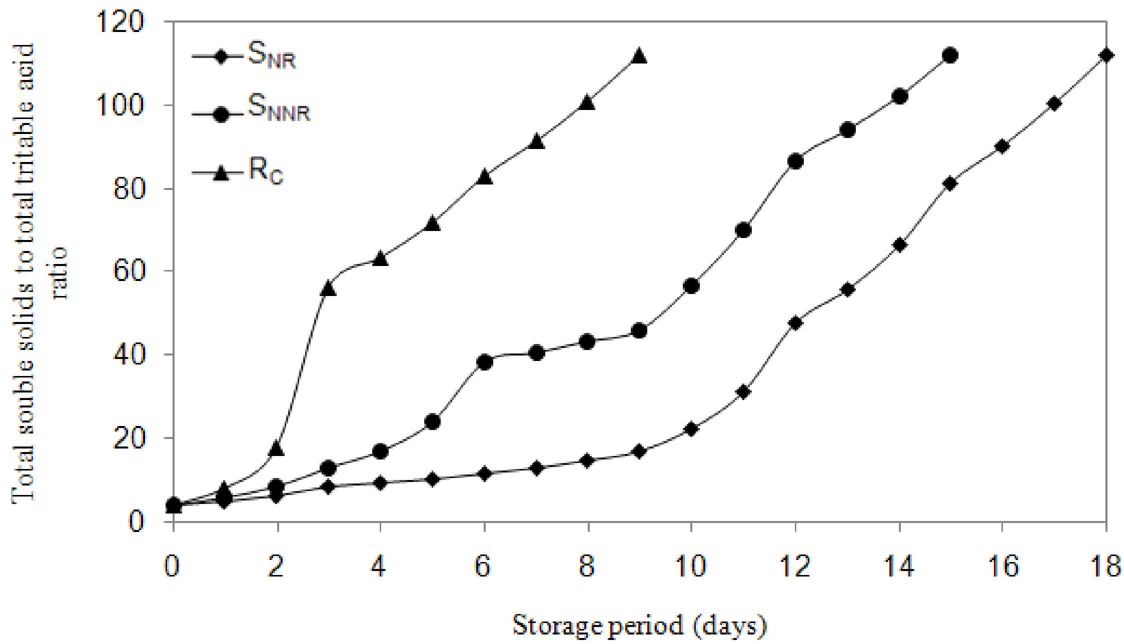


Figure 4. 22 Variation in TSS to TTA with storage period for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C

The ratio of TSS to TTA for both varieties at the start of experiment was 4.0. This value increased to 112.0 and 86.0 at the end of the experiment for the Apple and Kent mangoes, respectively. The increase in the ratio might be due to increase in TSS with decrease in TTA during storage. The increase in the TSS might be due modification of the cell wall structure and conversion of carbohydrates into simple sugars while the decrease in TTA could be due to degradation of citric acid, conversion of the acid to sugars and use of the acid in the metabolic activities. Hosakote *et al.* (2006) observed an increase in TSS but a decrease in TTA during storage.

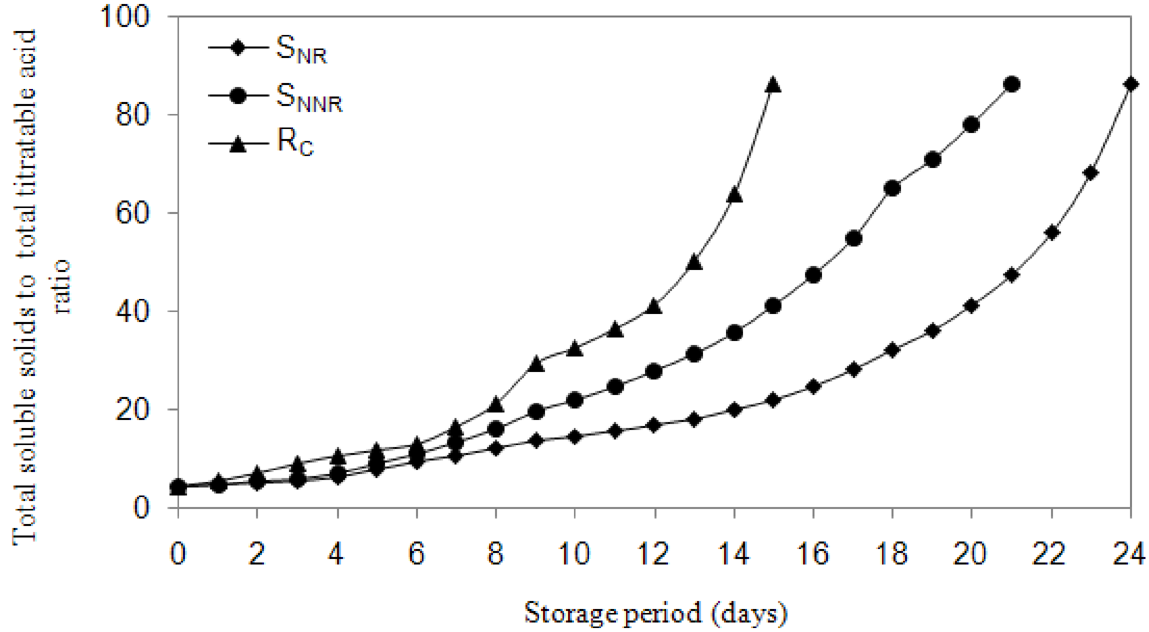


Figure 4. 23 Variation in TSS to TTA ratio with storage time for the Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C

Regression analysis showed a correlation among the TSS, TTA, pH, and storage period as indicated in equation 4.16, 4.17, and 4.18 for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively. In these equations, $TSS_{a,NR}$, $TSS_{a,NNR}$, and $TSS_{a,R}$ are estimated TSS for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively, $pH_{a,NR}$, $pH_{a,NNR}$, and $pH_{a,R}$ are pH for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively while $TTA_{a,NR}$, $TTA_{a,NNR}$, and $TTA_{a,R}$ are total titratable acid for Apple mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively.

$$TSS_{a,NR} = 9.42 + 1.13\, pH_{a,NR} - 3.68\, TTA_{a,NR} + 0.22\, S_p \tag{4.16}$$

$$TSS_{a,NNR} = 22.93 - 3.43\ pH_{a,NNR} - 2.18\ TTA_{a,NNR} + 1.02\ S_p \qquad (4.17)$$

$$TSS_{a,R} = 12.18 + 1.35\ pH_{a,R} - 6.13\ TTA_{a,R} + 0.08\ S_p \qquad (4.18)$$

The regression analysis further yielded linear equation 4.19, 4.20, and 4.21 for estimating TSS for the fruit stored in the S_{NR}, S_{NNR}, and R_C, where $TSS_{k,NR}$, $TSS_{k,NNR}$, and $TSS_{k,R}$ are estimated total soluble solids for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively, $pH_{k,NR}$, $pH_{k,NNR}$, and $pH_{k,R}$ are pH for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively whereas $TTA_{k,NR}$, $TTA_{k,NNR}$, and $TTA_{k,R}$ are total titratable acid for Kent mangoes stored in the S_{NR}, S_{NNR}, and R_C, respectively.

$$TSS_{k,NR} = 25.39 - 0.45\ pH_{k,NR} - 13.90\ TTA_{k,NR} - 0.22\ S_p \qquad (4.19)$$

$$TSS_{k,NNR} = 19.75 - 2.24\ pH_{k,NNR} - 5.44\ TTA_{k,NNR} + 0.37\ S_p \qquad (4.20)$$

$$TSS_{k,R} = 24.90 - 4.46\ pH_{k,R} - 3.62\ TTA_{k,R} + 1.01\ S_p \qquad (4.21)$$

4.5 Computer simulation model for predicting the performance of the improved store

Figure 4.24 presents a computer simulation model for predicting the performance of the S_{NR}. In this figure, the time and date at which the input parameters were entered into the model using time and date picker options, respectively. The input parameters including inlet air conditions, coolant conditions, cooler characteristics, and air properties were entered into their corresponding check boxes. By pressing the save icon, the output parameters were generated automatically and stored in a database (Figure 4.25). A new set of input parameters could be entered by resetting the model using the reset icon.

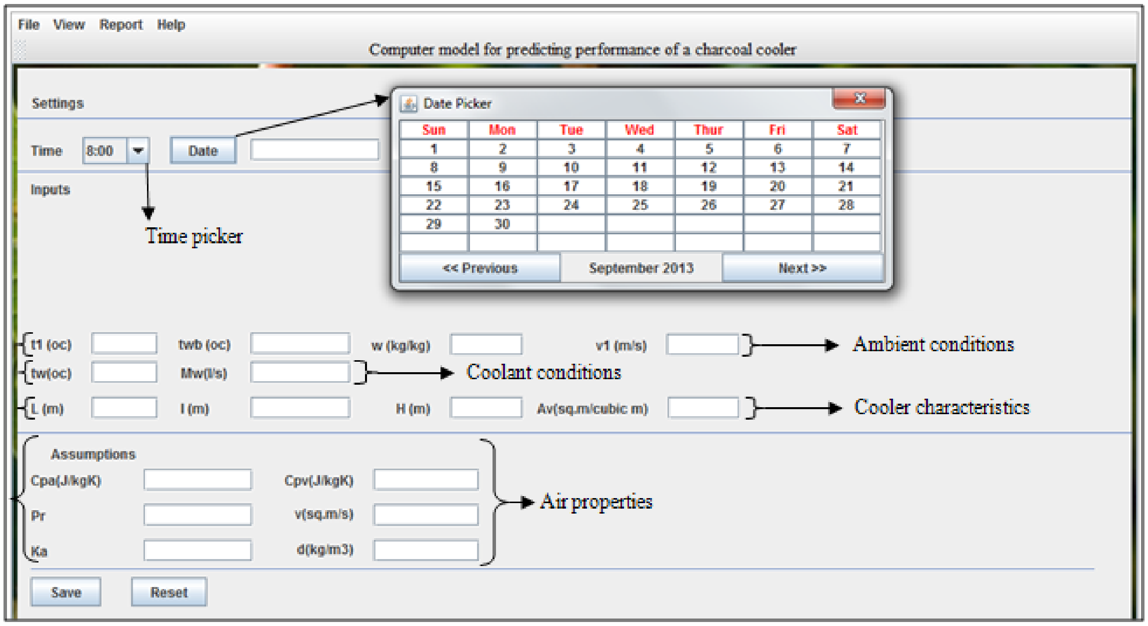
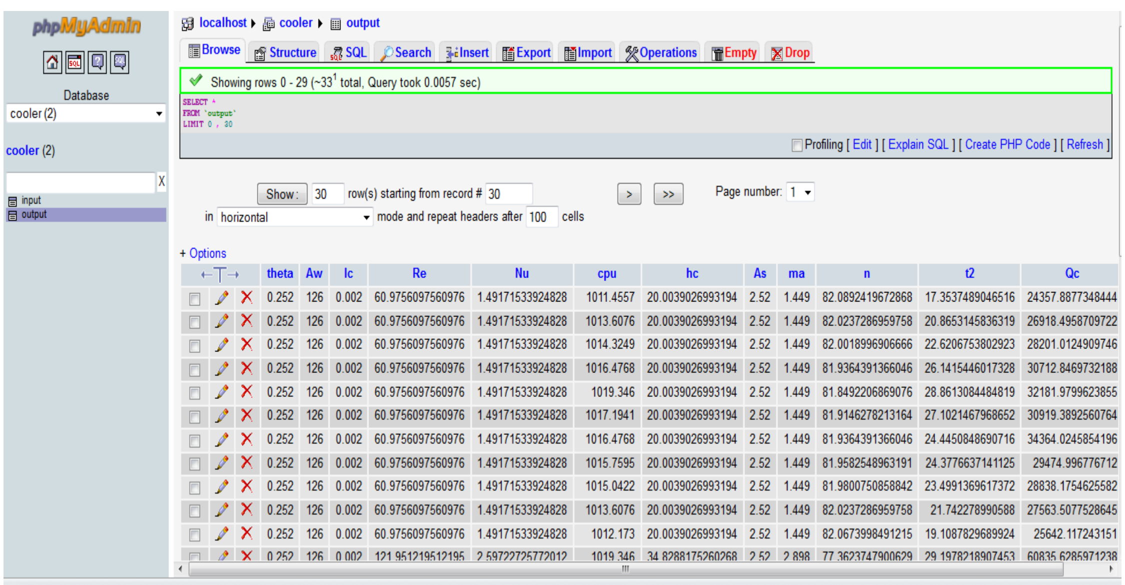


Figure 4. 24 A computer simulation model for predicting performance of the S_{NR}



theta	Aw	lc	Re	Nu	cpu	hc	As	ma	n	t2	Qc
0.252	126	0.002	60.9756097560976	1.49171533924828	1011.4557	20.0039026993194	2.52	1.449	82.0892419672868	17.3537489046516	24357.8877348444
0.252	126	0.002	60.9756097560976	1.49171533924828	1013.6076	20.0039026993194	2.52	1.449	82.0237286959758	20.8653145836319	26918.4958709722
0.252	126	0.002	60.9756097560976	1.49171533924828	1014.3249	20.0039026993194	2.52	1.449	82.0018996906666	22.6206753802923	28201.0124909746
0.252	126	0.002	60.9756097560976	1.49171533924828	1016.4768	20.0039026993194	2.52	1.449	81.9364391366046	26.1415446017328	30712.8469732188
0.252	126	0.002	60.9756097560976	1.49171533924828	1019.346	20.0039026993194	2.52	1.449	81.8492206869076	28.8613084484819	32181.9799623855
0.252	126	0.002	60.9756097560976	1.49171533924828	1017.1941	20.0039026993194	2.52	1.449	81.9146278213164	27.1021467968652	30919.3892560764
0.252	126	0.002	60.9756097560976	1.49171533924828	1016.4768	20.0039026993194	2.52	1.449	81.9364391366046	24.4450848690716	34364.0245854196
0.252	126	0.002	60.9756097560976	1.49171533924828	1015.7595	20.0039026993194	2.52	1.449	81.9582548963191	24.3776637141125	29474.996776712
0.252	126	0.002	60.9756097560976	1.49171533924828	1015.0422	20.0039026993194	2.52	1.449	81.9800750858842	23.4991369617372	28838.1754625582
0.252	126	0.002	60.9756097560976	1.49171533924828	1013.6076	20.0039026993194	2.52	1.449	82.0237286959758	21.742278990588	27563.5077528645
0.252	126	0.002	60.9756097560976	1.49171533924828	1012.173	20.0039026993194	2.52	1.449	82.0673998491215	19.1087829689924	25642.117243151
0.252	126	0.002	121.951219512195	2.59722725772012	1019.346	34.8288175260268	2.52	2.898	77.3623747900629	29.1978218907453	60835.6285971238

Figure 4. 25 A sample of database results of the model for the unloaded S_{NR}

4.5.1 Validation of the simulation model

Table 4.40 shows the actual and simulated parameters for the unloaded S_{NR} with increased in the inlet air velocity. The actual and predicted saturation efficiency of the S_{NR} at various inlet air velocities ranged from 66.9 to 68.9% and 66.9 to 69.0%, respectively while the actual and predicted cooling capacity ranged from 105.67 to 136.48 mJ/h and 105.73 to 136.68 mJ/h, respectively

Figure 4.26 presents the variation in actual and predicted saturation efficiency and cooling capacity with inlet air velocity. The saturation efficiency linearly decreased as air velocity increased. This corroborates the results of Kulkarni and Rajput (2011) who observed that at higher velocities, air has less contact time with water, leading to decrease in evaporation. Once evaporation is reduced, the quantity of heat used in vapourization of moisture is reduced, leading to decline in evaporative cooling of the system.

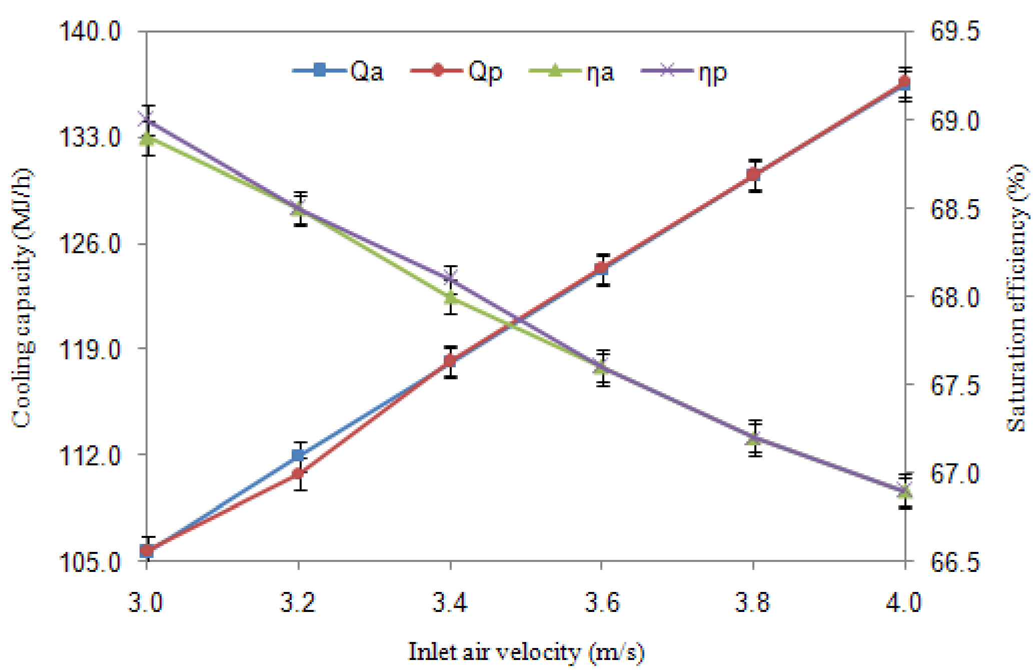


Figure 4. 26 Comparison of actual and predicted saturation efficiency and cooling capacity for the S_{NR} at various inlet air velocities

A regression analysis showed a linear relationship between the actual and the predicted saturation efficiency. Further, a strong correlation was established between the predicted and actual saturation efficiency data as in the value of R^2 was 0.999 and the *RMSE* corresponding to actual and predicted saturation efficiency was 0.00028. The ideal values of $R^2$and *RMSE* for a perfect linear correlation between the actual and simulated data is 1, and 0, respectively. In addition, the *Student's t*-test results did not show the existence of any significant difference ($t_{stat,}$= 0.06*;* $t_{crit, 5\%}$ = 2.23) between the predicted and actual saturation efficiency data.

The figure further shows that the cooling capacity of the S_{NR} increases with increase in the air velocity. Kulkarni and Rajput (2011) further reported that at high inlet air velocities large mass of air can be cooled leading to high cooling capacity. The predicted and actual cooling capacity curves have the same trend and increase as the inlet air velocity increases. In addition, the figure shows that the increase in cooling capacity as velocity increases is linear, and the two curves are almost indistinct. A high R^2 value of 0.998 and low *RMSE* value of 0.118 mJ/h between the actual and predicted cooling capacity data indicated a strong correlation between the actual and predicted values. The *Student's t*-test did not show any significant difference (t_{stat} = 0.01; $t_{crit,5\%}$ = 2.23) between the actual and predicted cooling capacity. Thus, based on R^2, *RMSE,* and *Student's t*-test, it can be concluded that the simulation model can be used satisfactorily in the prediction of saturation efficiency and cooling capacity for S_{NR}.

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CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The specific conclusions drawn from the study were as follow:

1. The postharvest challenges facing subsistence farmers in the Lower Eastern region of Kenya included inadequate availability of storage structures for mangoes with 63% of the farmers without store, short shelf-life for mangoes with 95% of the farmers unable to store the fruit safely beyond 7 days, ineffective harvesting methods namely use of untreated hooks and tree shaking with 55% and 7% of the farmers practicing these methods, respectively and improper packaging techniques with 40%, 37%, 18%, 3% and 2% of the farmers using gunny bags, cartons, plastic crates, baskets and sisal bags, respectively.
2. The temperature in the S_{NR} was lower by 3.2, 7.0, and 11.4°C compared to the S_{NNR}, R_C, and A_C, respectively while the relative humidity was higher by 3.5, 10.1, and 6.7% compared to S_{NNR}, R_C, and A_C, respectively.
3. The S_{NR} extended the shelf-life for Apple and Kent mangoes by 3 and 9 days compared to the S_{NNR} and R_C, respectively. The S_{NR} reduced weight loss in Apple mangoes by 4.64 and 9.77% compared to S_{NNR} and R_C, respectively while the weight loss in Kent mangoes was decreased by 4.09 and 8.82% compared to S_{NNR} and R_C, respectively.
4. The actual saturation efficiency of the S_{NR} at various inlet air velocities ranged from 66.9 to 68.9% while the predicted saturation efficiency ranged from 66.9 to 69.0%. The high R^2 (0.999) and low *RMSE* (0.00028) between the actual and predicted saturation efficiency measurements showed a high correlation. Moreover, the actual and predicted cooling capacity ranged from 105.67 to 136.48 mJ/h while the predicted cooling capacity ranged from 105.73 to 136.68 mJ/h. The high R^2 (0.998) and low *RMSE* (0.118 mJ/h) between the actual and predicted cooling capacity indicated a strong correlation. Therefore, the high R^2 and low *RMSE* between the actual and predicted values imply the model is reliable in the prediction of saturation efficiency and cooling capacity for S_{NR}.

5.2 Recommendations

This study recommends the following key areas:

1. The postharvest challenges facing subsistence mango farmers in the Lower Eastern region of Kenya can be addressed through development and use of the improved store, proper harvesting and packaging methods.
2. The S_{NR} with storage environment temperature in the range of 15.4 to 18.6°C and relative humidity ranging from 58.3 to 88.4% should be developed and used to extend the shelf-life and preserve the quality of mangoes
3. The developed simulation model with high R^2 and low *RMSE* between the actual and predicted data should be used in the prediction of saturation efficiency and cooling capacity for S_{NR}.

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APPENDICES

APPENDIX A: LIST OF TABLES

Table A1 Physiological loss in weight for Apple mangoes stored in the S_{NR}

Storage period (days)	Sample 1 Weight loss (%)	Sample 2 Weight loss (%)	Sample 3 Weight loss (%)	Sample 4 Weight loss (%)	Mean value ± standard error (%)
0	0.00	0.00	0.00	0.00	**0.00±0.00**
1	0.78	0.88	0.95	0.69	**0.82±0.06**
2	1.56	1.76	1.89	1.38	**1.65±0.11**
3	2.33	2.64	2.84	2.07	**2.47±0.17**
4	3.71	4.04	4.19	3.53	**3.87±0.15**
5	5.09	5.44	5.54	5.00	**5.27±0.13**
6	6.48	6.85	6.89	6.46	**6.67±0.12**
7	7.29	7.66	7.81	7.36	**7.53±0.12**
8	8.10	8.47	8.74	8.26	**8.39±0.14**
9	8.91	9.29	9.67	9.16	**9.26±0.16**
10	9.76	10.15	10.73	10.05	**10.17±0.20**
11	10.60	11.01	11.78	10.93	**11.08±0.25**
12	11.44	11.87	12.84	11.82	**11.99±0.30**
13	12.24	12.70	13.80	12.86	**12.90±0.33**
14	13.05	13.53	14.76	13.90	**13.81±0.36**
15	13.85	14.36	15.72	14.94	**14.72±0.40**
16	14.52	15.26	16.68	15.82	**15.57±0.45**
17	15.20	16.17	17.64	16.69	**16.42±0.51**
18	15.88	17.07	18.60	17.57	**17.28±0.57**

Table A2 Physiological loss in weight for Apple mangoes stored in the S_{NNR}

Storage period (days)	Sample 1 Weight loss (%)	Sample 2 Weight loss (%)	Sample 3 Weight loss (%)	Sample 4 Weight loss (%)	Mean values ± standard error (%)
0	0.00	0.00	0.00	0.00	**0.00±0.00**
1	1.98	1.85	2.18	2.41	**2.10±0.12**
2	4.74	3.00	3.54	4.58	**3.97±0.42**
3	6.20	3.99	4.19	5.63	**5.00±0.54**
4	7.40	5.49	5.77	6.31	**6.34±0.42**
5	10.13	6.64	7.66	9.87	**8.57±0.85**
6	11.62	8.31	9.14	10.50	**9.89±0.73**
7	14.25	9.39	10.62	11.99	**11.56±1.04**
8	14.83	10.46	11.29	14.30	**12.72±1.08**
9	16.42	11.54	12.57	15.13	**13.91±1.13**
10	19.92	13.19	13.06	16.22	**15.60±1.61**
11	21.07	14.49	15.39	19.33	**17.57±1.57**
12	23.79	15.96	17.31	20.67	**19.44±1.76**
13	24.19	17.09	18.16	22.71	**20.54±1.72**
14	28.18	18.39	19.62	24.75	**22.73±2.28**
15	30.14	19.69	21.08	26.79	**24.43±2.45**

Table A3 Physiological loss in weight for Apple mangoes stored in the R_C

Storage period (days)	Sample 1 Weight loss (%)	Sample 2 Weight loss (%)	Sample 3 Weight loss (%)	Sample 4 Weight loss (%)	Mean values ± standard error (%)
0	0.00	0.00	0.00	0.00	**0.00±0.00**
1	3.98	3.62	4.26	3.37	**3.81±0.20**
2	5.17	6.24	5.02	5.91	**5.59±0.29**
3	7.02	8.37	7.13	7.05	**7.39±0.33**
4	8.36	11.63	9.39	9.14	**9.63±0.70**
5	10.51	14.39	11.38	11.22	**11.88±0.86**
6	12.39	16.65	13.92	13.31	**14.07±0.92**
7	13.51	18.42	16.77	14.71	**15.85±1.09**
8	15.08	20.06	18.88	15.60	**17.41±1.22**
9	17.11	21.51	19.99	17.52	**19.03±1.04**

Table A4 Physiological loss in weight for Kent mangoes stored in the S_{NR}

Storage period (days)	Sample 1 Weight loss (%)	Sample 2 Weight loss (%)	Sample 3 Weight loss (%)	Sample 4 Weight loss (%)	Mean values ± standard error (%)
0	0.00	0.00	0.00	0.00	**0.00±0.00**
1	0.44	0.53	0.50	0.65	**0.53±0.04**
2	0.88	1.06	1.01	1.31	**1.06±0.09**
3	1.32	1.59	1.51	1.96	**1.60±0.13**
4	2.11	2.45	2.35	3.04	**2.49±0.20**
5	2.89	3.30	3.19	4.12	**3.37±0.26**
6	3.68	4.16	4.02	5.20	**4.26±0.33**
7	4.16	4.70	4.57	5.88	**4.83±0.37**
8	4.64	5.23	5.11	6.56	**5.39±0.41**
9	5.12	5.77	5.65	7.25	**5.95±0.46**
10	5.68	6.35	6.22	7.96	**6.55±0.49**
11	6.23	6.92	6.79	8.67	**7.15±0.53**
12	6.78	7.50	7.36	9.39	**7.76±0.57**
13	7.35	8.14	7.83	10.25	**8.39±0.64**
14	7.91	8.78	8.30	11.12	**9.03±0.72**
15	8.48	9.42	8.77	11.98	**9.66±0.80**
16	9.04	10.06	9.24	12.85	**10.30±0.88**
17	9.61	10.70	9.71	13.72	**10.94±0.96**
18	10.18	11.34	10.18	14.58	**11.57±1.04**
19	10.74	11.99	10.65	15.45	**12.21±1.12**
20	11.31	12.63	11.13	16.31	**12.84±1.20**
21	11.87	13.27	11.60	17.18	**13.48±1.29**
22	12.44	13.91	12.07	18.05	**14.12±1.37**
23	13.00	14.55	12.54	18.91	**14.75±1.45**
24	13.57	15.19	13.01	19.78	**15.39±1.54**

Table A5 Physiological loss in weight for Kent mangoes stored in the S_{NNR}

Storage period (days)	Sample 1 Weight loss (%)	Sample 2 Weight loss (%)	Sample 3 Weight loss (%)	Sample 4 Weight loss (%)	Mean values ± standard error (%)
0	0.00	0.00	0.00	0.00	**0.00±0.00**
1	0.82	0.60	0.81	0.61	**0.71±0.06**
2	3.00	1.90	4.22	2.22	**2.83±0.52**
3	4.21	3.01	3.94	3.23	**3.60±0.28**
4	5.22	4.05	4.86	3.70	**4.46±0.35**
5	5.65	4.67	6.21	4.97	**5.38±0.35**
6	7.43	6.69	6.48	5.64	**6.56±0.37**
7	9.06	6.09	8.14	6.04	**7.33±0.76**
8	9.72	6.88	8.27	7.03	**7.98±0.66**
9	10.00	7.45	9.71	7.62	**8.70±0.67**
10	10.47	8.33	10.75	8.26	**9.45±0.67**
11	10.94	9.21	11.79	8.69	**10.16±0.73**
12	11.61	9.39	12.83	9.92	**10.94±0.79**
13	12.54	10.53	13.65	10.65	**11.84±0.76**
14	13.87	11.89	14.03	11.39	**12.79±0.68**
15	14.80	12.79	15.07	12.32	**13.75±0.70**
16	15.54	13.69	16.03	13.05	**14.58±0.72**
17	16.29	14.59	16.99	13.78	**15.41±0.74**
18	16.83	15.72	17.74	14.71	**16.25±0.66**
19	18.73	13.83	19.35	16.23	**17.04±1.26**
20	19.48	14.73	20.10	17.15	**17.86±1.22**
21	20.22	15.63	21.28	17.68	**18.70±1.27**

Table A6 Physiological loss in weight for Kent mangoes stored in the R_C

Storage period (days)	Sample 1 Weight loss (%)	Sample 2 Weight loss (%)	Sample 3 Weight loss (%)	Sample 4 Weight loss (%)	Mean values ± standard error (%)
0	0.00	0.00	0.00	0.00	**0.00±0.00**
1	1.16	1.12	1.45	1.16	**1.22±0.08**
2	2.32	2.25	2.91	2.31	**2.45±0.15**
3	3.48	3.37	4.36	3.47	**3.67±0.23**
4	4.96	4.76	5.90	5.03	**5.16±0.25**
5	6.43	6.15	7.44	6.59	**6.65±0.28**
6	7.91	7.54	8.97	8.15	**8.14±0.30**
7	8.98	8.57	10.07	9.31	**9.23±0.32**
8	10.05	9.60	11.16	10.46	**10.32±0.33**
9	11.12	10.62	12.25	11.61	**11.40±0.35**
10	12.17	11.63	13.33	12.65	**12.45±0.36**
11	13.22	12.63	14.41	13.69	**13.49±0.38**
12	14.27	13.63	15.49	14.74	**14.53±0.39**
13	15.71	14.77	16.95	15.97	**15.85±0.45**
14	17.15	15.91	18.41	17.19	**17.16±0.51**
15	18.59	17.04	19.86	18.42	**18.48±0.58**

Table A7 Colour values (*L**, *a**, *b**) of the peel for Apple mangoes stored in the S_{NR}

	Day 0				Day 7				Day 14		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	63.8	-9.8	41.1	**Sample 1**	73.9	8.8	45.5	**Sample 1**	70.2	14.7	46.0
Sample 2	63.15	-11.1	39.2	**Sample 2**	70.7	8.6	47.0	**Sample 2**	72.3	14.2	48.5
Sample 3	66.6	-13.2	40.9	**Sample 3**	71.3	11.2	45.1	**Sample 3**	65.6	15.5	42.9
Sample 4	63.9	-11.2	40.4	**Sample 4**	66.9	14.3	42.6	**Sample 4**	61.9	16.5	41.4
	Day 1				**Day 8**				**Day 15**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	64.7	-9.7	41.2	**Sample 1**	72.7	11.1	45.8	**Sample 1**	70.0	15.0	45.9
Sample 2	63.3	-10.4	39.4	**Sample 2**	72.2	10.7	47.4	**Sample 2**	72.0	14.5	48.6
Sample 3	66.2	-13.5	40.7	**Sample 3**	71.3	13.6	44.9	**Sample 3**	64.5	15.4	42.5
Sample 4	62.7	-9.9	39.3	**Sample 4**	65.3	15.2	41.4	**Sample 4**	61.6	16.6	41.6
	Day 2				**Day 9**				**Day 16**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	65.9	-9.7	41.4	**Sample 1**	71.4	13.3	46.2	**Sample 1**	69.7	15.2	45.9
Sample 2	63.4	-9.7	39.7	**Sample 2**	73.7	12.8	47.7	**Sample 2**	71.7	14.8	48.8
Sample 3	65.8	-13.8	40.5	**Sample 3**	71.3	16.0	44.8	**Sample 3**	63.4	15.4	42.1
Sample 4	61.4	-8.7	38.2	**Sample 4**	63.6	16.0	40.3	**Sample 4**	61.2	16.7	41.9
	Day 3				**Day 10**				**Day 17**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	66.8	-9.9	41.5	**Sample 1**	71.7	13.6	46.1	**Sample 1**	69.5	15.5	45.8
Sample 2	63.6	-9.7	39.9	**Sample 2**	73.4	13.1	47.9	**Sample 2**	71.4	15.0	48.9
Sample 3	65.5	-12.5	40.3	**Sample 3**	70.2	15.9	44.4	**Sample 3**	62.2	15.3	41.7
Sample 4	60.2	-7.4	37.2	**Sample 4**	63.3	16.1	40.5	**Sample 4**	60.9	16.8	42.1
	Day 4				**Day 11**				**Day 18**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	69.6	-4.4	42.7	**Sample 1**	71.9	13.9	46.1	**Sample 1**	69.2	15.8	45.8
Sample 2	65.5	-4.3	42.7	**Sample 2**	73.2	13.3	48.0	**Sample 2**	71.1	15.3	49.1
Sample 3	67.4	-5.4	41.9	**Sample 3**	69.1	15.8	44.0	**Sample 3**	61.1	15.2	41.3
Sample 4	63.0	-0.5	41.9	**Sample 4**	62.9	16.2	40.7	**Sample 4**	60.5	16.9	42.3
	Day 5				**Day 12**						
	L*	***a****	***b****		***L****	***a****	***b****				
Sample 1	72.3	1.1	43.9	**Sample 1**	70.7	14.1	46.0				
Sample 2	67.3	1.1	43.9	**Sample 2**	72.9	13.6	48.2				
Sample 3	69.3	1.8	43.6	**Sample 3**	67.9	15.7	43.6				
Sample 4	65.8	6.5	43.6	**Sample 4**	62.6	16.3	41.0				
	Day 6				**Day 13**						
	L*	***a****	***b****		***L****	***a****	***b****				
Sample 1	75.1	6.6	45.1	**Sample 1**	70.5	14.4	46.0				
Sample 2	69.2	6.5	46.6	**Sample 2**	72.6	13.9	48.3				
Sample 3	71.2	8.9	45.2	**Sample 3**	66.8	15.6	43.3				
Sample 4	68.6	13.4	43.8	**Sample 4**	62.3	16.4	41.2				

Table A8 Colour values (L^*, a^*, b^*) of the peel for Apple mangoes stored in the S_{NNR}

	Day 0				Day 8		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	66.3	-9.7	39.6	**Sample 1**	72.0	11.7	43.9
Sample 2	61.6	-8.7	37.1	**Sample 2**	71.3	13.1	46.7
Sample 3	64.5	-14.9	40.5	**Sample 3**	69.2	9.9	47.4
Sample 4	65.7	-11.9	41.4	**Sample 4**	71.6	13.4	44.7
	Day 1				**Day 9**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	66.4	-8.0	40.0	**Sample 1**	71.7	12.3	44.4
Sample 2	63.5	-8.0	39.2	**Sample 2**	71.3	13.6	47.0
Sample 3	64.7	-13.6	41.6	**Sample 3**	69.6	11.0	47.2
Sample 4	66.1	-11.4	40.9	**Sample 4**	71.0	13.7	44.5
	Day 2				**Day 10**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	66.5	-6.3	40.4	**Sample 1**	71.4	12.9	44.9
Sample 2	65.5	-7.3	41.3	**Sample 2**	71.3	14.1	47.3
Sample 3	65.0	-12.2	42.7	**Sample 3**	70.0	12.1	47.0
Sample 4	66.4	-11.0	40.4	**Sample 4**	70.3	13.9	44.3
	Day 3				**Day 11**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	66.7	-4.5	40.8	**Sample 1**	71.2	13.5	45.3
Sample 2	67.4	-6.6	43.4	**Sample 2**	71.3	14.6	47.6
Sample 3	65.2	-10.9	43.8	**Sample 3**	70.3	13.2	46.8
Sample 4	66.8	-10.6	39.9	**Sample 4**	69.6	14.2	44.1
	Day 4				**Day 12**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	68.6	-0.5	41.5	**Sample 1**	70.9	14.1	45.8
Sample 2	68.7	-0.3	44.3	**Sample 2**	71.3	15.0	47.9
Sample 3	66.3	-4.7	45.1	**Sample 3**	70.7	14.3	46.6
Sample 4	68.8	-2.8	41.6	**Sample 4**	69.0	14.5	43.9
	Day 5				**Day 13**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	70.6	5.5	42.3	**Sample 1**	70.7	14.4	45.8
Sample 2	70.0	5.9	45.2	**Sample 2**	69.6	16.0	48.1
Sample 3	67.3	1.5	46.4	**Sample 3**	69.8	14.9	47.9
Sample 4	70.9	5.0	43.3	**Sample 4**	69.1	15.1	44.3
	Day 6				**Day 14**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	72.5	10.6	43.0	**Sample 1**	70.6	14.8	45.7
Sample 2	71.3	12.2	46.1	**Sample 2**	67.9	16.9	48.3
Sample 3	68.4	7.7	47.7	**Sample 3**	68.9	15.4	49.1
Sample 4	73.0	12.9	45.0	**Sample 4**	69.2	15.8	44.7
	Day 7				**Day 15**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	72.3	11.2	43.5	**Sample 1**	70.4	15.1	45.7
Sample 2	71.3	12.6	46.4	**Sample 2**	66.2	17.9	48.6
Sample 3	68.8	8.8	47.5	**Sample 3**	67.9	16.0	50.4
Sample 4	72.3	13.1	44.8	**Sample 4**	69.3	16.4	45.1

Table A9 Colour values (*L**, *b**, *a**) of the peel for Apple mangoes stored in the R_C

	Day 0				Day 5		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	60.9	-7.3	38.4	**Sample 1**	64.4	-1.7	45.8
Sample 2	64.3	-13.1	41.0	**Sample 2**	67.8	6.2	48.7
Sample 3	60.2	-11.2	38.0	**Sample 3**	65.2	4.3	47.6
Sample 4	63.0	-14.4	42.3	**Sample 4**	65.8	1.6	48.5
	Day 1				**Day 6**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	60.4	-8.3	38.9	**Sample 1**	66.9	2.6	48.8
Sample 2	65.4	-12.2	42.9	**Sample 2**	68.0	14.4	49.7
Sample 3	60.8	-10.5	40.0	**Sample 3**	66.8	11.0	49.4
Sample 4	62.3	-13.4	42.7	**Sample 4**	68.2	8.1	51.0
	Day 2				**Day 7**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	59.8	-9.3	39.4	**Sample 1**	67.2	7.2	48.3
Sample 2	66.5	-11.2	44.7	**Sample 2**	68.7	15.3	50.3
Sample 3	61.5	-9.8	41.9	**Sample 3**	66.5	12.8	48.4
Sample 4	61.6	-12.5	43.2	**Sample 4**	67.9	10.4	50.1
	Day 3				**Day 8**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	59.3	-10.3	39.8	**Sample 1**	67.4	11.9	47.7
Sample 2	67.5	-10.3	46.6	**Sample 2**	69.3	16.2	50.9
Sample 3	62.1	-9.1	43.9	**Sample 3**	66.2	14.7	47.4
Sample 4	60.8	-11.5	43.6	**Sample 4**	67.5	12.7	49.2
	Day 4				**Day 9**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	61.8	-6.0	42.8	**Sample 1**	67.7	16.5	47.2
Sample 2	67.7	-2.0	47.6	**Sample 2**	70.0	17.0	51.5
Sample 3	63.6	-2.4	45.7	**Sample 3**	65.9	16.5	46.4
Sample 4	63.3	-5.0	46.1	**Sample 4**	67.1	15.0	48.3

Table A10 Colour values (L*, b*, a*) of the flesh for Apple mangoes stored in the S_{NR}

	Day 0				**Day 7**				**Day 14**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	89.2	-5.5	41.3	**Sample 1**	74.2	12.1	61.0	**Sample 1**	72.3	15.4	64.6
Sample 2	89.1	-4.8	37.5	**Sample 2**	73.6	12.1	61.3	**Sample 2**	72.5	15.5	64.1
	Day 1				**Day 8**				**Day 15**		
	*L**	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	64.7	-1.1	47.0	**Sample 1**	74.0	12.7	61.8	**Sample 1**	71.8	15.4	64.5
Sample 2	64.7	0.7	44.8	**Sample 2**	73.5	12.7	61.7	**Sample 2**	72.0	15.6	64.4
	Day 2				**Day 9**				**Day 16**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	65.9	3.3	52.7	**Sample 1**	73.9	13.4	62.6	**Sample 1**	71.2	15.4	64.3
Sample 2	65.9	6.2	52.1	**Sample 2**	73.5	13.4	62.2	**Sample 2**	71.5	15.6	64.6
	Day 3				**Day 10**				**Day 17**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	72.6	7.7	58.4	**Sample 1**	74.0	14.1	63.3	**Sample 1**	70.7	15.4	64.2
Sample 2	73.7	6.2	59.4	**Sample 2**	73.5	14.0	62.7	**Sample 2**	71.1	15.7	64.9
	Day 4				**Day 11**				**Day 18**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	73.2	8.9	59.0	**Sample 1**	74.2	14.7	64.1	**Sample 1**	70.2	15.4	64
Sample 2	73.7	7.9	59.9	**Sample 2**	73.6	14.7	63.1	**Sample 2**	70.6	15.8	65.1
	Day 5				**Day 12**						
	L*	***a****	***b****		***L****	***a****	***b****				
Sample 1	73.8	10.2	59.6	**Sample 1**	73.3	15.4	64.9				
Sample 2	73.6	9.7	60.3	**Sample 2**	73.4	15.3	63.6				
	Day 6				**Day 13**						
	*L**	*a**	*b**		*L**	*a**	*b**				
Sample 1	74.4	11.4	60.2	**Sample 1**	72.8	15.4	64.8				
Sample 2	73.6	11.4	60.8	**Sample 2**	72.9	15.4	63.9				

Table A11 Colour values ($L*$, $b*$, $a*$) of the flesh for Apple mangoes stored in the S_{NNR}

	Day 0				Day 8		
	L*	***a****	***b****		***L****	***a****	***b****
Sample1	89.7	-5.0	37.6	**Sample1**	74.13	12.6	61.3
Sample2	89.0	-5.4	38.5	**Sample2**	73.67	11.7	62.1
	Day 1				**Day 9**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample1	83.5	1.2	46.9	**Sample1**	74.0	13.0	62.1
Sample2	82.1	2.8	46.6	**Sample2**	73.9	12.9	63.5
	Day 2				**Day 10**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample1	77.2	7.4	56.3	**Sample1**	73.4	13.4	62.1
Sample2	75.3	10.9	54.8	**Sample2**	73.4	13.2	63.6
	Day 3				**Day 11**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample1	76.2	7.4	56.3	**Sample1**	72.8	13.9	62.0
Sample2	74.3	11.9	55.8	**Sample2**	72.7	13.4	63.8
	Day 4				**Day 12**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample1	73.2	9.1	61.5	**Sample1**	72.2	14.3	62.0
Sample2	72.3	11.9	59.9	**Sample2**	72.1	13.7	63.9
	Day 5				**Day 13**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample1	74.4	11.8	60.9	**Sample1**	71.5	14.7	62.0
Sample2	73.2	9.3	60.5	**Sample2**	71.4	13.9	64.0
	Day 6				**Day 14**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample1	73.2	8.4	56.3	**Sample1**	70.9	15.2	61.9
Sample2	72.3	11.9	55.8	**Sample2**	70.8	14.2	64.2
	Day 7				**Day 15**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample1	74.3	12.2	60.5	**Sample1**	70.3	15.6	61.9
Sample2	73.4	10.5	60.7	**Sample2**	70.2	14.4	64.3

Table A12 Colour values (L^*, b^*, a^*) of the flesh for Apple mangoes stored in the R_C

	Day 0				Day 5		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	90.4	-4.4	33.5	**Sample 1**	74.5	10.4	60.1
Sample 2	89.1	-6.3	41.6	**Sample 2**	75.2	8.9	61.0
	Day 1				**Day 6**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	84.3	-0.1	42.7	**Sample 1**	75.7	11.4	59.5
Sample 2	83.4	-1.6	47.9	**Sample 2**	76.8	9.4	61.3
	Day 2				**Day 7**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	78.1	4.2	52.0	**Sample 1**	74.5	13.3	60.5
Sample 2	77.8	3.1	54.1	**Sample 2**	75.7	11.8	62.6
	Day 3				**Day 8**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	72	8.5	61.2	**Sample 1**	73.3	15.1	61.4
Sample 2	72.1	7.8	60.4	**Sample 2**	74.7	14.1	63.9
	Day 4				**Day 9**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	73.2	9.5	60.6	**Sample 1**	72.1	17	62.4
Sample 2	73.7	8.3	60.7	**Sample 2**	73.6	16.5	65.2

Table A13 Colour values (L^*,b^*, a^*) of the peel for Kent mangoes stored in the S_{NR}

	Day 0				**Day 9**				**Day 18**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	47.5	-13.8	20.6	**Sample 1**	47.4	-15.6	25.6	**Sample 1**	44.0	-12.7	18.6
Sample 2	49.1	-14.3	20.3	**Sample 2**	47.2	-12.6	16.9	**Sample 2**	49.1	-15.3	22.7
Sample 3	44.7	-8	17.7	**Sample 3**	46.9	-12.9	18.7	**Sample 3**	47.7	-15.0	24.4
Sample 4	46.8	-11.9	18.3	**Sample 4**	47.2	-13.9	21.0	**Sample 4**	45.9	-14.8	24.3
	Day 1				**Day 10**				**Day 19**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	48.5	-14.4	22.0	**Sample 1**	46.1	-15.3	25.1	**Sample 1**	44.8	-13.1	19.8
Sample 2	48.4	-13.7	20.2	**Sample 2**	47.6	-13	16.2	**Sample 2**	49.1	-15.6	23.7
Sample 3	45.3	-8.8	17.9	**Sample 3**	46.7	-13.1	18.7	**Sample 3**	47.5	-15.0	24.5
Sample 4	47.7	-12.1	18.8	**Sample 4**	46.2	-14.1	21	**Sample 4**	45.6	-15.0	24.6
	Day 2				**Day 11**				**Day 20**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	49.5	-15.0	23.5	**Sample 1**	45.2	-14.6	23.1	**Sample 1**	45.6	-13.5	21
Sample 2	47.6	-13.1	20.1	**Sample 2**	47.9	-13.3	16.9	**Sample 2**	49.1	-15.8	24.7
Sample 3	45.9	-9.6	18.2	**Sample 3**	47.0	-13.4	19.7	**Sample 3**	47.3	-15.1	24.7
Sample 4	48.5	-12.3	19.3	**Sample 4**	46.4	-14.1	21.5	**Sample 4**	45.2	-15.2	24.9
	Day 3				**Day 12**				**Day 21**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	50.6	-15.7	24.9	**Sample 1**	44.3	-13.8	21.1	**Sample 1**	45.6	-13.8	23.2
Sample 2	46.9	-12.4	19.9	**Sample 2**	48.2	-13.6	17.6	**Sample 2**	48.5	-15.5	25.8
Sample 3	46.4	-10.5	18.4	**Sample 3**	47.3	-13.8	20.8	**Sample 3**	47.1	-15.0	25.9
Sample 4	49.4	-12.6	19.9	**Sample 4**	46.5	-14.2	21.9	**Sample 4**	45.6	-15.0	26.0
	Day 4				**Day 13**				**Day 22**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	51.6	-16.3	26.4	**Sample 1**	43.5	-13.1	19.1	**Sample 1**	45.6	-14.1	25.4
Sample 2	46.1	-11.8	19.8	**Sample 2**	48.5	-14.0	18.4	**Sample 2**	47.9	-15.1	27.0
Sample 3	47.0	-11.3	18.7	**Sample 3**	47.7	-14.1	21.8	**Sample 3**	47.0	-14.8	27.0
Sample 4	50.2	-12.8	20.4	**Sample 4**	46.7	-14.2	22.4	**Sample 4**	46.0	-14.8	27.0
	Day 5				**Day 14**				**Day 23**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	52.6	-16.9	27.8	**Sample 1**	42.6	-12.3	17.1	**Sample 1**	45.6	-14.3	27.5
Sample 2	45.4	-11.2	19.7	**Sample 2**	48.8	-14.3	19.1	**Sample 2**	47.3	-14.8	28.1
Sample 3	47.6	-12.1	18.9	**Sample 3**	48.0	-14.5	22.9	**Sample 3**	46.8	-14.7	28.2
Sample 4	51.1	-13	20.9	**Sample 4**	46.8	-14.3	22.8	**Sample 4**	46.4	-14.5	28.1
	Day 6				**Day 15**				**Day 24**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	51.3	-16.6	27.3	**Sample 1**	41.7	-11.6	15.1	**Sample 1**	45.6	-14.6	29.7
Sample 2	45.8	-11.6	19.0	**Sample 2**	49.1	-14.6	19.8	**Sample 2**	46.7	-14.4	29.2
Sample 3	47.4	-12.3	18.9	**Sample 3**	48.3	-14.8	23.9	**Sample 3**	46.6	-14.5	29.3
Sample 4	50.1	-13.2	20.9	**Sample 4**	47	-14.3	23.3	**Sample 4**	46.8	-14.3	29.1
	Day 7				**Day 16**						
	L*	***a****	***b****		***L****	***a****	***b****				
Sample 1	50.0	-16.3	26.7	**Sample 1**	42.5	-12.0	16.3				
Sample 2	46.3	-11.9	18.3	**Sample 2**	49.1	-14.8	20.8				
Sample 3	47.2	-12.5	18.8	**Sample 3**	48.1	-14.9	24.1				
Sample 4	49.1	-13.4	20.9	**Sample 4**	46.6	-14.5	23.6				
	Day 8				**Day 17**						
	L*	***a****	***b****		***L****	***a****	***b****				
Sample 1	48.7	-15.9	26.2	**Sample 1**	43.3	-12.4	17.5				
Sample 2	46.7	-12.3	17.6	**Sample 2**	49.1	-15.1	21.8				
Sample 3	47.1	-12.7	18.8	**Sample 3**	47.9	-14.9	24.2				
Sample 4	48.2	-13.7	21.0	**Sample 4**	46.3	-14.7	23.9				

Table A14 Colour values (L^*, b^*, a^*) of the peel for Kent mangoes stored in the S_{NNR}

	Day 0				Day 8				Day 16		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	**b***
Sample 1	45.9	-9.5	23.7	**Sample 1**	45.4	-13.0	19.5	**Sample 1**	46.1	-15.3	22.5
Sample 2	47.3	-9.6	20.3	**Sample 2**	48.6	-7.9	24.6	**Sample 2**	44.0	-14.6	20.9
Sample 3	46.2	-9.9	18.8	**Sample 3**	46.6	-13.1	19.2	**Sample 3**	43.5	-13.9	21.7
Sample 4	58.5	-17	39.0	**Sample 4**	57.2	-18.5	37.5	**Sample 4**	51.4	-16.6	28.1
	Day 1				**Day 9**				**Day 17**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	45.4	-10.0	22.9	**Sample 1**	46.1	-13.3	19.5	**Sample 1**	45.5	-15.3	22.3
Sample 2	46.7	-10.2	20.0	**Sample 2**	49.9	-6.4	26.5	**Sample 2**	43.9	-14.7	21.0
Sample 3	46.3	-10.1	17.6	**Sample 3**	46.7	-13.8	21.3	**Sample 3**	43.9	-14.5	22.7
Sample 4	58.4	-17.3	39.1	**Sample 4**	57.0	-18.5	36.9	**Sample 4**	51.0	-16.2	27.3
	Day 2				**Day 10**				**Day 18**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	44.8	-10.5	22.1	**Sample 1**	46.8	-13.6	19.4	**Sample 1**	45.0	-15.4	22.2
Sample 2	46.2	-10.8	19.7	**Sample 2**	51.3	-4.9	28.4	**Sample 2**	43.8	-14.9	21.2
Sample 3	46.3	-10.3	16.4	**Sample 3**	46.7	-14.6	23.5	**Sample 3**	44.4	-15.1	23.8
Sample 4	58.3	-17.6	39.2	**Sample 4**	56.7	-18.5	36.2	**Sample 4**	50.5	-15.8	26.5
	Day 3				**Day 11**				**Day 19**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	44.3	-11.0	21.3	**Sample 1**	46.8	-13.9	20.1	**Sample 1**	44.5	-15.4	22.0
Sample 2	45.6	-11.3	19.4	**Sample 2**	49.9	-6.8	26.9	**Sample 2**	43.7	-15.0	21.4
Sample 3	46.4	-10.4	15.1	**Sample 3**	46.0	-14.3	22.9	**Sample 3**	44.9	-15.7	24.8
Sample 4	57.7	-18.5	38.8	**Sample 4**	55.7	-18.2	34.7	**Sample 4**	50.0	-15.3	25.7
	Day 4				**Day 12**				**Day 20**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	43.7	-11.5	20.5	**Sample 1**	46.7	-14.3	20.7	**Sample 1**	43.9	-15.4	21.8
Sample 2	45.1	-11.9	19.1	**Sample 2**	48.4	-8.7	25.3	**Sample 2**	43.6	-15.2	21.5
Sample 3	46.4	-10.6	13.9	**Sample 3**	45.2	-14.1	22.3	**Sample 3**	45.3	-16.3	25.9
Sample 4	58.2	-17.9	39.3	**Sample 4**	54.8	-17.9	33.3	**Sample 4**	49.6	-14.9	24.9
	Day 5				**Day 13**				**Day 21**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	43.2	-12	19.7	K_{W1}	46.7	-14.6	21.4	**Sample 1**	43.4	-15.4	21.6
Sample 2	44.5	-12.5	18.8	K_{W2}	47.0	-10.6	23.8	**Sample 2**	43.5	-15.3	21.7
Sample 3	46.5	-10.8	12.7	K_{W3}	44.5	-13.8	21.8	**Sample 3**	45.8	-16.9	26.9
Sample 4	58.0	-18.5	39.5	K_{W4}	53.8	-17.6	31.8	**Sample 4**	49.1	-14.5	24.1
	Day 6				**Day 14**						
	L*	***a****	***b****		***L****	***a****	***b****				
Sample 1	43.9	-12.3	19.6	**Sample 1**	46.6	-15.0	22.0				
Sample 2	45.9	-11.0	20.7	**Sample 2**	45.5	-12.5	22.2				
Sample 3	46.5	-11.6	14.9	**Sample 3**	43.7	-13.6	21.2				
Sample 4	58.1	-18.2	39.4	**Sample 4**	52.9	-17.3	30.4				
	Day 7				**Day 15**						
	L*	***a****	***b****		***L****	***a****	***b****				
Sample 1	44.6	-12.6	19.6	**Sample 1**	46.6	-15.3	22.7				
Sample 2	47.2	-9.5	22.6	**Sample 2**	44.1	-14.4	20.7				
Sample 3	46.6	-12.3	17.0	**Sample 3**	43	-13.3	20.6				
Sample 4	57.5	-18.5	38.2	**Sample 4**	51.9	-17	28.9				

Table A15 Colour values (L^*, b^*, a^*) of the peel for Kent mangoes stored in the R_C

	Day 0				Day 8		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	47.3	-8.8	25.7	**Sample 1**	45	-12.4	25
Sample 2	46.5	-9.8	23.8	**Sample 2**	42.1	-14.8	23.7
Sample 3	49.7	-12.4	27	**Sample 3**	47.9	-13.4	24.8
Sample 4	45.3	-13.1	28.3	**Sample 4**	45.6	-14.4	27.4
	Day 1				**Day 9**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	46.8	-9.6	23.5	**Sample 1**	43.8	-12.7	24.1
Sample 2	46.4	-10.7	22.9	**Sample 2**	41.7	-14.6	22.7
Sample 3	49.2	-12.3	23.9	**Sample 3**	46.5	-13.4	23.2
Sample 4	45.8	-13.3	28.4	**Sample 4**	44.1	-14.3	25.8
	Day 2				**Day 10**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	46.4	-10.5	21.3	**Sample 1**	42.6	-13.0	23.2
Sample 2	46.4	-11.7	22.0	**Sample 2**	41.3	-14.3	21.6
Sample 3	48.7	-12.3	20.8	**Sample 3**	45.1	-13.4	21.5
Sample 4	46.3	-13.5	28.4	**Sample 4**	42.6	-14.2	24.2
	Day 3				**Day 11**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	45.9	-11.3	19.0	**Sample 1**	41.3	-13.3	22.3
Sample 2	46.3	-12.6	21.0	**Sample 2**	40.9	-14.1	20.6
Sample 3	48.1	-12.2	17.6	**Sample 3**	43.6	-13.3	19.9
Sample 4	46.7	-13.7	28.5	**Sample 4**	41.1	-14.1	22.6
	Day 4				**Day 12**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	45.4	-12.1	16.8	**Sample 1**	40.1	-13.6	21.4
Sample 2	46.2	-13.5	20.1	**Sample 2**	40.5	-13.8	19.5
Sample 3	47.6	-12.1	14.5	**Sample 3**	42.2	-13.3	18.2
Sample 4	47.2	-13.9	28.5	**Sample 4**	39.6	-14	21
	Day 5				**Day 13**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	45.3	-12.2	18.9	**Sample 1**	41.0	-13.7	22.1
Sample 2	45.2	-13.8	21.0	**Sample 2**	41.5	-14.3	20.2
Sample 3	47.7	-12.4	17.1	**Sample 3**	43.3	-14.5	21.1
Sample 4	46.8	-14.0	28.2	**Sample 4**	42.8	-14.2	22.0
	Day 6				**Day 14**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	45.2	-12.3	20.9	**Sample 1**	41.8	-13.7	22.7
Sample 2	44.2	-14.2	21.9	**Sample 2**	42.5	-14.8	21.0
Sample 3	47.8	-12.8	19.7	**Sample 3**	44.4	-15.7	24.0
Sample 4	46.4	-14.2	28.0	**Sample 4**	45.9	-14.3	23.1
	Day 7				**Day 15**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	45.1	-12.3	23.0	**Sample 1**	42.7	-13.8	23.4
Sample 2	43.1	-14.5	22.8	**Sample 2**	43.5	-15.3	21.7
Sample 3	47.8	-13.1	22.2	**Sample 3**	45.5	-16.9	26.9
Sample 4	46.0	-14.3	27.7	**Sample 4**	49.1	-14.5	24.1

Table A16 Colour values (L^*, b^*, a^*) of the flesh for Kent mangoes stored in the S_{NR}

	Day 0				Day 9				Day 18		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	83.3	-7.3	44.8	**Sample 1**	71.4	-0.6	59.4	**Sample 1**	73.5	7.6	61.9
Sample 2	83.1	-7.7	44.9	**Sample 2**	72.4	-0.7	59.5	**Sample 2**	72.6	8.1	64.3
	Day 1				**Day 10**				**Day 19**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	80.1	-6.6	45.4	**Sample 1**	72.4	0.7	61.0	**Sample 1**	73.3	8.3	61.5
Sample 2	79.6	-6.8	45.43	**Sample 2**	72.6	0.9	62.10	**Sample 2**	72.5	8.8	63.80
	Day 2				**Day 11**				**Day 20**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	76.9	-5.9	45.9	**Sample 1**	73.4	1.9	62.7	**Sample 1**	73.1	9.0	61.0
Sample 2	76.1	-5.9	45.97	**Sample 2**	72.7	2.4	64.70	**Sample 2**	72.4	9.5	63.30
	Day 3				**Day 12**				**Day 21**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	73.7	-5.2	46.5	**Sample 1**	74.4	3.2	64.3	**Sample 1**	73.0	9.7	60.6
Sample 2	72.6	-5	46.5	**Sample 2**	72.9	4	67.3	**Sample 2**	72.4	10.2	62.8
	Day 4				**Day 13**				**Day 22**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	74.2	-4.1	50.5	**Sample 1**	74.2	3.9	63.9	**Sample 1**	72.8	10.5	60.2
Sample 2	73.9	-4.1	49.93	**Sample 2**	72.8	4.7	66.80	**Sample 2**	72.3	10.8	62.30
	Day 5				**Day 14**				**Day 23**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	74.8	-3.1	54.4	**Sample 1**	74.1	4.7	63.5	**Sample 1**	72.7	11.2	59.8
Sample 2	75.3	-3.3	53.37	**Sample 2**	72.8	5.4	66.30	**Sample 2**	72.3	11.5	61.80
	Day 6				**Day 15**				**Day 24**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	75.3	-2	58.4	**Sample 1**	73.9	5.4	63.1	**Sample 1**	72.5	11.9	59.42
Sample 2	76.6	-2.4	56.8	**Sample 2**	72.7	6.1	65.8	**Sample 2**	72.2	12.2	61.3
	Day 7				**Day 16**						
	L*	***a****	***b****		***L****	***a****	***b****				
Sample 1	74.0	-1.5	58.7	**Sample 1**	73.8	6.1	62.7				
Sample 2	75.2	-1.8	57.70	**Sample 2**	72.7	6.7	65.30				
	Day 8				**Day 17**						
	L*	***a****	***b****		***L****	***a****	***b****				
Sample 1	72.7	-1.1	59.1	**Sample 1**	73.6	6.8	62.3				
Sample 2	73.8	-1.3	58.60	**Sample 2**	72.6	7.4	64.80				

Table A17 Colour values (*L**, *b**, *a**) of the flesh for Kent mangoes stored in the S_{NNR}

	Day 0				Day 8				Day 16		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	83.6	-7.5	44.2	**Sample 1**	74.6	-1.5	61.9	**Sample 1**	70.1	5.5	61.9
Sample 2	82.4	-7.6	40.1	**Sample 2**	74.3	-2.2	63.2	**Sample 2**	69.9	5.4	62.8
	Day 1				**Day 9**				**Day 17**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	79.3	-6.1	46.6	**Sample 1**	76.1	-0.9	61.9	**Sample 1**	69.7	6.0	61.6
Sample 2	78.1	-6.1	43.8	**Sample 2**	75.8	-1	64.2	**Sample 2**	69.7	5.9	62.4
	Day 2				**Day 10**				**Day 18**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	75.1	-4.6	49.0	**Sample 1**	74.5	0.7	62.2	**Sample 1**	69.4	6.4	61.4
Sample 2	73.8	-4.7	47.5	**Sample 2**	74.1	0.6	64.3	**Sample 2**	69.5	6.3	61.9
	Day 3				**Day 11**				**Day 19**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	70.8	-3.2	51.4	**Sample 1**	72.9	2.3	62.6	**Sample 1**	69.1	6.8	61.1
Sample 2	69.5	-3.2	51.2	**Sample 2**	72.3	2.2	64.5	**Sample 2**	69.4	6.7	61.5
	Day 4				**Day 12**				**Day 20**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	71.1	-3.1	54.9	**Sample 1**	71.3	3.9	62.9	**Sample 1**	68.8	8.2	60.9
Sample 2	70.1	-3.6	54.5	**Sample 2**	70.6	3.8	64.6	**Sample 2**	69.2	8.1	61.0
	Day 5				**Day 13**				**Day 21**		
	L*	***a****	***b****		***L****	***a****	***b****		***L****	***a****	***b****
Sample 1	71.4	-2.9	58.4	**Sample 1**	71.0	4.3	62.6	**Sample 1**	68.5	11.8	60.1
Sample 2	70.8	-4.1	57.9	**Sample 2**	70.4	4.2	64.2	**Sample 2**	69	10.7	60.2
	Day 6				**Day 14**						
	L*	***a****	***b****		***L****	***a****	***b****				
Sample 1	71.7	-2.8	61.9	**Sample 1**	70.7	4.7	62.4				
Sample 2	71.4	-4.5	61.2	**Sample 2**	70.2	4.6	63.7				
	Day 7				**Day 15**						
	L*	***a****	***b****		***L****	***a****	***b****				
Sample 1	73.2	-2.2	61.9	**Sample 1**	70.4	5.1	62.1				
Sample 2	72.9	-3.3	62.2	**Sample 2**	70.1	5.0	63.3				

Table A18 Colour values (L^*, b^*, a^*) of the flesh for Kent mangoes at stored in the R_C

	Day 0				Day 8		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	85.4	-8	40.9	**Sample 1**	73.5	5.6	67.6
Sample 2	84	-7.6	43.7	**Sample 2**	75.3	4.2	66.5
	Day 1				**Day 9**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	79.6	-4.3	47.4	**Sample 1**	72	7.4	68.1
Sample 2	78.4	-4.1	49.4	**Sample 2**	74.8	5.3	66.5
	Day 2				**Day 10**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	73.9	-0.7	53.9	**Sample 1**	70.4	8.1	67.0
Sample 2	72.7	-0.6	55.1	**Sample 2**	72.2	6.6	66.3
	Day 3				**Day 11**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	68.1	3	60.4	**Sample 1**	68.7	8.7	66.0
Sample 2	67.1	2.9	60.8	**Sample 2**	69.7	7.8	66.1
	Day 4				**Day 12**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	70.9	2.6	62.5	**Sample 1**	67.1	9.4	64.9
Sample 2	70.2	2.6	62.7	**Sample 2**	67.1	9.1	65.9
	Day 5				**Day 13**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	73.6	2.3	64.5	**Sample 1**	67.5	10.3	63.7
Sample 2	73.2	2.3	64.6	**Sample 2**	67.2	9.8	64.0
	Day 6				**Day 14**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	76.4	1.9	66.6	**Sample 1**	67.9	11.1	62.6
Sample 2	76.3	2	66.5	**Sample 2**	67.4	10.4	62.0
	Day 7				**Day 15**		
	L*	***a****	***b****		***L****	***a****	***b****
Sample 1	74.9	3.7	67.1	**Sample 1**	68.3	12	61.4
Sample 2	75.8	3.1	66.5	**Sample 2**	67.5	11.1	60.1

Table A19 Firmness of the peel for Apple mangoes stored in the S_{NR}

Storage period (days)	Sample 1 Peel firmness (N)	Sample 2 Peel firmness (N)	Sample 3 Peel firmness (N)	Mean ± standard error
0	41.87	40.11	40.40	**40.80±0.55**
1	37.82	36.68	37.00	**37.17±0.34**
2	33.77	33.24	33.60	**33.54±0.15**
3	29.71	29.81	30.20	**29.91±0.15**
4	23.34	22.88	23.86	**23.36±0.28**
5	16.97	15.95	17.52	**16.81±0.46**
6	10.59	9.02	11.18	**10.26±0.64**
7	8.92	8.27	9.90	**9.03±0.47**
8	7.26	7.52	8.63	**7.80±0.42**
9	5.59	6.77	7.35	**6.57±0.52**
10	5.39	6.24	6.47	**6.04±0.33**
11	5.20	5.72	5.59	**5.50±0.16**
12	5.00	5.20	4.71	**4.97±0.14**
13	4.87	5.03	4.61	**4.84±0.12**
14	4.74	4.87	4.51	**4.71±0.11**
15	4.61	4.71	4.41	**4.58±0.09**
16	4.25	4.35	4.09	**4.23±0.08**
17	3.89	3.99	3.76	**3.88±0.07**
18	3.53	3.63	3.43	**3.53±0.06**

Table A20 Firmness of the peel for Apple mangoes stored in the S_{NNR}

Storage period (days)	Sample 1 Peel firmness (N)	Sample 2 Peel firmness (N)	Sample 3 Peel firmness (N)	Mean ± standard error
0	41.87	40.11	40.40	**40.80±0.55**
1	37.95	33.08	30.96	**34.00±2.07**
2	34.03	26.05	21.51	**27.20±3.66**
3	30.11	19.02	12.06	**20.40±5.25**
4	22.65	15.17	10.04	**15.95±3.66**
5	15.20	11.31	8.01	**11.51±2.08**
6	7.75	7.45	5.98	**7.06±0.55**
7	7.03	6.73	5.72	**6.49±0.40**
8	6.31	6.01	5.46	**5.93±0.25**
9	5.59	5.30	5.20	**5.36±0.12**
10	5.07	4.74	4.84	**4.88±0.10**
11	4.54	4.18	4.48	**4.40±0.11**
12	4.02	3.63	4.12	**3.92±0.15**
13	3.82	3.63	3.92	**3.79±0.09**
14	3.63	3.63	3.73	**3.66±0.03**
15	3.43	3.63	3.53	**3.53±0.06**

Table A21 Firmness of the peel for Apple mangoes stored in the R_C

Storage period (days)	Sample 1 Peel firmness (N)	Sample 2 Peel firmness (N)	Sample 3 Peel firmness (N)	Mean ± standard error
0	41.87	40.11	40.40	**40.80±0.55**
1	29.71	28.80	28.99	**29.17±0.28**
2	17.55	17.49	17.59	**17.54±0.03**
3	5.39	6.18	6.18	**5.92±0.26**
4	5.00	5.62	5.59	**5.40±0.20**
5	4.61	5.07	5.00	**4.89±0.14**
6	4.22	4.51	4.41	**4.38±0.09**
7	4.05	4.12	4.09	**4.09±0.02**
8	3.89	3.73	3.76	**3.79±0.25**
9	3.73	3.33	3.43	**3.50±0.12**

Table A22 Firmness of the flesh for Apple mangoes stored in the S_{NR}

Storage period (days)	**Sample 1** **Flesh firmness (N)**	**Sample 2** **Flesh firmness (N)**	**Sample 3** **Flesh firmness (N)**	**Mean ± standard error**
0	25.40	25.69	24.91	**25.33±0.23**
1	19.58	19.68	19.12	**19.46±0.17**
2	13.76	13.66	13.34	**13.59±0.13**
3	7.94	7.65	7.55	**7.71±0.12**
4	6.64	6.31	6.41	**6.45±0.10**
5	5.33	4.97	5.26	**5.19±0.11**
6	4.02	3.63	4.12	**3.92±0.15**
7	3.27	2.94	3.40	**3.20±0.14**
8	2.52	2.26	2.68	**2.48±0.12**
9	1.77	1.57	1.96	**1.77±0.11**
10	1.73	1.54	1.77	**1.68±0.07**
11	1.70	1.50	1.57	**1.59±0.06**
12	1.67	1.47	1.37	**1.50±0.09**
13	1.50	1.44	1.34	**1.43±0.05**
14	1.34	1.41	1.31	**1.35±0.03**
15	1.18	1.37	1.27	**1.27±0.06**
16	1.08	1.21	1.21	**1.17±0.04**
17	0.98	1.05	1.14	**1.06±0.05**
18	0.88	0.88	1.08	**0.95±0.07**

Table A23 Firmness of the flesh for Apple mangoes stored in the S_{NNR}

Storage period (days)	Sample 1 Flesh firmness (N)	Sample 2 Flesh firmness (N)	Sample 3 Flesh firmness (N)	Mean ± standard error
0	25.40	25.69	24.91	**25.33±0.23**
1	19.06	19.29	18.80	**19.05±0.14**
2	12.72	12.88	12.68	**12.76±0.06**
3	6.37	6.47	6.57	**6.47±0.06**
4	4.81	4.81	4.94	**4.85±0.04**
5	3.24	3.14	3.30	**3.23±0.05**
6	1.67	1.47	1.67	**1.60±0.07**
7	1.54	1.37	1.57	**1.49±0.06**
8	1.41	1.27	1.47	**1.38±0.06**
9	1.27	1.18	1.37	**1.27±0.06**
10	1.18	1.11	1.41	**1.23±0.09**
11	1.08	1.05	1.44	**1.19±0.13**
12	0.98	0.98	1.47	**1.14±0.16**
13	0.95	0.95	1.37	**1.09±0.14**
14	0.92	0.92	1.27	**1.04±0.12**
15	0.88	0.88	1.18	**0.98±0.10**

Table A24 Firmness of the flesh for Apple mangoes stored in the R_C

Storage period (days)	Sample 1 Flesh firmness (N)	Sample 2 Flesh firmness (N)	Sample 3 Flesh firmness (N)	Mean ± standard error
0	25.40	25.69	24.91	**25.33±0.23**
1	17.46	17.62	17.06	**17.38±0.16**
2	9.51	9.55	9.22	**9.43±0.10**
3	1.57	1.47	1.37	**1.47±0.06**
4	1.50	1.44	1.21	**1.38±0.09**
5	1.44	1.41	1.05	**1.30±0.13**
6	1.37	1.37	0.88	**1.21±0.16**
7	1.18	1.21	1.01	**1.13±0.06**
8	0.98	1.05	1.14	**1.06±0.05**
9	0.78	0.88	1.27	**0.98±0.15**

Table A25 Firmness of the peel for Kent mangoes stored in the S_{NR}

Storage period (days)	<u>Sample 1</u> Peel firmness (N)	<u>Sample 2</u> Peel firmness (N)	<u>Sample 3</u> Peel firmness (N)	<u>Sample 4</u> Peel firmness (N)	Mean ± standard error
0	59.13	66.59	71.98	69.82	**66.88±2.81**
1	60.57	66.52	70.77	68.81	**66.67±2.21**
2	62.01	66.46	69.56	67.80	**66.46±1.61**
3	63.45	66.39	68.35	66.78	**66.24±1.02**
4	63.06	66.06	68.19	63.97	**65.32±1.14**
5	62.66	65.74	68.03	61.16	**64.40±1.54**
6	62.27	65.41	67.86	58.35	**63.47±2.06**
7	60.90	60.28	64.69	58.74	**61.15±1.26**
8	59.53	55.15	61.52	59.13	**58.83±1.34**
9	58.15	50.01	58.35	59.53	**56.51±2.19**
10	56.85	52.40	57.86	58.06	**56.29±1.32**
11	55.54	54.79	57.37	56.58	**56.07±0.57**
12	54.23	57.17	56.88	55.11	**55.85±0.71**
13	49.82	52.17	52.01	50.80	**51.20±0.55**
14	45.40	47.17	47.14	46.48	**46.55±0.41**
15	40.99	42.17	42.27	42.17	**41.90±0.30**
16	33.02	34.19	34.98	33.93	**34.03±0.40**
17	25.04	26.22	27.69	25.69	**26.16±0.56**
18	17.06	18.24	20.40	17.46	**18.29±0.74**
19	15.46	17.62	17.10	16.54	**16.68±046**
20	13.86	17.00	13.79	15.63	**15.07±0.77**
21	12.26	16.38	10.49	14.71	**13.46±1.30**
22	11.87	14.32	9.84	12.59	**12.15±0.93**
23	11.47	12.26	9.19	10.46	**10.84±0.66**
24	11.08	10.20	8.53	8.34	**9.54±0.66**

Table A26 Firmness of the peel for Kent mangoes stored in the S_{NNR}

Storage period (days)	Sample 1 Peel firmness (N)	Sample 2 Peel firmness (N)	Sample 3 Peel firmness (N)	Sample 4 Peel firmness (N)	Mean ± standard error
0	59.13	66.59	71.98	69.82	**66.88±2.81**
1	60.25	66.19	70.44	67.89	**66.17±2.17**
2	61.36	65.80	68.91	65.97	**65.51±1.56**
3	62.47	65.41	67.37	64.04	**64.82±1.04**
4	61.10	63.02	64.85	62.53	**62.88±0.78**
5	59.72	60.64	62.34	61.03	**60.93±0.54**
6	58.35	58.25	59.82	59.53	**58.99±0.40**
7	56.98	57.24	58.12	58.06	**57.60±0.29**
8	55.60	56.22	56.42	56.58	**56.21±0.21**
9	54.23	55.21	54.72	55.11	**54.82±0.22**
10	49.56	49.79	49.13	50.83	**49.83±0.36**
11	44.88	44.36	43.54	46.55	**44.83±0.64**
12	40.21	38.93	37.95	42.27	**39.84±0.93**
13	32.49	31.71	31.12	34.00	**32.33±0.62**
14	24.78	24.48	24.29	25.73	**24.82±0.32**
15	17.06	17.26	17.46	17.46	**17.31±0.09**
16	15.53	16.41	16.12	16.31	**16.09±0.20**
17	13.99	15.56	14.78	15.17	**14.87±0.33**
18	12.45	14.71	13.44	14.02	**13.66±0.48**
19	11.67	12.65	12.68	12.13	**12.28±0.24**
20	10.89	10.59	11.93	10.23	**10.91±0.37**
21	10.10	8.53	11.18	8.34	**9.54±0.68**

Table A27 Firmness of the peel for Kent mangoes stored in the R_C

Storage period (days)	Sample 1 Peel firmness (N)	Sample 2 Peel firmness (N)	Sample 3 Peel firmness (N)	Sample 4 Peel firmness (N)	Mean ± standard error
0	59.13	66.59	71.98	69.82	**66.88±2.81**
1	57.50	63.45	66.65	64.92	**66.13±1.99**
2	55.87	60.31	61.32	60.02	**59.38±1.20**
3	54.23	57.17	56.00	55.11	**55.63±0.63**
4	49.92	52.07	51.26	50.73	**50.99±0.45**
5	45.60	46.97	46.52	46.35	**46.36±0.29**
6	41.29	41.87	41.78	41.97	**41.73±0.15**
7	33.21	34.00	34.65	33.80	**33.91±0.30**
8	25.14	26.12	27.52	25.63	**26.10±0.51**
9	17.06	18.24	20.40	17.46	**18.29±0.74**
10	15.46	17.62	17.10	16.54	**16.68±0.46**
11	13.86	17.00	13.79	15.63	**15.07±0.77**
12	12.26	16.38	10.49	14.71	**13.46±1.30**
13	11.11	14.22	10.17	13.01	**12.13±0.91**
14	9.97	12.06	9.84	11.31	**10.80±0.54**
15	8.83	9.90	9.51	9.61	**9.46±0.23**

Table A28 Firmness of the flesh for Kent mangoes stored in the S_{NR}

Storage period (days)	Sample 1 Flesh firmness (N)	Sample 2 Flesh firmness (N)	Sample 3 Flesh firmness (N)	Sample 4 Flesh firmness (N)	Mean ± standard error
0	48.25	46.68	47.37	46.88	**47.29±0.35**
1	47.89	45.40	47.01	46.39	**46.67±0.52**
2	47.53	44.13	46.65	45.90	**46.05±0.72**
3	47.17	42.86	46.29	45.40	**45.43±0.93**
4	45.93	40.70	42.36	42.56	**42.89±1.10**
5	44.69	38.54	38.44	39.72	**40.35±1.48**
6	43.44	36.38	34.52	36.87	**37.80±1.95**
7	39.10	34.26	33.11	34.65	**35.28±1.31**
8	34.75	32.13	31.71	32.43	**32.75±0.68**
9	30.40	30.01	30.30	30.20	**30.23±0.08**
10	29.84	29.52	29.22	29.52	**29.53±0.13**
11	29.29	29.03	28.15	28.83	**28.82±0.24**
12	28.73	28.54	27.07	28.15	**28.12±0.37**
13	27.10	27.88	24.97	26.05	**26.50±0.63**
14	25.46	27.23	22.88	23.96	**24.88±0.94**
15	23.83	26.58	20.79	21.87	**23.27±1.27**
16	22.26	22.20	19.48	19.91	**20.96±0.74**
17	20.69	17.82	18.17	17.95	**18.66±0.68**
18	19.12	13.44	16.87	15.98	**16.35±1.18**
19	14.22	11.83	12.62	13.37	**13.01±0.51**
20	9.32	10.23	8.37	10.75	**9.67±0.53**
21	4.41	8.63	4.12	8.14	**6.33±1.19**
22	3.24	6.37	3.30	6.08	**4.75±0.86**
23	2.06	4.12	2.48	4.02	**3.17±0.53**
24	0.88	1.86	1.67	1.96	**1.59±0.24**

Table A29 Firmness of the flesh for Kent mangoes stored in the S_{NNR}

Storage period (days)	Sample 1 Flesh firmness (N)	Sample 2 Flesh firmness (N)	Sample 3 Flesh firmness (N)	Sample 4 Flesh firmness (N)	Mean ± standard error
0	46.68	48.25	47.37	46.88	**47.29±0.39**
1	44.00	45.57	44.85	44.16	**44.64±0.39**
2	41.32	42.89	42.33	41.45	**42.00±0.40**
3	38.64	40.21	39.81	38.74	**39.35±0.41**
4	36.45	36.84	36.48	35.96	**36.43±0.11**
5	34.26	33.47	33.15	33.18	**33.51±0.29**
6	32.07	30.11	29.81	30.40	**30.60±0.61**
7	30.47	29.13	28.64	29.71	**29.49±0.47**
8	28.86	28.15	27.46	29.03	**28.37±0.35**
9	27.26	27.16	26.28	28.34	**27.26±0.27**
10	25.73	25.76	25.24	26.67	**25.85±0.15**
11	24.19	24.35	24.19	25.01	**24.43±0.05**
12	22.65	22.95	23.14	23.34	**23.02±0.12**
13	22.29	22.72	22.78	22.88	**22.67±0.13**
14	21.93	22.49	22.42	22.42	**22.32±0.15**
15	21.57	22.26	22.06	21.97	**21.97±0.18**
16	17.82	17.95	18.04	17.91	**17.93±0.06**
17	14.06	13.63	14.02	13.86	**13.89±0.12**
18	10.30	9.32	10.00	9.81	**9.86±0.25**
19	7.35	6.70	7.16	7.09	**7.08±0.17**
20	4.41	4.09	4.31	4.38	**4.30±0.08**
21	1.46	1.45	1.47	1.67	**1.51±0.01**

Table A30 Firmness of the flesh for Kent mangoes stored in the R_C

Storage period (days)	Sample 1 Flesh firmness (N)	Sample 2 Flesh firmness (N)	Sample 3 Flesh firmness (N)	Sample 4 Flesh firmness (N)	Mean ± standard error
0	46.68	48.25	47.37	46.88	**47.29±0.35**
1	44.00	44.95	44.85	44.59	**44.60±0.21**
2	41.32	41.65	42.33	42.30	**41.90±0.25**
3	38.64	38.34	39.81	40.01	**39.20±0.42**
4	34.68	33.38	34.55	34.88	**34.37±0.34**
5	30.73	28.41	29.29	29.75	**29.54±0.48**
6	26.77	23.44	24.03	24.61	**24.71±0.73**
7	22.95	19.74	19.91	20.14	**20.68±0.76**
8	19.12	16.05	15.79	15.66	**16.65±0.83**
9	15.30	12.36	11.67	11.18	**12.63±0.92**
10	10.85	8.99	8.53	8.20	**9.14±0.59**
11	6.41	5.62	5.39	5.23	**5.66±0.26**
12	1.96	2.26	2.26	2.26	**2.18±0.07**
13	1.90	1.96	1.99	2.06	**1.98±0.03**
14	1.83	1.67	1.73	1.86	**1.77±0.05**
15	1.77	1.37	1.47	1.67	**1.57±0.09**

Table A31 TSS for Apple mangoes stored in the S_{NR}

Storage periods (days)	Sample 1 TSS (%)	Sample 2 TSS (%)	Sample 3 TSS (%)	Sample 4 TSS (%)	Mean ± standard error
0	7.1	6.5	6.9	6.7	**6.80±0.13**
1	8.2	7.7	7.9	7.8	**7.90±0.11**
2	9.3	8.9	8.9	8.9	**9.00±0.10**
3	10.4	10.1	9.9	10.0	**10.10±0.11**
4	11.1	10.9	10.8	10.8	**10.92±0.08**
5	11.9	11.7	11.7	11.7	**11.73±0.05**
6	12.6	12.5	12.6	12.5	**12.55±0.03**
7	12.7	12.7	12.8	12.7	**12.73±0.03**
8	12.9	13.0	13.0	12.8	**12.92±0.04**
9	13.0	13.2	13.2	13.0	**13.10±0.06**
10	14.1	14.2	14.2	14.1	**14.17±0.03**
11	15.3	15.2	15.3	15.2	**15.23±0.02**
12	16.4	16.2	16.3	16.3	**16.30±0.04**
13	16.7	16.6	16.7	16.6	**16.65±0.03**
14	17.1	16.9	17.0	17.0	**17.00±0.03**
15	17.4	17.3	17.4	17.3	**17.35±0.03**
16	18.0	17.9	17.9	17.9	**17.93±0.02**
17	18.6	18.5	18.5	18.5	**18.52±0.03**
18	19.2	19.1	19.0	19.1	**19.10±0.04**

Table A32 TSS for Apple mangoes stored in the S_{NNR}

Storage period (days)	Sample 1 TSS (%)	Sample 2 TSS (%)	Sample 3 TSS (%)	Sample 4 TSS (%)	Mean ± standard error
0	7.1	6.5	6.9	6.7	**6.80±0.13**
1	8.6	8.2	8.4	8.5	**8.42±0.09**
2	10.1	9.8	9.9	10.3	**10.03±0.11**
3	11.6	11.5	11.4	12.1	**11.65±0.16**
4	12.1	12.0	12.0	12.5	**12.15±0.11**
5	12.7	12.6	12.5	12.8	**12.65±0.07**
6	13.2	13.1	13.1	13.2	**13.15±0.03**
7	13.3	13.3	13.4	13.4	**13.35±0.02**
8	13.5	13.5	13.6	13.6	**13.55±0.04**
9	13.6	13.7	13.9	13.8	**13.75±0.06**
10	15.3	15.1	15.5	15.5	**15.33±0.11**
11	16.9	16.4	17.2	17.1	**16.92±0.17**
12	18.6	17.8	18.8	18.8	**18.50±0.24**
13	18.8	18.2	18.8	18.9	**18.69±0.16**
14	19.1	18.6	18.9	19.0	**18.88±0.10**
15	19.3	19.0	18.9	19.1	**19.08±0.09**

Table A33 TSS for Apple mangoes stored in the R_C

Storage period (days)	Sample 1 TSS (%)	Sample 2 TSS (%)	Sample 3 TSS (%)	Sample 4 TSS (%)	Mean ± standard error
0	7.1	6.5	6.9	6.7	**6.80±0.13**
1	10.4	9.9	10.3	10.0	**10.15±0.10**
2	13.6	13.4	13.6	13.4	**13.50±0.08**
3	16.9	16.8	17.0	16.7	**16.85±0.06**
4	17.2	17.1	17.3	17.0	**17.13±0.06**
5	17.5	17.3	17.5	17.3	**17.42±0.06**
6	17.8	17.6	17.8	17.6	**17.70±0.06**
7	18.2	18.1	18.3	18.0	**18.16±0.06**
8	18.7	18.6	18.7	18.5	**18.62±0.06**
9	19.1	19.1	19.2	18.9	**19.08±0.06**

Table A34 TSS for Kent mangoes stored in the S_{NR}

Storage period (days)	Sample 1 TSS (%)	Sample 2 TSS (%)	Sample 3 TSS (%)	Sample 4 TSS (%)	Mean ± standard error
0	5.7	5.1	5.5	5.3	**5.40±0.13**
1	6.5	5.4	5.6	5.6	**5.78±0.25**
2	7.3	5.6	5.7	6.0	**6.15±0.39**
3	8.1	5.9	5.8	6.3	**6.53±0.54**
4	8.4	6.9	6.8	7.1	**7.28±0.36**
5	8.6	7.8	7.9	7.8	**8.04±0.20**
6	8.9	8.8	8.9	8.6	**8.80±0.07**
7	9.6	9.6	9.7	9.4	**9.58±0.05**
8	10.4	10.4	10.4	10.3	**10.37±0.04**
9	11.1	11.2	11.2	11.1	**11.15±0.03**
10	11.2	11.3	11.2	11.2	**11.23±0.03**
11	11.2	11.4	11.3	11.3	**11.30±0.04**
12	11.3	11.5	11.3	11.4	**11.38±0.05**
13	11.6	11.7	11.6	11.6	**11.62±0.04**
14	11.8	12.0	11.8	11.8	**11.86±0.04**
15	12.1	12.2	12.1	12.0	**12.10±0.04**
16	12.6	12.7	12.6	12.6	**12.63±0.04**
17	13.2	13.3	13.1	13.1	**13.17±0.04**
18	13.7	13.8	13.6	13.7	**13.70±0.04**
19	13.8	13.9	13.8	13.8	**13.85±0.03**
20	13.9	14.1	14.1	14.0	**14.00±0.04**
21	14.0	14.2	14.3	14.1	**14.15±0.06**
22	14.5	14.6	14.5	13.8	**14.35±0.19**
23	15.1	15.0	14.6	13.5	**14.55±0.36**
24	15.6	15.4	14.8	13.2	**14.75±0.54**

Table A35 TSS for Kent mangoes stored in the S_{NNR}

Storage periods (days)	Sample 1 TSS (%)	Sample 2 TSS (%)	Sample 3 TSS (%)	Sample 4 TSS (%)	Mean ± standard error
0	5.7	5.1	5.5	5.3	**5.40±0.13**
1	6.1	5.4	6.3	5.9	**5.93±0.19**
2	6.6	5.8	7.1	6.4	**6.47±0.27**
3	7.0	6.1	7.9	7.0	**7.00±0.37**
4	7.8	7.2	8.4	7.8	**7.80±0.24**
5	8.7	8.3	8.8	8.6	**8.60±0.11**
6	9.5	9.4	9.3	9.4	**9.40±0.04**
7	10.3	10.2	10.2	10.1	**10.20±0.04**
8	11.1	10.9	11.1	10.9	**11.00±0.06**
9	11.9	11.7	12.0	11.6	**11.80±0.09**
10	11.8	11.7	12.0	11.7	**11.83±0.08**
11	11.8	11.8	12.1	11.8	**11.85±0.07**
12	11.7	11.8	12.1	11.9	**11.88±0.09**
13	11.9	12.0	12.1	12.0	**12.00±0.04**
14	12.2	12.1	12.1	12.1	**12.13±0.02**
15	12.4	12.3	12.1	12.2	**12.25±0.06**
16	12.9	12.8	12.7	12.7	**12.78±0.04**
17	13.4	13.3	13.4	13.2	**13.32±0.04**
18	13.9	13.8	14.0	13.7	**13.85±0.06**
19	13.6	14.2	14.5	14.3	**14.15±0.18**
20	13.4	14.5	14.9	15.0	**14.45±0.37**
21	13.1	14.9	15.4	15.6	**14.75±0.57**

Table A36 TSS for Kent mangoes stored in the R_C

Storage period (days)	Sample 1 TSS (%)	Sample 2 TSS (%)	Sample 3 TSS (%)	Sample 4 TSS (%)	Mean ± standard error
0	5.7	5.1	5.5	5.3	**5.40±0.13**
1	6.5	6.3	6.9	6.5	**6.58±0.12**
2	7.4	7.6	8.3	7.8	**7.75±0.20**
3	8.2	8.8	9.7	9.0	**8.93±0.31**
4	9.6	10.0	10.5	10.1	**10.04±0.20**
5	10.9	11.1	11.4	11.2	**11.16±0.09**
6	12.3	12.3	12.2	12.3	**12.28±0.03**
7	12.8	12.8	12.7	12.7	**12.77±0.03**
8	13.4	13.3	13.2	13.2	**13.26±0.05**
9	13.9	13.8	13.7	13.6	**13.75±0.06**
10	13.9	13.8	13.8	14.0	**13.87±0.05**
11	14.0	13.7	13.9	14.3	**13.98±0.13**
12	14.0	13.7	14.0	14.7	**14.10±0.21**
13	13.7	14.1	14.5	15.0	**14.32±0.28**
14	13.4	14.5	14.9	15.3	**14.53±0.41**
15	13.1	14.9	15.4	15.6	**14.75±0.57**

Table A37 TTA for Apple mangoes stored in the S_{NR}

Storage period (days)	Sample 1 TTA (%)	Sample 2 TTA (%)	Sample 3 TTA (%)	Mean ± standard error
0	1.79	1.54	1.66	**1.66±0.07**
1	1.62	1.41	1.49	**1.51±0.06**
2	1.45	1.28	1.32	**1.35±0.05**
3	1.28	1.15	1.15	**1.19±0.04**
4	1.24	1.11	1.11	**1.15±0.04**
5	1.19	1.07	1.07	**1.11±0.04**
6	1.15	1.02	1.02	**1.07±0.04**
7	1.07	0.94	0.90	**0.97±0.05**
8	0.98	0.85	0.77	**0.87±0.06**
9	0.90	0.77	0.64	**0.77±0.07**
10	0.73	0.64	0.51	**0.63±0.06**
11	0.55	0.51	0.38	**0.48±0.05**
12	0.38	0.38	0.26	**0.34±0.04**
13	0.34	0.30	0.26	**0.30±0.02**
14	0.30	0.21	0.26	**0.26±0.02**
15	0.26	0.13	0.26	**0.21±0.04**
16	0.26	0.13	0.21	**0.20±0.04**
17	0.26	0.13	0.17	**0.18±0.04**
18	0.26	0.13	0.13	**0.17±0.04**

Table A38 TTA for Apple mangoes stored in the S_{NNR}

Storage period (days)	Sample 1 TTA (%)	Sample 2 TTA (%)	Sample 3 TTA (%)	Mean ± standard error
0	1.79	1.54	1.66	**1.66±0.07**
1	1.54	1.28	1.41	**1.41±0.07**
2	1.28	1.02	1.15	**1.15±0.07**
3	1.02	0.77	0.9	**0.90±0.04**
4	0.77	0.64	0.73	**0.71±0.04**
5	0.51	0.51	0.55	**0.53±0.01**
6	0.26	0.38	0.38	**0.34±0.04**
7	0.26	0.34	0.38	**0.33±0.04**
8	0.26	0.3	0.38	**0.31±0.04**
9	0.26	0.26	0.38	**0.30±0.04**
10	0.21	0.26	0.34	**0.27±0.04**
11	0.17	0.26	0.3	**0.24±0.04**
12	0.13	0.26	0.26	**0.21±0.04**
13	0.13	0.21	0.26	**0.20±0.04**
14	0.13	0.17	0.26	**0.18±0.04**
15	0.13	0.13	0.26	**0.17±0.04**

Table A39 TTA for Apple mangoes stored in the R_C

Storage period (days)	Sample 1 TTA (%)	Sample 2 TTA (%)	Sample 3 TTA (%)	Mean ± standard error
0	1.79	1.54	1.66	**1.66±0.07**
1	1.28	1.11	1.24	**1.21±0.05**
2	0.77	0.68	0.81	**0.75±0.04**
3	0.26	0.26	0.38	**0.30±0.04**
4	0.21	0.26	0.34	**0.27±0.04**
5	0.17	0.26	0.3	**0.24±0.04**
6	0.13	0.26	0.26	**0.21±0.04**
7	0.17	0.21	0.21	**0.20±0.01**
8	0.21	0.17	0.17	**0.18±0.01**
9	0.26	0.13	0.13	**0.17±0.04**

Table A40 TTA for Kent mangoes stored in the S_{NR}

Storage period (days)	Sample 1 TTA (%)	Sample 2 TTA (%)	Sample 3 TTA (%)	Mean ± standard error
0	1.29	1.27	1.28	**1.28±0.01**
1	1.28	1.24	1.28	**1.27±0.01**
2	1.28	1.19	1.28	**1.25±0.03**
3	1.28	1.15	1.28	**1.24±0.04**
4	1.19	1.07	1.15	**1.14±0.04**
5	1.11	0.98	1.02	**1.04±0.04**
6	1.02	0.9	0.9	**0.94±0.04**
7	0.98	0.85	0.85	**0.90±0.04**
8	0.94	0.81	0.81	**0.85±0.04**
9	0.9	0.77	0.77	**0.81±0.04**
10	0.85	0.73	0.73	**0.77±0.04**
11	0.81	0.68	0.68	**0.73±0.04**
12	0.77	0.64	0.64	**0.68±0.04**
13	0.68	0.6	0.64	**0.64±0.02**
14	0.6	0.55	0.64	**0.60±0.02**
15	0.51	0.51	0.64	**0.55±0.04**
16	0.51	0.47	0.55	**0.51±0.02**
17	0.51	0.43	0.47	**0.47±0.02**
18	0.51	0.38	0.38	**0.43±0.04**
19	0.43	0.34	0.38	**0.38±0.02**
20	0.34	0.3	0.38	**0.34±0.02**
21	0.26	0.26	0.38	**0.30±0.04**
22	0.26	0.21	0.3	**0.26±0.02**
23	0.26	0.17	0.21	**0.21±0.02**
24	0.26	0.13	0.13	**0.17±0.04**

Table A41 TTA for Kent mangoes stored in the S_{NNR}

Storage period (days)	Sample 1 TTA (%)	Sample 2 TTA (%)	Sample 3 TTA (%)	Mean ± standard error
0	1.28	1.28	1.28	**1.28±0.01**
1	1.28	1.24	1.24	**1.25±0.02**
2	1.28	1.19	1.19	**1.22±0.04**
3	1.28	1.15	1.15	**1.19±0.06**
4	1.15	1.02	1.07	**1.08±0.05**
5	1.02	0.90	0.98	**0.97±0.04**
6	0.90	0.77	0.90	**0.85±0.04**
7	0.77	0.77	0.77	**0.77±0.04**
8	0.64	0.77	0.64	**0.68±0.07**
9	0.51	0.77	0.51	**0.60±0.09**
10	0.51	0.64	0.47	**0.54±0.06**
11	0.51	0.51	0.43	**0.48±0.04**
12	0.51	0.38	0.38	**0.43±0.05**
13	0.47	0.34	0.34	**0.38±0.05**
14	0.43	0.30	0.30	**0.34±0.05**
15	0.38	0.26	0.26	**0.30±0.04**
16	0.30	0.26	0.26	**0.27±0.01**
17	0.21	0.26	0.26	**0.24±0.01**
18	0.13	0.26	0.26	**0.21±0.04**
19	0.13	0.21	0.26	**0.20±0.04**
20	0.13	0.17	0.26	**0.18±0.04**
21	0.13	0.13	0.26	**0.17±0.04**

Table A42 TTA for Kent mangoes stored in the R_C

Storage period (days)	Sample 1 TTA (%)	Sample 2 TTA (%)	Sample 3 TTA (%)	Mean ± standard error
0	1.27	1.29	1.28	**1.28±0.01**
1	1.19	1.19	1.15	**1.18±0.01**
2	1.11	1.11	1.02	**1.08±0.03**
3	1.02	1.02	0.90	**1.98±0.04**
4	0.98	1.02	0.90	**0.97±0.04**
5	0.94	1.02	0.90	**0.95±0.04**
6	0.90	1.02	0.90	**0.94±0.04**
7	0.77	0.85	0.73	**0.78±0.04**
8	0.64	0.68	0.55	**0.63±0.04**
9	0.51	0.51	0.38	**0.47±0.04**
10	0.47	0.47	0.34	**0.43±0.04**
11	0.43	0.43	0.30	**0.38±0.04**
12	0.38	0.38	0.26	**0.34±0.04**
13	0.30	0.34	0.21	**0.28±0.04**
14	0.21	0.30	0.17	**0.23±0.04**
15	0.13	0.26	0.13	**0.17±0.04**

Table A43 pH values for Apple mangoes stored in the S_{NR}

Storage period (days)	Sample 1 pH_1	Sample 2 pH_2	Sample 3 pH_3	Mean ± standard error
0	3.60	3.50	3.70	**3.60±0.06**
1	3.61	3.55	3.68	**3.61±0.04**
2	3.63	3.6	3.65	**3.63±0.02**
3	3.64	3.65	3.63	**3.64±0.01**
4	3.94	3.94	3.93	**3.94±0.01**
5	4.24	4.24	4.22	**4.23±0.01**
6	4.54	4.53	4.52	**4.53±0.01**
7	4.57	4.56	4.55	**4.56±0.01**
8	4.60	4.59	4.58	**4.59±0.01**
9	4.63	4.62	4.61	**4.62±0.01**
10	4.65	4.64	4.63	**4.64±0.01**
11	4.67	4.66	4.65	**4.66±0.01**
12	4.69	4.68	4.67	**4.68±0.01**
13	4.84	4.83	4.82	**4.83±0.01**
14	4.99	4.97	4.98	**4.98±0.01**
15	5.14	5.12	5.13	**5.13±0.01**
16	5.19	5.17	5.17	**5.18±0.01**
17	5.23	5.22	5.22	**5.22±0.01**
18	5.28	5.27	5.26	**5.27±0.01**

Table A44 pH values for Apple mangoes stored in the S_{NNR}

Storage period (days)	Sample 1 pH$_1$	Sample 2 pH$_2$	Sample 3 pH$_3$	Mean ± standard error
0	3.6	3.61	3.59	**3.60±0.01**
1	3.62	3.63	3.61	**3.62±0.01**
2	3.65	3.66	3.64	**3.65±0.01**
3	3.67	3.68	3.66	**3.67±0.01**
4	3.96	3.97	3.96	**3.96±0.00**
5	4.26	4.25	4.26	**4.26±0.00**
6	4.55	4.54	4.56	**4.55±0.01**
7	4.62	4.61	4.62	**4.62±0.00**
8	4.69	4.68	4.68	**4.68±0.00**
9	4.76	4.75	4.74	**4.75±0.01**
10	4.88	4.87	4.86	**4.87±0.01**
11	5.01	5	4.99	**5.00±0.01**
12	5.13	5.12	5.11	**5.12±0.01**
13	5.18	5.17	5.16	**5.17±0.01**
14	5.23	5.22	5.21	**5.22±0.01**
15	5.28	5.27	5.26	**5.27±0.01**

Table A45 pH values for Apple mangoes stored in the R_C

Storage period (days)	Sample 1 pH$_1$	Sample 2 pH$_2$	Sample 3 pH$_3$	Mean ± standard error
0	3.61	3.6	3.59	**3.60±0.01**
1	3.93	3.92	3.91	**3.92±0.01**
2	4.25	4.24	4.23	**4.24±0.01**
3	4.5	4.49	4.48	**4.49±0.01**
4	4.75	4.74	4.73	**4.74±0.01**
5	4.79	4.78	4.77	**4.78±0.01**
6	4.83	4.82	4.81	**4.82±0.01**
7	4.98	4.97	4.96	**4.97±0.00**
8	5.13	5.12	5.11	**5.12±0.00**
9	5.28	5.27	5.26	**5.27±0.01**

Table A46 pH values for Kent mangoes stored in the S_{NR}

Storage period (days)	Sample 1 pH_1	Sample 2 pH_2	Sample 3 pH_3	Mean ± standard error
0	3.23	3.22	3.21	**3.22±0.01**
1	3.26	3.25	3.24	**3.25±0.01**
2	3.3	3.29	3.28	**3.29±0.01**
3	3.33	3.32	3.31	**3.32±0.01**
4	3.37	3.36	3.35	**3.36±0.01**
5	3.42	3.41	3.4	**4.41±0.01**
6	3.46	3.45	3.44	**4.45±0.01**
7	3.49	3.48	3.47	**4.48±0.01**
8	3.51	3.50	3.49	**4.50±0.01**
9	3.54	3.53	3.52	**4.53±0.01**
10	3.87	3.86	3.85	**4.86±0.01**
11	4.19	4.2	4.18	**4.19±0.01**
12	4.52	4.53	4.51	**4.52±0.01**
13	4.53	4.54	4.52	**4.53±0.01**
14	4.55	4.54	4.52	**4.54±0.01**
15	4.56	4.55	4.53	**4.55±0.01**
16	4.69	4.68	4.66	**4.68±0.01**
17	4.83	4.82	4.8	**4.81±0.01**
18	4.96	4.95	4.93	**4.95±0.01**
19	5.01	5.00	4.98	**5.00±0.01**
20	5.05	5.06	5.04	**5.05±0.01**
21	5.1	5.11	5.09	**5.10±0.01**
22	5.15	5.15	5.13	**5.14±0.01**
23	5.19	5.18	5.17	**5.18±0.01**
24	5.24	5.22	5.21	**5.22±0.01**

Table A47 pH values for Kent mangoes stored in the S_{NNR}

Storage period (days)	Sample 1 pH_1	Sample 2 pH_2	Sample 3 pH_3	Mean ± standard error
0	3.21	3.22	3.23	**3.22±0.01**
1	3.26	3.26	3.28	**3.27±0.01**
2	3.31	3.31	3.32	**3.31±0.01**
3	3.36	3.35	3.37	**3.36±0.01**
4	3.40	3.39	3.40	**3.40±0.01**
5	3.45	3.44	3.44	**3.44±0.01**
6	3.49	3.48	3.47	**3.48±0.01**
7	3.51	3.50	3.49	**3.50±0.01**
8	3.54	3.53	3.52	**3.53±0.01**
9	3.56	3.55	3.54	**3.55±0.01**
10	3.90	3.89	3.88	**3.89±0.01**
11	4.24	4.23	4.22	**4.23±0.01**
12	4.58	4.57	4.56	**4.57±0.01**
13	4.70	4.69	4.68	**4.69±0.01**
14	4.83	4.82	4.81	**4.82±0.01**
15	4.95	4.94	4.93	**4.94±0.01**
16	5.00	4.99	4.98	**4.99±0.01**
17	5.06	5.05	5.04	**5.05±0.01**
18	5.11	5.10	5.09	**5.10±0.01**
19	5.15	5.14	5.13	**5.14±0.01**
20	5.19	5.18	5.17	**5.18±0.01**
21	5.23	5.22	5.21	**5.22±0.01**

Table A48 pH values for Kent mangoes stored in the R_C

Storage period (days)	Sample 1 pH_1	Sample 2 pH_2	Sample 3 pH_3	Mean ± standard error
0	3.23	3.22	3.21	**3.22±0.01**
1	3.31	3.30	3.29	**3.30±0.01**
2	3.38	3.37	3.36	**3.37±0.01**
3	3.46	3.45	3.44	**3.45±0.01**
4	3.49	3.48	3.47	**3.48±0.01**
5	3.51	3.50	3.49	**3.50±0.01**
6	3.54	3.53	3.52	**3.53±0.01**
7	3.73	3.72	3.71	**3.72±0.01**
8	3.91	3.90	3.89	**3.90±0.01**
9	4.10	4.09	4.08	**4.09±0.01**
10	4.43	4.43	4.42	**4.43±0.01**
11	4.77	4.77	4.75	**4.76±0.01**
12	5.10	5.11	5.09	**5.10±0.01**
13	5.14	5.15	5.13	**5.14±0.01**
14	5.19	5.18	5.17	**5.18±0.01**
15	5.23	5.22	5.21	**5.22±0.01**

Table A49 Variation of actual saturation efficiency with inlet air velocity

Time of day	V_a=3.0m/s	V_a=3.2m/s	V_a=3.4m/s	V_a=3.6m/s	V_a=3.8m/s	V_a=4.0m/s
8:00 a.m.	69.0	68.5	68.1	67.7	67.3	66.9
9:00 a.m.	69.1	68.4	68.1	67.7	67.4	66.8
10:00 a.m.	69.1	68.4	68.1	67.7	67.3	67.0
11:00 a.m.	68.9	68.5	68.0	67.5	67.2	67.0
12:00 p.m.	68.9	68.5	68.0	67.7	67.2	66.9
1:00 p.m.	69.0	68.5	68.1	67.6	67.2	66.9
2:00 p.m.	69.0	68.4	68.1	67.7	67.2	66.8
3:00 p.m.	68.9	68.5	68.0	67.7	67.2	66.8
4:00 p.m.	69.0	68.5	67.9	67.4	67.2	66.8
5:00 p.m.	68.8	68.5	67.9	67.5	67.0	66.8
6:00 p.m.	68.8	68.3	67.9	67.5	67.1	66.7
Mean (%)	**68.9**	**68.5**	**68.0**	**67.6**	**67.2**	**66.9**

Table A50 Variation in predicted saturation efficiency with inlet air velocity

Time of day	V_a=3.0m/s	V_a=3.2m/s	V_a=3.4m/s	V_a=3.6m/s	V_a=3.8m/s	V_a=4.0m/s
8:00 a.m.	69.0	68.5	68.2	67.7	67.3	66.9
9:00 a.m.	69.1	68.4	68.2	67.8	67.3	66.8
10:00 a.m.	69.1	68.5	68.1	67.7	67.4	67.0
11:00 a.m.	69.0	68.6	68.0	67.6	67.2	67.0
12:00 p.m.	68.9	68.6	68.0	67.6	67.2	66.9
1:00 p.m.	68.9	68.5	68.1	67.6	67.3	66.8
2:00 p.m.	69.0	68.5	68.0	67.6	67.2	66.8
3:00 p.m.	69.0	68.5	68.0	67.7	67.2	66.7
4:00 p.m.	69.0	68.5	67.9	67.5	67.2	66.9
5:00 p.m.	68.8	68.5	68.0	67.6	67.1	66.9
6:00 p.m.	68.9	68.4	68.0	67.6	67.2	66.9
Mean (%)	**69.0**	**68.5**	**68.1**	**67.6**	**67.2**	**66.9**

Table A51 Variation in inlet air velocity with actual cooling capacity

Time of day	V_a=3.0m/s	V_a=3.2m/s	V_a=3.4m/s	V_a=3.6m/s	V_a=3.8m/s	V_a=4.0m/s
8:00 a.m.	67.94	71.96	75.94	79.85	83.99	87.48
9:00 a.m.	46.91	49.53	52.39	55.16	57.96	60.39
10:00 a.m.	64.66	68.24	72.24	75.65	79.82	83.43
11:00 a.m.	93.15	98.62	104.25	109.55	115.03	120.47
12:00 p.m.	116.26	123.52	130.19	137.06	143.71	150.33
1:00 p.m.	135.78	143.95	151.88	159.70	167.65	175.58
2:00 p.m.	133.21	141.21	148.97	156.84	164.43	171.84
3:00 p.m.	148.42	157.15	165.91	174.83	183.36	191.76
4:00 p.m.	130.64	138.21	145.53	153.23	161.18	168.42
5:00 p.m.	124.11	131.99	138.92	146.25	153.19	160.81
6:00 p.m.	101.25	107.04	113.25	119.07	125.07	130.75
Mean (mJ/h)	**105.67**	**111.95**	**118.13**	**124.29**	**130.49**	**136.48**

Table A52 Variation in inlet air velocity with predicted cooling capacity

Time of day	V_a=3.0m/s	V_a=3.2m/s	V_a=3.4m/s	V_a=3.6m/s	V_a=3.8m/s	V_a=4.0m/s
8:00 a.m.	67.95	71.56	75.94	79.95	83.99	87.68
9:00 a.m.	46.92	49.13	52.59	55.16	57.96	60.98
10:00 a.m.	64.75	68.14	72.34	75.95	79.92	83.72
11:00 a.m.	93.27	98.22	104.35	109.55	115.03	120.56
12:00 p.m.	116.27	123.42	130.19	137.46	143.91	150.62
1:00 p.m.	135.68	140.45	151.98	159.70	167.65	175.83
2:00 p.m.	133.29	141.11	148.97	156.74	164.73	171.80
3:00 p.m.	148.52	150.25	165.91	174.83	183.36	191.66
4:00 p.m.	130.74	138.01	145.83	153.61	161.28	168.91
5:00 p.m.	124.31	131.49	138.92	146.74	153.29	160.81
6:00 p.m.	101.35	107.04	113.65	119.07	125.07	130.92
Mean (mJ/h)	**105.73**	**110.80**	**118.24**	**124.43**	**130.56**	**136.68**

Table A53 Variation in inlet air velocity with Reynolds number

Time of day	V_a=3.0m/s	V_a=3.2m/s	V_a=3.4m/s	V_a=3.6m/s	V_a=3.8m/s	V_a=4.0m/s
8:00 a.m.	373	398	423	447	472	497
9:00 a.m.	373	398	423	447	472	497
10:00 a.m.	373	398	423	447	472	497
11:00 a.m.	373	398	423	447	472	497
12:00 p.m.	373	398	423	447	472	497
1:00 p.m.	373	398	423	447	472	497
2:00 p.m.	373	398	423	447	472	497
3:00 p.m.	373	398	423	447	472	497
4:00 p.m.	373	398	423	447	472	497
5:00 p.m.	373	398	423	447	472	497
6:00 p.m.	373	398	423	447	472	497
Mean	**373**	**398**	**423**	**447**	**472**	**497**

Table A54 Variation in inlet air velocity with Nusselt number

Time of day	V_a=3.0m/s	V_a=3.2m/s	V_a=3.4m/s	V_a=3.6m/s	V_a=3.8m/s	V_a=4.0m/s
8:00 a.m.	6.4	6.7	7.0	7.4	7.7	8.0
9:00 a.m.	6.4	6.7	7.0	7.4	7.7	8.0
10:00 a.m.	6.4	6.7	7.0	7.4	7.7	8.0
11:00 a.m.	6.4	6.7	7.0	7.4	7.7	8.0
12:00 p.m.	6.4	6.7	7.0	7.4	7.7	8.0
1:00 p.m.	6.4	6.7	7.0	7.4	7.7	8.0
2:00 p.m.	6.4	6.7	7.0	7.4	7.7	8.0
3:00 p.m.	6.4	6.7	7.0	7.4	7.7	8.0
4:00 p.m.	6.4	6.7	7.0	7.4	7.7	8.0
5:00 p.m.	6.4	6.7	7.0	7.4	7.7	8.0
6:00 p.m.	6.4	6.7	7.0	7.4	7.7	8.0
Mean	**6.4**	**6.7**	**7.0**	**7.4**	**7.7**	**8.0**

Table A55 Variation in inlet air velocity with specific heat of humid air

Time of day	Va=3.0m/s	Va=3.2m/s	Va=3.4m/s	Va=3.6m/s	Va=3.8m/s	Va=4.0m/s
8:00 a.m.	1031	1032	1028	1028	1030	1031
9:00 a.m.	1028	1033	1028	1028	1028	1032
10:00 a.m.	1028	1032	1030	1030	1028	1028
11:00 a.m.	1030	1028	1033	1033	1033	1028
12:00 p.m.	1033	1030	1032	1032	1032	1030
1:00 p.m.	1032	1033	1031	1032	1031	1033
2:00 p.m.	1032	1032	1032	1032	1032	1033
3:00 p.m.	1032	1031	1032	1031	1032	1035
4:00 p.m.	1032	1031	1035	1035	1032	1032
5:00 p.m.	1035	1031	1033	1033	1035	1032
6:00 p.m.	1033	1035	1032	1032	1033	1032
Mean (J/kgK)	**1031**	**1031**	**1031**	**1031**	**1031**	**1031**

Table A56 Variation in inlet air velocity with convective heat transfer coefficient

Time of day	V_a=3.0m/s	V_a=3.2m/s	V_a=3.4m/s	V_a=3.6m/s	V_a=3.8m/s	V_a=4.0m/s
8:00 a.m.	84.3	88.8	93.2	97.5	101.8	106.1
9:00 a.m.	84.3	88.8	93.2	97.5	101.8	106.1
10:00 a.m.	84.3	88.8	93.2	97.5	101.8	106.1
11:00 a.m.	84.3	88.8	93.2	97.5	101.8	106.1
12:00 p.m.	84.3	88.8	93.2	97.5	101.8	106.1
1:00 p.m.	84.3	88.8	93.2	97.5	101.8	106.1
2:00 p.m.	84.3	88.8	93.2	97.5	101.8	106.1
3:00 p.m.	84.3	88.8	93.2	97.5	101.8	106.1
4:00 p.m.	84.3	88.8	93.2	97.5	101.8	106.1
5:00 p.m.	84.3	88.8	93.2	97.5	101.8	106.1
6:00 p.m.	84.3	88.8	93.2	97.5	101.8	106.1
Mean (W/m^2K)	**84.3**	**88.8**	**93.2**	**97.5**	**101.8**	**106.1**

Table A57 Variation in inlet air velocity with mass flow rate

Time of day	V_a=3.0m/s	V_a=3.2m/s	V_a=3.4m/s	V_a=3.6m/s	V_a=3.8m/s	V_a=4.0m/s
8:00 a.m.	6.5	6.9	7.3	7.7	8.2	8.6
9:00 a.m.	6.5	6.9	7.3	7.7	8.2	8.6
10:00 a.m.	6.5	6.9	7.3	7.7	8.2	8.6
11:00 a.m.	6.5	6.9	7.3	7.7	8.2	8.6
12:00 p.m.	6.5	6.9	7.3	7.7	8.2	8.6
1:00 p.m.	6.5	6.9	7.3	7.7	8.2	8.6
2:00 p.m.	6.5	6.9	7.3	7.7	8.2	8.6
3:00 p.m.	6.5	6.9	7.3	7.7	8.2	8.6
4:00 p.m.	6.5	6.9	7.3	7.7	8.2	8.6
5:00 p.m.	6.5	6.9	7.3	7.7	8.2	8.6
6:00 p.m.	6.5	6.9	7.3	7.7	8.2	8.6
Mean (kg/s)	**6.5**	**6.9**	**7.3**	**7.7**	**8.2**	**8.6**

APPENDIX B: LIST OF FIGURES

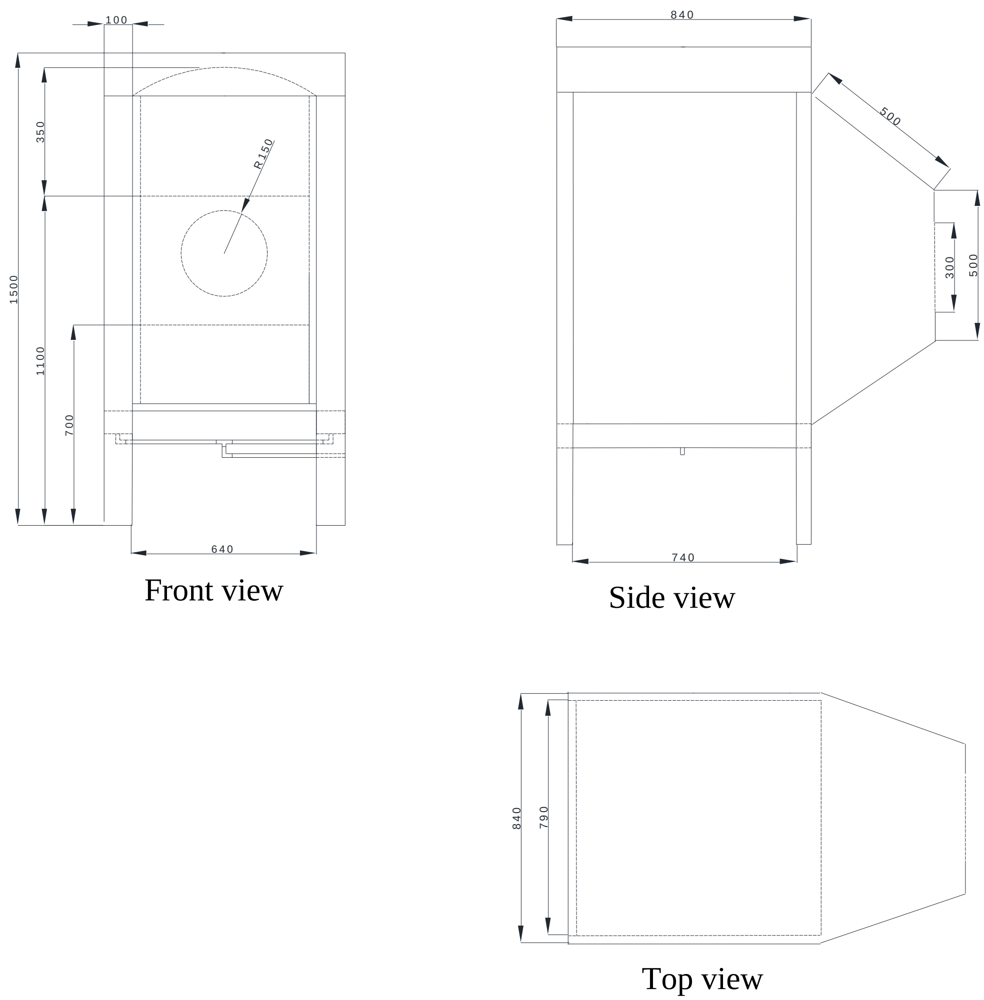

Figure B1 A front, side and top view for both the S_{NR} and S_{NNR}. All dimensions in mm.

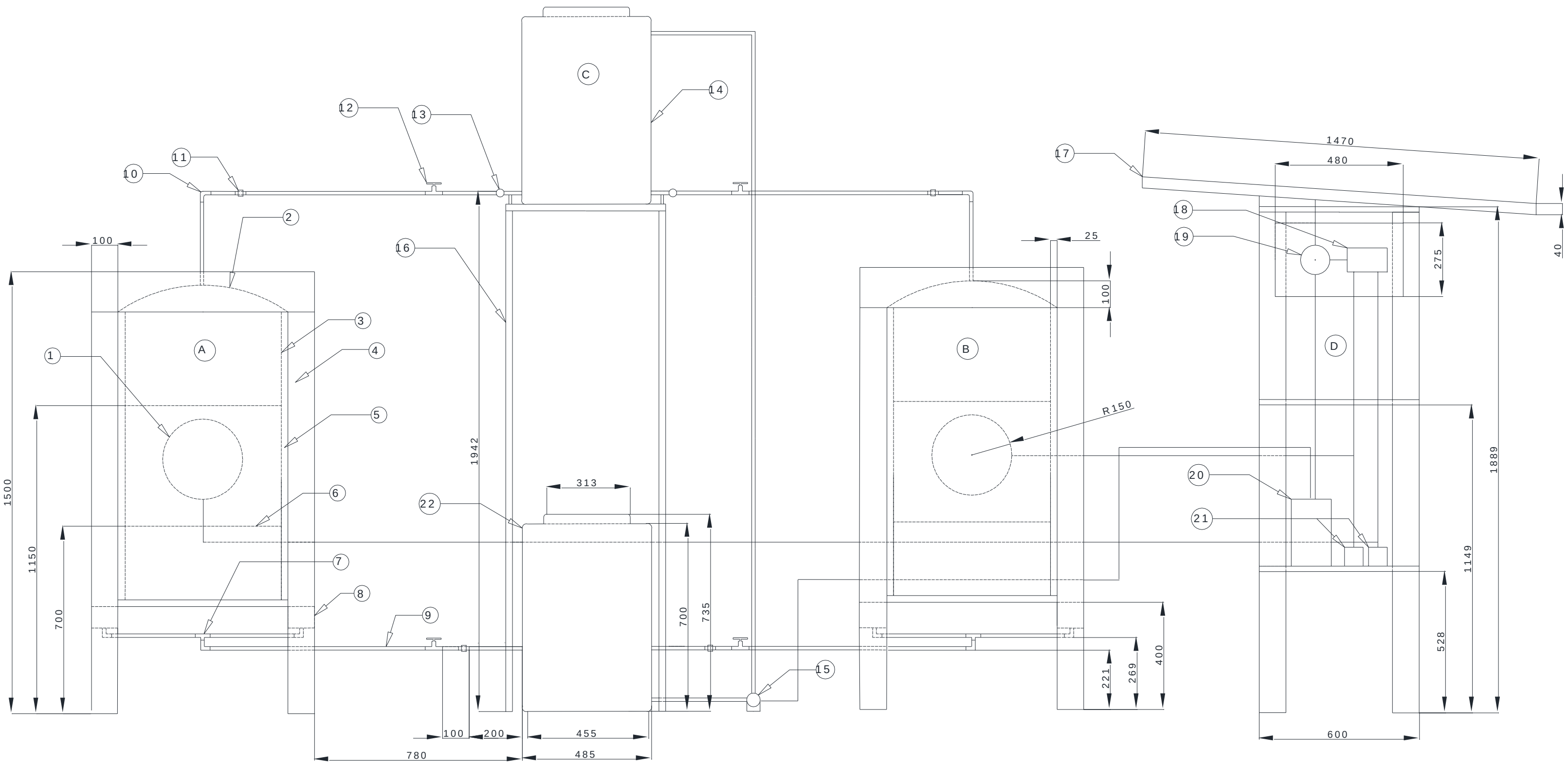

Figure B2 Schematic S_{NR} (A), S_{NNR} (B), water distribution system (C) and solar PV system (D). All dimensions in mm.

In this figure, 1 is a 12 V fan; 2 is an aluminium roof; 3 is an aluminium sheet lining; 4 is a wooden post 5 is 25 mm inlet air channel; 6 is a coffee tray mesh shelf; 7 is a12.7 mm PPR tee; 8 is a gutter; 9 is a 12.7 mm PPR pipe; 10 is a 12.7 mm PPR elbow; 11 is a 12.7 mm PPR union; 12 is a 12.7 mm PPR gate valve; 13 is a 12.7 mm water flow meter; 14 is an overhead tank; 15 is a 12 V pump; 16 is an overhead tank stand; 17 is a solar panel; 18 is a double switch; 19 is a battery charge controller; 20 is a battery; 21 is a slide rheostat; 22 is a water reservoir.

Figure B3 A photograph of the developed S_{NR} (A) and S_{NNR} (B)

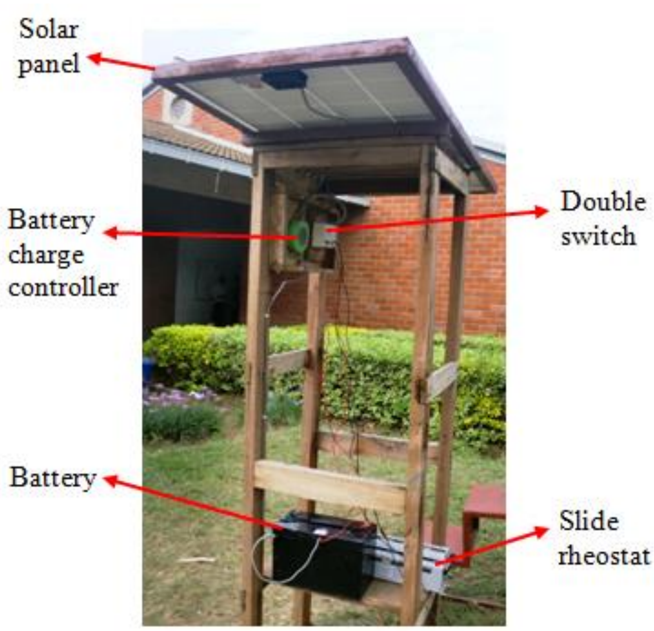

Figure B4 A photograph of the solar PV system for both the S_{NR} and S_{NNR}

Figure B5 A photograph of the water distribution system for both the S_{NR} and S_{NNR}

Figure B6 A photograph of Apple mangoes taken before storage (A_1) and after storage in the S_{NR} (A_N), S_{NNR} (A_w), and R_C (A_R).

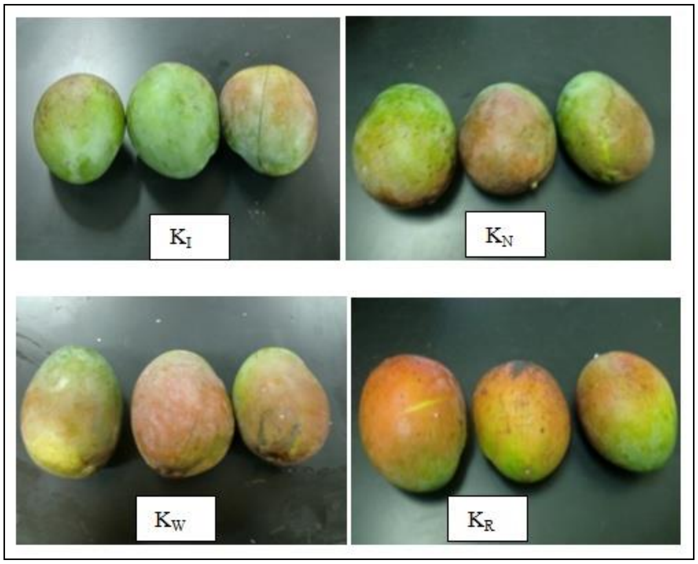

Figure B7 A photograph of Kent mangoes taken before storage (K_1) and after storage in the S_{NR} (K_N), S_{NNR} (K_w), and R_C (K_R).

APPENDIX C: CODE FOR THE SIMULATION MODEL

The Main Java

```
/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */
package Korir;
import javax.swing.*;
/**
 *
 * @author Korir
 */
public class Main extends JFrame
{
public Main()
    {
this.setTitle("Computer model for predicting performance of a charcool cooler");
this.setSize(900,900);
this.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
this.add(new home());
this.setVisible(true);
    }
public static void main(String args[])
    {
Main app =new Main();
    }
}
```

The Home Java

```
/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */
package Korir;
import javax.swing.*;
import java.awt.*;
import static java.lang.Math.exp;
/**
 *
 * @author Korir
 */
public class home extends javax.swing.JPanel {
    /**
     * Creates new form home
     */
Double Qc=0.0;
Double t2=0.0;
Double n=0.0;
Double ma=0.0;
Double As=0.0;
Double theta=0.0;
Double Aw=0.0;
Double lc=0.0;
Double Re=0.0;
Double cpu=0.0;
Double Nu=0.0;
Double hc=0.0;
```

```
Double t1=0.0;
Double twb=0.0;
Double w=0.0;
Double v1=0.0;
Double tw=0.0;
Double mw=0.0;
Double L=0.0;
Double H=0.0;
Double I=0.0;
Double Av=0.0;
Double cpa=1006.0;
Double cpv=1033.0;
Double Pr=0.7135;
Double v=0.00001609;
Double ka=0.02644;
Double p=1.164;
public home() {
initComponents();
this.setVisible(true);
    }
void readFile()
{
t1=Double.parseDouble(txtt1.getText());
twb=Double.parseDouble(txttwb.getText());
w=Double.parseDouble(txtw.getText());
v1=Double.parseDouble(txtv1.getText());
tw=Double.parseDouble(txttw.getText());
mw=Double.parseDouble(txtmw.getText());
L=Double.parseDouble(txtL.getText());
```

```
H=Double.parseDouble(txtH.getText());
I=Double.parseDouble(txtI.getText());
Av=Double.parseDouble(txtAv.getText());
cpa=Double.parseDouble(txtcpa.getText());
cpv=Double.parseDouble(txtcpv.getText());
Pr=Double.parseDouble(txtPr.getText());
v=Double.parseDouble(txtv.getText());
ka=Double.parseDouble(txtka.getText());
p=Double.parseDouble(txtp.getText());
calcValues();
}
Double getValue1(double L,double I,double H)
{
return 2*(L*I*H);
}
Double getValue2(double theta,double Av)
{
return theta*Av;
}
Double getValue3(double theta,double Aw)
{
return theta/Aw;
}
Double getValue4(double lc,double v1,double v)
{
return (lc*v1)/v;
}
Double getValue5(double lc,double I,double Re,double Pr)
{
```

```
double x=Math.pow(Pr,(1.0/3.0));
double y=Math.pow(Re,0.8);
double z=0.1*(Math.pow((lc/I),0.12));
return z*y*x;
}
Double getValue6(double cpa,double wc,double cpv)
{
return cpa+(w*cpv);
}
Double getValue7(double Nu,double ka,double lc)
{
return Nu*ka/lc;
}
Double getValue8(double L,double H)
{
return 2*(L*H);
}
Double getValue9(double p,double As,double v1)
{
return p*As*v1;
}
Double getValue10(double hc,double Aw,double ma,double cpu)
{
return 1-exp((-hc*Aw)/(ma*cpu));
}
Double getValue11(double t1,double n,double twb)
{
return t1-n*(t1-twb);
}
Double getValue12(double ma,double cpa,double t1,double t2)
{
return ma*cpa*(t1-t2);
}
void calcValues()
{
theta=getValue1(L,I,H);
```

```
Aw=getValue2(theta,Av);
lc=getValue3(theta,Aw);
Re=getValue4(lc,v1,v);
Nu=getValue5(lc,I,Re,Pr);
cpu=getValue6(cpa,w,cpv);
hc=getValue7(Nu,ka,lc);
As=getValue8(L,H);
ma=getValue9(p,As,v1);
n=getValue10(hc,Aw,ma,cpu);
t2=getValue11(t1,n,twb);
Qc=getValue12(ma,cpa,t1,t2);
txttheta.setText(getValue1(L,I,H).toString());
txtAw.setText(getValue2(theta,Av).toString());
txtlc.setText(getValue3(theta,Aw).toString());
//Re=);
txtRe.setText(getValue4(lc,v1,v).toString());
txtNu.setText(getValue5(lc,I,Re,Pr).toString());
//Nu=6.19;
txtcpu.setText(getValue6(cpa,w,cpv).toString());
txthc.setText(getValue7(Nu,ka,lc).toString());
txtAs.setText(getValue8(L,H).toString());
txtma.setText(getValue9(p,As,v1).toString());
txtn.setText(getValue10(hc,Aw,ma,cpu).toString());
txtt2.setText(getValue11(t1,n,twb).toString());
txtQc.setText(getValue12(ma,cpa,t1,t2).toString());
}
```

PUBLICATIONS

JOURNALS

Korir, M.K., Mutwiwa, U., Kituu, G.M., and Sila, D.N. (2014). Simulation of saturation efficiency and cooling capacity of an unloaded near infrared reflecting charcoal cooler for on-farm storage of mango fruits. *Journal of Sustainable Research in Engineering 1* (2), 34-39.

Korir, M.K., Mutwiwa, U., Kituu, G.M., and Sila, D.N. (2014). Assessment of postharvest challenges facing mangoes at Upper Athi River Basin, Kenya. *8th JKUAT Scientific and Technological Conference* (pp.668-675). Retrieved from http://elearning.jkuat.ac.ke/journals/ojs/index.php/jscp/article/view/1092

CONFERENCE PROCEEDINGS

Korir, M.K., Mutwiwa, U., Kituu, G.M., and Sila, D.N. (2014). Development of a computer model simulation for predicting the performance of a near infrared reflecting charcoal cooler for on farm storage of mangoes. *Sustainable, Research and Innovation (SRI) Conference* (pp.178-181), ISSN 2079-6226.

Korir, M.K., Mutwiwa, U., Kituu, G.M., and Sila, D.N. (2013). Assessment of postharvest challenges facing mangoes at Upper Athi River Basin, Kenya. *8th JKUAT Scientific and Technological Conference* (pp.668-675).